Plurality and Complementarity of Approaches in Design and Technology Education

Marjolaine Chatoney

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Conference | PATT 29

Plurality and Complementarity of Approaches in Design and Technology Education

EDITOR Marjolaine **Chatoney**

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PATT 29

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Marjolaine Chatoney, ed.

École supérieure du professorat et de l'éducation, Aix-Marseille Université

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PATT 29

Welcome to 29th PATT conference

Plurality and complementarity of approaches in design & technology education

in Marseilles, France, 7-10 April 2015

PATT 29

PATT 29 is hosted by the École supérieure du professorat et de l'éducation (ESPE), Aix-Marseille Université – and the laboratory of research in education "Apprentissage, Didactique, Évaluation, Formation" (ADEF – gestepro team), Aix-Marseille Université. PATT conference will be as usual focused on school design & technology education and teachers' education. Our ambition is to arrange common seminar and social events.

We hereby welcome international colleagues to this golden opportunity to share and learn more about the latest on-going and completed research in the field of technology education research, spanning from early years school through to upper secondary education and teacher education.

The overarching theme of PATT 29 is "Plurality and Complementarity of Approaches in Design & Technology Education". The papers in these peer-reviewed conference proceedings all reflect this board theme, but they also relate to a variety of key areas in school technology education. Research topics include, for example, aspect of learning, teaching and assessing; Science, technology, engineering & mathematic (STEM); linked with languages; together all these research areas are representatives of plurality and complementarity of relevant approach for design & technology education.

PATT 29

PATT association

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The **P**upil's **A**ttitudes **T**owards **T**echnology association (PATT) is an international organization based in the Netherlands. It aims to promote research in technology education. It brings together educators, researchers and professionals in the field of technology education and training. It is mainly intended to promote international trade on innovation, design and teaching engineering. This association is presided over by Professor JM. De Vries of the Delft University. Among other activities, since its creation in 1985, PATT organizes every year one of the few scientific meetings that bring together professionals in technology education coming from many countries around the world. PATT conferences have been held in the Netherlands, Israel, Kenya, Poland, Scotland, South Africa, USA, Sweden and New-Zealand. This is the first time that France is responsible for hosting this event. Indeed, during the Stockholm conference PATT26, the general meeting adopted decision to entrust the organization and responsibility of the 29th PATT conference to the GESTEPRO research team, EA 4671 ADEF Aix-Marseille University (AMU) and the *École supérieure du professorat et de l'éducation* (ESPE). The 29th PATT will be held at the *palais du Pharo* – 58, boulevard Charles Livon, 13007 Marseille – from Tuesday 7th April to Friday 10th April 2015.

The PATT 29th conference will be a moment of exchange focused on technological education and teachers' training. Issues, methods and advances in research and teaching engineering related to this field will be tackled. It is also an opportunity to introduce contributions of interdisciplinary research fields (sociology, didactics, philosophy,…). These scientific meetings are intended to accommodate all research actors but also all those who are concerned with technology education (teachers, trainers, policy makers, managers). Teachers of the ESPE and their students are invited.

The PATT conferences are highlights into the life of the researchers' community who are interested in technology education. PATT contributes to the current research on learning, teaching, training and the dissemination of technology education and practices and cultural relationship to the technological environment. Current issues of technology education refer to some of the major concerns, in particular to the struggle against the disaffection of science and technology education (especially for girls). Another important issue relates to the decompartmentalization of disciplines which aims to bring closer education technology lessons of math and science.

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Thank for your help and for your time!

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The implications of the philosophy of technology for the academic majors of technology student teachers

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Abstract

Technology is globally a developing subject at school level with no distinct, clearly demarcated, underlying, academic discipline as academic major for undergraduate technology student teachers at higher education institutions (HEIs). However, technology student teachers also have to be enrolled for academic majors as part of their teaching qualification. The literature reports on Mitcham's philosophical framework of technology (1994) that consists of four modes of the manifestation of technology, namely object, knowledge, activity and volition. This conceptual paper reports on desktop research with the purpose of investigating how this philosophical framework of technology may be directive for the underlying academic majors of technology student teachers.

A fourfold set of criteria based on the philosophy of technology has been applied to critically evaluate a curriculum framework for the academic majors of technology student teachers enrolled for a four-year undergraduate degree in technology at a South African university. Firstly, the set of criteria was found to be a useful tool for this particular purpose. Secondly, the criteria succeeded well in evaluating the intended curricula for the academic majors comprehensively from a philosophical perspective. It revealed that the intended curricula had been fairly well developed in terms of epistemology and methodology. The balance between conceptual and procedural knowledge is a concern, as well as whether there are sufficient opportunities for practising procedural knowledge. The criteria also revealed that the volitional aspects of technology are largely ignored in the intended curricula. Despite the shortcomings mentioned, it is accepted that student teachers may indeed be exposed to these specific aspects in lectures as the enacted curriculum. However, the explicit inclusion of these in the intended curricula will ensure that they are included in the enacted curricula.

Keywords

Technology education, philosophical framework, curriculum development, curriculum evaluation

Introduction

Technology is globally still a relatively new school subject that lacks a substantive research base and a well-established classroom pedagogy (Mawson, 2007; Rauscher, 2011). Unlike other school subjects with a well-established, subject-based philosophy at least for particular components, there is as yet no established philosophy for technology as subject – in fact, the dynamic nature of technology as such leaves its own philosophy in a tentative and flexible state. Curricula and learning programmes for technology education and the facilitation of these at chalk level thus often lack a scientifically founded, subject-based philosophical framework that may serve as a directive (Moreland & Jones, 2000; Van Niekerk, 2003; Van Niekerk, Ankiewicz & De Swardt, 2010).

Matters are complicated by the fact that technology at school level is globally a developing subject with no equivalent academic discipline which may serve as a source upon which curriculum development and classroom pedagogy may rely in practice (Ankiewicz, De Swardt & De Vries, 2006; De Vries, 2001; De Vries, 2003). In contrast, mathematics as school subject, for example, is based on the academic discipline of mathematics with an established, scientifically founded, subject-based philosophical framework which has been developed over centuries.

The academic discipline on which technology is based is manifested in more than one of the existing disciplines, due to its magnitude as well as the manner in which disciplines are at present structured at universities. The underlying discipline is presently still a multi-discipline or a poly-discipline, of which components are spread over more than one discipline (D_1-D_n, as indicated in Figure 1) and will probably only reveal itself as a mono-discipline (as indicated in Figure 2) at higher education institutions (HEIs) after careful abstraction from and restructuring of the other disciplines. The abstraction of technological knowledge components from the other disciplines and their incorporation into technology as a mono-discipline would leave other disciplines with less knowledge (hence the 'holes' in Figure 2) (Ankiewicz, nd).

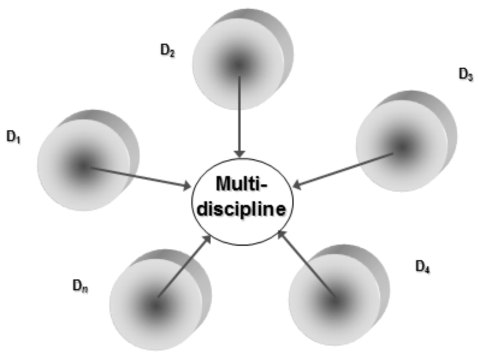

Fig.1: Technology as a multi-discipline

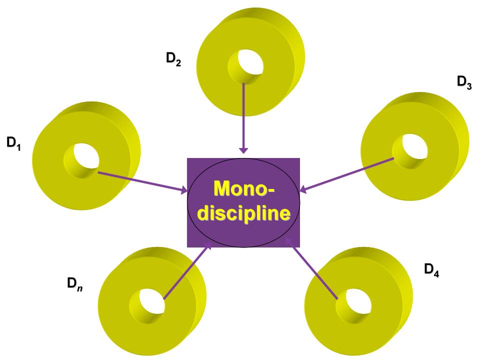

Fig. 2: Technology as a mono-discipline

It is against the above background that HEIs have to devise and offer academic majors for technology student teachers. Within this context it is important to apply scientifically founded criteria for the evaluation of the intended technology curricula. Based on Mitcham's framework (1994), the relevant literature reports on a philosophical framework of technology that consists of four modes of the manifestation of technology, namely object, knowledge, activity and volition (Custer, 1995; De Vries, 2003). These serve as directives for technology classroom pedagogy (Ankiewicz, 2013a), technology teacher education (Ankiewicz, 2013b) and for science, technology and society (STS) studies (Ankiewicz, De Swardt & De Vries, 2006).

This conceptual paper reports on desktop research aimed at investigating how the above philosophical framework of technology may also be directive for the academic majors of technology student teachers enrolled at a South African university. The choice of the University and country was merely convenient as the researcher works and resides there. However, the intended school curriculum for technology in South Africa requires from learners to learn technology from both doing and knowing. Countries with a similar approach might benefit from research in this context. The following research questions serve as points of departure for the theoretical reflection that underpins the paper:

1. Based on the four modes of the manifestation of technology, namely as object, knowledge, activity, and volition, which scientifically founded criteria may be directive for the academic majors of technology student teachers?
2. To what extent does the curriculum framework for the academic majors of technology student teachers enrolled for a four-year undergraduate degree in technology at a South African university comply with the above-mentioned criteria?

A sound philosophy of technology may yield insights into technology curriculum development (De Vries, 2005) and subsequently also into the evaluation of the intended curriculum. In answer to the first research question only the key aspects of Mitcham's philosophical framework for technology will be discussed briefly, due to space restrictions. These have been thoroughly described and discussed by Ankiewicz, De Swardt and De Vries (2006). The key aspects underpin the derived criteria for developing and evaluating a curriculum framework for the academic majors of the technology student teachers mentioned.

A philosophical framework of technology and criteria for curriculum evaluation

Ontology

Technology as ontology is the first mode in which technology is manifested. Technology as object is the 'most immediate, not to say the simplest, mode in which technology is found manifested, and it can include all human fabricated material artefacts whose function depends on a specific materiality as such' (Mitcham, 1994, p.161).

An ontological perspective of technology reflects the following fundamental aspects or universal characteristics, namely that it is:

– a phenomenon unique to **humans;**
– employed by **using tools**;
– a way of human **form creation;**
– giving form to **nature;**
– for human purposes;
– to deliver a product or process;
– being determined by world views (Ankiewicz, 2013a; Van der Walt & Dekker, 1982; Van Schalkwyk, 1996).

The philosophy of technology helps position the teaching of technology among other subjects (De Vries, 2005). Thus, when evaluating a curriculum framework for the academic majors of technology student teachers it is important to ensure that the assumed technology is true to the ontology of technology, in other words that what is included in the curriculum framework is in fact technology and not something else, for example applied science (Ankiewicz, 2013a; Rauscher, 2012).

Epistemology

According to Mitcham (1994) technology as knowledge has most frequently been the subject of analytical investigations in the epistemology or theory of knowledge. The epistemology of technology has its basis in theoretical reflections and more recently also in empirical studies (Broens & De Vries, 2003; Ropohl, 1997).

Technology as knowledge may be distinguished on the basis of various types of knowledge, namely conceptual knowledge (*knowing that*) and procedural knowledge (*knowing how*) (Ankiewicz 2013a, p. 4; 2013b, p. 3–5). Although a distinction is made between conceptual and procedural knowledge in technology (McCormick, 1997; Ropohl, 1997; Ryle, 1949), these two types of knowledge cannot be separated (McCormick, 1997).

Methodology

The third mode in which technology is manifested is technology as activity. Epistemology usually includes methodology (Van der Walt, Dekker & Van der Walt, 1985), which in particular provides insight into procedural knowledge in technology. Design processes constitute the object studied in the discipline of design methodology (De Vries, 2001) and two different paradigms, namely the rational problem-solving and the reflective practice paradigm form the basis of design methodology (Ankiewicz, 2013a; Ankiewicz, 2013b; Ankiewicz, De Swardt & De Vries, 2006).

Various kinds of complex thinking processes (creative and critical thinking, decision-making and problem-solving) underpin and form part of technological activities (Ankiewicz & De Swardt, 2002; De Swardt, 1998; De Swardt, Ankiewicz & Gross, 2010; Jakovljevic, 2002; Jakovljevic, Ankiewicz, De Swardt & Gross, 2004; Johnson, 1997; Reddy, Ankiewicz, De Swardt & Gross, 2003; Sharpe, 1996; Van Niekerk, Ankiewicz & De Swardt, 2010). Technology may therefore be regarded as both 'minds-on' (complex thinking) and 'hands-on' (practical activities) (McCormick & Davidson, 1996).

Technological procedural knowledge is not only associated with technical skills but also with thinking processes and skills (McCormick, 1997). Complex thinking processes are part of technological activities as '… technical know-how implies cognitive resources' (Ropohl, 1997, p. 69).

Some of these thinking processes also form the core of aspects such as innovation, entrepreneurial attitude and behaviour associated with technology as volition. Conradie (1996) contends that creativity (innovation) is therefore a prerequisite and a non-negotiable core element of entrepreneurial behaviour.

From a design methodology perspective it has also become clear that the conceptual phase of a design project may be described most effectively by the reflective paradigm (Dorst, 1997) and learners should therefore be provided with opportunities for reflective design. Thinking and intellectual skills development should therefore receive sufficient emphasis in the technology curriculum (Ankiewicz, 2013a).

Volition

The fourth mode in which technology is manifested is technology as volition (Mitcham, 1994), which is the most complex manifestation (Custer, 1995) and refers to the volition of the practitioner involved (Mitcham, 1994). Technologies are associated with a wide array of volitional activities, drives, motivation, aspiration, intentions and choice. The phrase 'the will to …' is found in various definitions of technology (Ankiewicz, 2013b; Mitcham, 1994). Technology as volition points towards the need for an ethical analysis of technology (Mitcham, 1994). There is a recurring tendency to think about technology in terms of its impact on entities outside of its essential nature, such as the impact of technology on the environment and society, and also the impact of human values and needs on technology (Custer, 1995).

A technology assessment (TA) study as one of the approaches in STS studies (Ropohl, 1997), is an instrument for forecasting possible effects of new technological development on societal groups and on society as a whole in a systematic manner (Smit & Van Oost, 1999). Exploring new technological development and forecasting the consequences of such development on society and the environment are two important TA activities. When an intensive interaction between designers or producers and other participants is central, it is referred to as an interactive technology assessment (ITA) approach which is a specific form of constructive technology assessment (CTA) (Smit & Van Oost, 1999). As has been mentioned, some of the complex thinking processes also form the core of aspects such as innovation, entrepreneurial attitude and behaviour associated with technology as volition.

Findings

Criteria that may be directive for the academic majors of technology student teachers

Based on the four modes of the manifestation of technology, which scientifically founded criteria may be directive for the underlying academic majors of technology student teachers?

Scientifically founded criteria (as indicated in Table 1) have been derived for the development and evaluation of the intended technology curricula (Ankiewicz, nd). In some instances the criteria originated from aspects of technology classroom pedagogy, teacher education and STS studies discussed previously, due to the intertwinedness of these aspects. The curriculum also forms the core of classroom pedagogy and serves as important point of departure for teacher education. Such origins and relationships are not necessarily repeated in this paper.

Ontology (O)	Epistemology (E)	Methodology (M)	Volition (V)
O1. The intended technology curricula must ensure that the assumed technology is true to the ontology of technology, i.e. it must be technology and not something else, for example applied science. (Thus, instead of merely teaching e.g. the application of Ohm's law it should be contextualised as part of a project where learners solve a real-life problem that requires from them to design and make an electrical device by using tools and manipulating materials.) O2. The definition/concept of technology in the intended curricula must be in line with the universal characteristics of technology. O3. The intended technology curricula must explicitly emphasise the universal characteristics of technology as part of the learning content to be taught to learners.	E1. Both conceptual knowledge and procedural knowledge must be included in technology curricula. E2. Intended technology curricula should not merely include conceptual knowledge of technology as artefacts, but should also contain procedural knowledge on how to design and make such artefacts, and vice versa. E3. A balance must be maintained between the two types of knowledge without one being overemphasised at the expense of the other. E4. The relationship between the two types of knowledge must be acknowledged. E5. The conceptual knowledge relevant to technology must include that which is unique to technology as well as that which belongs to other subjects, such as science. E6. Technological procedural knowledge should be accommodated in such a way that learners are accorded sufficient opportunities for practice. E7. If the intended curricula assume ontologically justified technology in classrooms, procedural knowledge may be taken as point of departure, and then be contextualised by involving conceptual knowledge (with the main themes of structures, control systems and processing of materials).	M1. Based on the paradigm of rational problem-solving a stage model which may serve as explicit organisational framework for the teacher and learner may be used to provide learners the opportunity to develop procedural knowledge through practice. M2. Based on the reflective paradigm learners must be provided with opportunities for reflective design, especially during the conceptual phase of a design project, where they may design more freely and in a less structured way. M3. Technology education should in essence be activity-based and accord learners ample opportunity to practise it. M4. The intended technology curricula must provide for explicit teaching of creative and critical thinking, decision making, problem solving and design as sub processes of complex thinking, as well as for the related thinking skills as so-called enabling tasks before learners are expected to apply these.	V1. Technology as volition must not be included in isolation but integrated with the ontology, epistemology and methodology of technology. V2. The intended technology curricula must provide for the direct teaching of complex thinking processes and skills as so-called enabling tasks before learners are expected to apply these. Complex thinking processes and skills relate to, inter alia, innovation, entrepreneurial attitude and behaviour as volition. V3. Aspects pertaining to the complex relationship between science, technology and society must be included in the intended technology curricula. V4. The co-evolution of technology and society, as well as the ITA model, that both emphasise the interplay between the various role-players within STS studies must also be included. The impact of technology on the environment should not be over-emphasised.

Table 1: Criteria for the development and evaluation of the intended technology curricula

Applying the criteria to the academic majors of technology student teachers

Background

The University concerned focuses only on teacher education for middle (Senior Phase; Grades 7-9) and high schools (Further Education and Training [FET]; Grade 10-12). Technology as subject is compulsory for learners in the Senior Phase, after which they have a choice of two out of four so-called technology subjects in FET, namely Engineering Graphics and Design, Civil Technology, Mechanical Technology and Electrical Technology. Currently most learners who opt for the technology subjects in FET choose Engineering Graphics and Design and Civil Technology. Based on the specifications of the school curriculum, demand (such as learner choice) and some practical reasons (such as the availability of facilities, finances and staff capacity) the University has decided to currently only offer the majors that relate to three of the five school subjects, namely Technology, Engineering Graphics and Design and Civil Technology. The minimum requirements for teacher education qualifications (South Africa, 2011) restrict the number of academic majors as part of the four-year undergraduate degree to two only. Furthermore, it specifies that one major should be taken up to third-year and the remaining one to second-year level. It has in fact designated Technology and Engineering Graphics and Design as the single compulsory major for student teachers up to third-year level. Civil Technology as a major is only offered up to second-year level. The University may consider adding the option of Mechanical Technology or Electrical Technology as second elective major in future. Students start with both majors in their first year.

The framework documents that serve as intended curricula for Engineering Graphics and Technology Education (EGTE) and Civil Technology as majors and were approved by the Department of Higher Education (DHET) and the Council for Higher Education (CHE) are very concise, mainly outlining the purpose of every module and briefly describing the content of the modules (in fact mainly topics). An analysis by applying the above-mentioned set of criteria revealed that the purpose statements of all the modules for both EGTE and Civil Technology focused mainly on epistemology (E) and methodology (M). When applying the criteria to the brief description of the content of every module for EGTE (refer to Table 2) and Civil Technology (refer to Table 3) a similar pattern emerged, with limited additional reference to ontology (O). There was no direct reference to volition (V).

It was subsequently decided to rather apply the criteria to the learning guides that have been developed so far for the majors. The third-year module for EGTE will only be implemented at the beginning of 2015, and had not been completed at the time of writing this paper. The learning guides as extensions of the frameworks may more accurately be regarded as intended work schedules. These indicate the weekly distribution of the themes and their related assessment criteria for a specific semester. Applying the technology criteria to the assessment criteria in the learning guides supported the outcome of the initial analysis of the framework documents. However, it was possible to better determine to what extent the learning guides comply with every individual criterion. Due to space restrictions Table 4 and 5 only indicate excerpts from the EGTE and Civil Technology learning guides respectively and the way in which the analysis was done.

Ontology

It seemed that what the learning guides assume as technology is indeed true to the ontology of technology, and not something else, for example applied science (O1). However, there is no explicit definition of technology in the learning guides (O2), and no explicit reference to the universal characteristics of technology as part of the learning content (O3).

Epistemology

Both conceptual knowledge and procedural knowledge have been included in the learning guides (E1). The learning guides do not merely include conceptual knowledge of technology as artefacts, but also contain procedural knowledge on how to design and make such artefacts, and vice versa (E2). Despite a strong emphasis on conceptual knowledge the practical sessions may contribute to maintaining a balance between the two types of knowledge. However, its time table restricts the University to offering the practical sessions within scheduled lecturing time slots, which is a reason for concern. In the third year of EGTE, students will spend a whole semester on a design project, which may contribute to such a balance (E3) and may also accord student teachers sufficient opportunities for practice (E6). Scheduling the practical sessions towards the middle and the end of the semester is a way of acknowledging the relationship between the two types of knowledge (E4). It is evident that the learning guides include both the conceptual knowledge that is unique to technology (structures, control systems; the processing of materials; graphic communication) as well as that which belongs to other subjects, such as science. In the third year of EGTE, students will for example spend a semester on electrical systems, electronic devices and basic integrated circuits with the purpose of designing (and drawing) electrical and electronic circuits. Despite revising the basic theory on electricity that is part of the Science curriculum for schools it is doubtful whether the other related aspects would have been included in the Science curriculum for schools (E5). Civil Technology students will also revise the basic theory on electricity with the purpose of designing an electrical system for a simple house (E5). Procedural knowledge is not necessarily taken as point of departure for the learning guides, but it is in some cases taken as point of departure for projects as part of the practical sessions. The design project during the last semester of EGTE takes procedural knowledge as point of departure, which is then contextualised by involving conceptual knowledge (with the main themes of structures, control systems and the processing of materials) (E7).

Methodology

During the first semester EGTE student teachers study the technological process as a stage model that is based on the paradigm of rational problem-solving. They also apply the process during a practical session and apply the technological process as part of their design project during the last semester of EGTE in the third year (M1). It is not clear from the learning guide whether student teachers will be provided with opportunities for reflective design, especially during the conceptual phase of a design project, where they may design more freely and in a less structured way (M2). Time restrictions have already been mentioned as an inhibiting factor to accord student teachers sufficient opportunities to practise activities (M3). The learning guides neither emphasise the explicit teaching of creative and critical thinking, decision making, problem solving and design as sub processes of complex thinking, nor the related thinking skills as so-called enabling tasks before learners are expected to apply these (M4).

Volition

It is evident from the analysis that volitional aspects do not feature at all in the learning guides. There is also little evidence that such aspects have been integrated with the ontology, epistemology and methodology of technology. The only reference to volitional aspects is found in the EGTE second year semester 4, related to neat drawings (V1). As mentioned, the learning guides do not provide for the direct teaching of complex thinking processes and skills as so-called enabling tasks before learners are expected to apply these (M4). The complex thinking processes and skills that relate to inter alia innovation, entrepreneurial attitude and behaviour as volition (V2) are subsequently also not emphasised. The learning guides neither include aspects pertaining to the complex relationship between Science, Technology and Society (V3), nor the co-evolution of technology and society or the ITA model, which both emphasise the interplay between the various role-players within STS studies (V4).

Discussion and conclusion

The findings indicated that it is essential for curriculum developers to familiarise themselves with the philosophical framework for technology, based on the four modes of the manifestation of technology, as these are also important directives for curriculum development and evaluation. The set of criteria which has been derived from these manifestations may be further refined while being applied.

The fourfold set of criteria has for the first time been used to determine the extent to which the curricula for the academic majors of undergraduate technology student teachers comply with the criteria. It was found to be a useful tool for this specific purpose. Firstly, it indicated that bureaucratic intended curriculum templates might be restrictive in the sense that they are too brief, and thus allow for different interpretations. Secondly, the criteria succeeded well in evaluating the specific learning guides comprehensively from an ontological, epistemological, methodological and volitional perspective. The analysis revealed that the curricula have been fairly well developed in terms of epistemology and methodology. Concerns are the balance between conceptual and procedural knowledge and whether there are sufficient opportunities for practising procedural knowledge. The sixth module of EGTE in the third year is still to be developed and may contribute towards creating such a balance. An explicit definition of technology and its universal characteristics as ontological aspects need to be included in the curricula.

The criteria revealed that the volitional aspects of technology are ignored in the intended curricula. The complex thinking processes and skills which relate to inter alia innovation, entrepreneurial attitude and behaviour as volition should explicitly be included, as well as the complex relationship between Science, Technology and Society (STS). The co-evolution of technology and society and the ITA model, that both emphasise the interplay between the various role-players within STS studies should also be included. These aspects should be considered when revising the said learning guides for 2015.

Despite the shortcomings mentioned, it is accepted that student teachers may indeed be exposed to these specific aspects in lectures as the enacted curriculum. However, the explicit inclusion of these in the intended curricula will ensure that they are included in the enacted curricula.

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Table 2: Curriculum framework for Engineering Graphics and Technology Education

Faculty of Education **BEd Senior Phase and FET Teaching**				
Name of module	**NQF level**	**Credits**	**Purpose of the module**	**Brief description of the content of the module**
Engineering Graphics and Technology Education 1A	5	16	The purpose of the module is to introduce students to the fundamentals of technology and graphic communication (O, E) in order to develop an ability to apply technological knowledge and basic drawing techniques (M).	Introduction to technology education, Civil technology, Electrical technology and Mechanical technology (O). Fundamentals of drawing (E); Freehand drawing techniques (M); Instrument drawings: Geometrical constructions and scales (E & M). Practical application of the basic technological process (E & M).
Engineering Graphics and Technology Education 1B	6	16	The purpose of the module is to guide students in developing an understanding of geometrical and orthographic concepts (E) in order to enable multi-view drawing (M).	Geometric elements; descriptive geometry; solid geometry and the principles of first and third angle orthographic projection (E & M).
Engineering Graphics and Technology Education 2A	6	16	The purpose of the module is to guide students in developing knowledge (E) and skills enabling them to apply computer-aided drawing software to present and communicate mechanical artefacts (M).	Mechanical systems and control (E); materials for mechanical systems, e.g. metals and plastics (E); mechanical drawings (E & M); isometric drawings (E & M).
Engineering Graphics and Technology Education 2B	6	16	The purpose of the module is to guide students in developing knowledge (E) and skills enabling them to apply computer-aided drawing software to present and communicate civil artefacts (M).	Structures (E); materials for structures, e.g. steel, timber and concrete (E); construction methods (E & M); civil drawings; perspective drawings (E & M).
Engineering Graphics and Technology Education 3A	6	16	The purpose of the module is to guide students in developing knowledge (E) and skills enabling them to apply computer-aided drawing software to present and communicate electrical artefacts (M).	Electrical systems: Electron theory, Ohm's law, resistance (parallel and series), components, diodes, transistors as switches and amplifiers. Basic integrated circuits (E). Drawing and planning electric and electronic circuits (E & M). Interpenetrations. Developments. Loci (E & M).
Engineering Graphics and Technology Education 3B	7	16	The purpose of this module is to guide students in developing knowledge (E) and skills enabling them to apply the principles taught to identify and solve complex and diverse design problems (M).	Application of the technological process: design principles, investigative techniques, data processing techniques, calculations and communication techniques within the contexts of civil and mechanical technologies (E & M).

Table 3: Curriculum framework for Civil Technology

Faculty of Education BEd FET Teaching				
Name of module	**NQF level**	**Credits**	**Purpose of the module**	**Brief description of the content of the module**
Civil Technology 1A	5	16	The purpose of the module is to introduce students to the fundamentals of the construction industry (O) in order to develop skills and knowledge regarding simulation, experimentation and workshop practice skills (M).	Stakeholders in the South African construction industry and their functions (E). Construction legislation and regulations (E). Planning and organising construction activities (E & M). Safety (E). Materials (E). Tools and equipment (E). Site preparation (E & M?).
Civil Technology 1B	6	16	The purpose of the module is to guide students in developing an understanding of construction methods in the built environment (E) in order to develop skills and knowledge regarding simulation, experimentation and workshop practice skills (M).	Substructure. Superstructure. Roof construction. Reinforced concrete construction (E & M?).
Civil Technology 2A	6	16	The purpose of the module is to guide students in developing an understanding of civil services and finishing concepts used in simple house construction (E) enabling them to design and simulate the installation and maintenance of service systems and finishing concepts (M).	Cold water supply, plumbing for a house, materials, hot water systems, solar systems. Alternate fresh water supplies. Sewerage layout for a building. Sewage disposal systems and regulations. Disposal of storm-water and regulations. Electrical symbols and layout for a house (E & M?). Floor and wall finishes, windows, doors, ceilings, roof coverings, glass and paints (E & M?).
Civil Technology 2B	6	16	The purpose of the module is to guide students in developing an understanding of quantity surveying and applied mechanics (E) enabling them to conduct detailed measurements and descriptions of a simple house and solve problems in the mechanics and technology fields (M).	Introduction to measurements, principles of measurements, foundations, superstructure, finishes, doors, windows, roof and roof covering (E). Graphic determination of the nature and magnitude for the different members in force diagrams of roof frames and structures. Beams: Reactions and calculations at the supports. Calculations and diagrams of shear force and bending moments. Centroids (E & M?).

Table 4: Learning guide for EGTE 2B

SEMESTER PROGRAMME

UNIT	THEME	WEEK	ASSESSMENT CRITERIA
5	Civil Technology and detailing: Roof construction Finishing Materials	6	Students will be deemed competent if they can: list and describe all components and materials needed to plan the roof construction of a simple residential building (E); list and describe all components and materials needed to plan finishing aspects of a simple residential building (E).
	Test 1 (Analytical)	7	
6	Civil Technology and detailing: Services Materials	8	Students will be deemed competent if they can: list and describe all components and materials needed to plan the drainage system of a simple residential building (E); list and describe all components and materials needed to plan the electrical system of a simple residential building (E).
7	Perspective drawing	9	Students will be deemed competent if they can: draw perspective views of civil structures (M).
	Test 2 (Drawing)	10	
8	Practical: Architectural modelling	11	Students will be deemed competent if they can: identify appropriate material and make a model according to a specific design (E & M); demonstrate safe conduct and use of tools in the workshop (E & M).
9	Drawing for Civil Engineering: Reinforced concrete	12	Students will be deemed competent if they can: produce complete and neatly (V) dimensioned concrete drawings of simple structures, e.g. columns, slabs and beams (M); produce the relevant reinforcing drawings for these structures (M).
10	Drawing for Civil Engineering: Structural steelwork	13	Students will be deemed competent if they can produce neat (V) and correctly dimensioned drawings of: typical base-to-column connections showing holding down bolts (M); typical welded and bolted column-to-beam connections (M); typical welded and bolted beam-to-beam connections (M); different types of welded and bolted roof trusses, lattice girders and portal frames (M).

Table 5: Learning guide for Civil Technology 2B

SEMESTER PROGRAMME

UNIT	THEME	WEEK	ASSESSMENT CRITERIA
	Orientation	1	
1	Introduction to civil services	2	Students will be deemed competent if they can: discuss the requirements for a healthy life (E); explain the role civil engineering (E) plays in our modern society (V); explain the natural water cycle (E); identify and discuss different sources of water supply (E); discuss the recycling of waste water (E); identify and discuss different ways electricity can be generated (E).
2	Civil services: Cold water supply	3	Students will be deemed competent if they can: read and interpret a building plan to make informed choices regarding the planning of a cold water system for a simple house (E & M); identify and explain the use of different types of material and fittings available for the installation of cold water systems (E); describe and demonstrate the function, use and care of basic tools and equipment used for the installation of cold water systems (E).
3	Civil services: Hot water supply	4	Students will be deemed competent if they can: read and interpret a building plan to make informed choices regarding the planning of a hot water system for a simple house (E & M); identify and explain the use of different types of material and fittings available for the installation of hot water systems (E); describe and demonstrate the function, use and care of basic tools and equipment used for the installation of hot water systems (E).
4	Practical 1: Designing and simulating a hot water installation	5	Students will be deemed competent if they can: use their knowledge of hot water systems to design and simulate part of a hot water system according to specific design requirements (E & M); demonstrate safe conduct and use of tools and equipment in the workshop (E & M).

How do male and female secondary students' attitudes towards technology evolve?

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Abstract

Considering the fact that more young people, boys and girls, are needed in technical studies and professions, as the relative number of students in technology related studies has been decreasing in most industrialized countries (OECD, 2008), one could wonder whether education succeeds to increase students' interest and career aspirations in this domain. To overcome this decrease several countries implemented mandatory technology classes in the curriculum of primary and/or secondary education. At age of 14, the end of the first cycle in secondary education, students have tasted all kinds of subjects, including technology.

Several researchers concluded that between the age of 10 and 14 students' interest in technology starts to decrease. Although longitudinal studies on this topic are rather scarce, these studies indicate that students' career aspirations and interest in science were largely stable from the age of 14'. This means students' attitudes change during the first cycle of secondary education, and education can have an impact on it.

This study has two goals: exploring the evolution of pupils' interest during the year(s) they attend the mandatory technology classes and exploring determining characteristics for differences in boys' and girls' attitude change over time. A longitudinal study with eight measurement occasions spread over the course of two years is presented in order to capture the evolution of students' attitudes, making use of a multilevel growth model analysis.

The results show that boys' and girls' interest in technology evolves a little different. For career aspirations we didn't see any significant difference between boys and girls. The evolution of students' attitude is far from linear, this strengths us in the choice for a more complex analysis model and the choice for more measuring points than only at the begin and the end when analysing students' attitudes towards technology.

Keywords

Technology, interest, attitude, longitudinal, technology education

Relevance of the study

Technology is playing an increasingly important role in all realms of life; in the private sphere, as citizens, as consumers and in work situations. As inhabitants of democratic societies, people are continuously being asked to take a stance on socio-scientific issues (Schreiner & Sjøberg, 2004). In 2006 the European Parliament and of the Council of 18 December 2006 defined eight key competences for lifelong learning. One of them regards 'mathematical competence and basic competences in science and technology'. Although technology education is more relevant today than ever before, youngsters' attitude to studying technology or having a technical job is not positive (Johansson, 2009). Often, this lack of enthusiasm is a result of negative experiences of technology at school (de Vries 2005; Osborne & Collins, 2000, 2003).

Students' decreasing preference for a technological study or job, drives a growing field of research on interest and career aspirations (e.g. Krapp & Prenzel, 2011; Skryabina, 2000; Hadden & Johnstone, 1983). Nevertheless the research on how interest in technology and career aspirations evolve during schooling is sparse and methodologically flaw. There is a longitudinal study of Lindahl (2007) focussing on evolution in interest and career aspirations in STEM (Science, Technology, Engineering and Mathematics). Based on following a small sample of students (n=70) she concluded that students' career aspirations and interest in STEM were largely formed around the age of 14. The small sample size used in this study can be considered as a weakness. As a result the generalizability of the findings can be questioned. Focussing on interest and career aspirations in technology, Ardies, De Maeyer, Gijbels and van Keulen (2014) described which factors influence students' attitudes, including interest in technology and career aspirations, at the age of 12 and 13. However, this study was cross-sectional and did not investigate the progress students made during an academic year. So, to the best of our knowledge, longitudinal research is lacking.

Especially girls continue to be underrepresented in the domain of STEM (e.g. Brickhouse,2001; Fadigan & Hammrich, 2004; Scantlebury & Baker, 2007), therefore when researching students' attitudinal development it is important to study the gender aspect as well.

Many studies compare the differences between girls' and boys' attitude towards science and technology (e.g., Schreiner & Sjøberg 2004; Volk & Yip 1999; Weinburgh, 1995). Boys are generally more interested in science and technology than girls (e.g. Gardner 1998; de Vries, 2005; Mawson, 2010) and are more ambitious for a career in technology (e.g. Brickhouse,2001; Fadigan & Hammrich, 2004; Scantlebury & Baker, 2007; Taskinen, Asseburg & Walter, 2008).

The differences between boys and girls are also related to their age (Kotte, 1992; Catsambis, 1995). Pell and Jarvis (2001) and Haworth, Dale and Plomin (2008) concluded that boys and girls interest in STEM is equal and rather high at the age of 10. From that age on interest starts to decline, especially for girls (Hoffman 2002). Mattern and Schau (2002) add through their study, the insight that girls' positive attitudes towards science as a student are indicative for more positive attitudes in their future life. Reid and Skryabina (2002) conclude that once a girl has opted for physics towards the end of the second grade, she tends to stay with it throughout school, which emphasizes the importance of researching girls' interest in technology.

Many scholars have described the fact that people differ in the perception of technology as, on the one hand something for boys only, instead of on the other hand something for both boys and girls (de Vries, 2005; Mawson, 2010; Rasinen et al., 2009; Salminen-Karlsson, 2007). Therefore, next to boys' and girls' differences in interest and career aspirations it is also relevant to look at stereotype ideas about girls and a technological career.

Design and methodology

Research context

This study focuses on data gathered in the first and second grade (12-14 years) of general secondary education in Flanders (the Dutch speaking part of Belgium). As Flemish students take a mandatory curriculum of 27 hours a week including two hours of technology classes this can be considered as an interesting context to study the attitudinal evolution. Next to this mandatory technology classes students can also choose for an extra 'technological package' of 5 hours a week. We will further on in this study make the distinction between this two groups, referring to students with a technological curriculum versus students with a non-technological curriculum (only the 2 mandatory hours).

We selected a good representation of geographically spread schools (n=20) of different size. In order to determine students' attitudes we used part of the PATT-SQ as validated by Ardies, et al. (2013). Example items and reliability measures (Cronbach's alpha) are shown in table 1. Measuring at the start of each trimester and at the end of the academic year we have a total of four measurement occasions each of both grades, what gives eight occasions in total.

Table 1. Factors of attitude towards technology

Sub-factor	α	# items	Example Item
Technological career aspirations	.92	4	I will probably choose a job in technology
Interest in technology	.84	6	If there was a school club about technology I would certainly join it
Perception on gender differences	.82	3	Boys are more capable of doing technological jobs than girls

Statistical analyses

In order to analyse the longitudinal data we used a multilevel growth curve modelling technique (Singer & Willet, 2003; Long, 2012; Hox, 2010; Goldstein, 2011). The multilevel model makes it possible to model the variation between the different measurement occasions of the individual students, the variation between students and the variances between groups of students, in this survey grouped by the school they are attending.

Concerning students' attitudes we have to be aware of the non-linearity of the evolution as Sorge (2007) unambiguous described a non-linear decline of students' attitudes over time. Therefore we will use the most common method of modelling nonlinear trends in the behavioural sciences, polynomial models (Singer & Willett, 2003; Long, 2012). In these models the scores on the different measurement occasions (MO) are modelled as non-linear function of time. This is done by adding a time-variable (e.g. month) raised to different powers as explanatory variables in the model.

In the result-section only the final models for all three attitudes will be reported and discussed.

As is the case in many longitudinal research there is missing data for some students at certain measurement occasions. Because the methodological literature has repeatedly found that listwise deletion leads to inaccurate estimates (Enders, 2001; Enders & Bandalos, 2001; Wothke, 2000) we retain all available data. Hereby we overcome two problems. First, leaving a large part of the sample out decreases sample size and thereby the statistical power. Secondly, we overcome a more harmful threat associated with listwise deletion: the group of students with complete data is very unlikely to be a random subset (Raudenbush, 2001) of all students. However we also don't want to ignore the possibility that effects found are due to this specific group of students that we could follow the complete first cycle. To overcome this problem we included a dummy variable that indicates all students which we could follow the complete first cycle. This variable is labelled as LongData. In the analyses we will introduce a number of explanatory variables that were found significant variables in previous studies.

After adding the main and interaction effects of these explanatory variables, we included interaction effects between some of these variables and the variable measurement occasion. We did this for the variables Gender and Technical Curriculum to analyse whether on the one hand boys and girls evolve differently or whether, on the other hand, students opting for a technological package in the first grade differ in how attitudes evolve as compared to students who don't choose such a technological package. Finally we also add the interaction between the indicator variable LongData and measurement occasion. As such we take into account the fact that the selection of students that didn't repeat the first year in secondary education might show a different evolution in attitudes than students that dropped out or had to repeat the first year.

Results

In order to increase the readability and possibility to compare the results for all the three attitudes we combine the parameter estimates of the final model in one table (Table 2). In the description of the results we handle each of the attitudes separately.

Table 2. Parameter estimates (est) and standard errors (se) of the best fitting models for Interest, Career and Gender perceptions

	Interest			Career			Gender Perceptions		
	est	se		est	se		est	se	
Fixed Part									
(Intercept)	0,676	0,098	**	-0,297	0,072	**	-0,080	0,104	
MO	-0,776	0,079	**	-0,029	0,009	**	-1,27E-03	0,006	
MO^2	0,203	0,026	**	0,001	0,000	**			
MO^3	-0,022	0,003	**						
MO^4	1,04E-03	0,000	**						
MO^5	-1,75E-05	0,000	**						
LongData	-0,161	0,073	*	0,046	0,071		-0,278	0,090	**
Boys	0,412	0,081	**	0,487	0,077	**	0,290	0,087	**
Second Grade	0,248	0,148		-0,073	0,074		0,073	0,081	
Tech.cur	0,037	0,100		0,588	0,099	**	-0,091	0,122	
H.Ed.Mother	-0,055	0,030		-0,109	0,031	**	0,032	0,033	
Tech.job.Father	0,090	0,028	**	0,167	0,029	**	0,011	0,031	
Tech.job.Mother	0,033	0,040		0,146	0,041	**	-0,088	0,043	*
Tech.Toys	0,173	0,038	**	0,238	0,039	**	-0,059	0,041	
MO:LongData	0,027	0,005	**	0,011	0,005	*	0,045	0,006	**
MO:Boys	-0,024	0,009	*	-0,010	0,007		0,008	0,008	
Second Grade:Tech.cur	0,117	0,121		0,319	0,119	**	0,014	0,144	
Boys: Second Grade	0,245	0,127		0,162	0,106		-0,257	0,115	*
Boys:Tech.Toys	0,071	0,062		0,091	0,064		0,036	0,067	
Random Part									
Level 3 - Schools									
Intercept variance Schools	0,030			0,023			0,124		
Slope variance Schools							1,04E-04		
Level2 - Students									
Intercept variance Students	0,736			0,451			0,710		
Slope variance MO Students	0,050			1,03E-03			0,003		
Slope variance MO^2 Students	1,29E-04								
Slope variance MO^3 Students	2,13E-08								
Level 1 - Residuals									
Intercept variance	0,550			0,445			0,551		

** p<0,01 ; * p<0,05

Interest

The estimates (Table 2) show a decrease of interest over time, as the effect of the variable Measurement Occasion (MO) is negative (-0,776). But given that the estimates associated with the effects of the different powers of the variable measurement occasion (MO^2 – MO^5) have a significant effect, the actual evolution is far more complicated than a linear decrease. In order to interpret these estimates a graph with predicted scores based on this final model is made (see figure 1).

The estimates also learn that boys score significantly higher on interest than girls (0,412) at the beginning of secondary education. The fact that the interaction effect between gender and measurement occasion is negative (-0,024) and statistically significant implies that the initial difference between boys and girls diminishes over time. When looking at figure 1 we see some differences between boys' and girls' evolution of interest in technology over the time of 21 months. On certain points during this timeframe girls' interest increases whereas boys' interest decreases or seems more stable. This is specifically the case at the end of the first grade. The first trimester at school is both for boys and girls in the first and second grade the timeframe where interest drops the strongest. Interest is dropping significantly over the complete first cycle, although mainly in the first grade. At the end of the first cycle in secondary education both boys and girls gain a bit interest in the subject again.

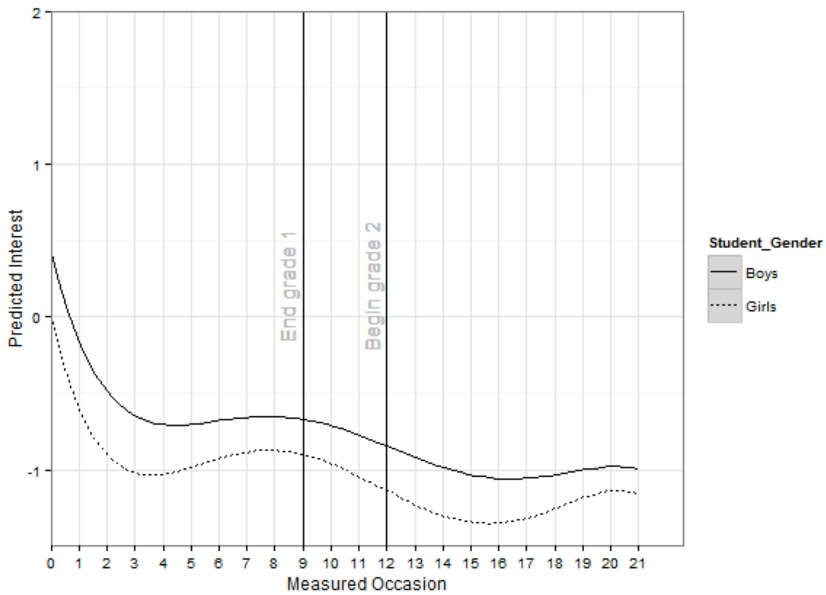

Figure 1. Evolution of predicted scores (based on the final model) for interest in technology for boys and girls based on the final model

Career

From the estimates in table 2 we can conclude that aspirations for a technological career are more or less stable over time for all students: there is a rather small effect of measurement occasion (-0,029). Given the significant effect of measurement occasion squared, we can derive that this small negative down trend of career aspirations isn't linear. Figure 2 visualizes this evolution.

Considering gender, no significant difference in boys' or girls' evolution was found. Only the main effect of gender shows a significant effect: boys' career aspirations for a technical job are significantly higher than for girls: boys score 0,487 higher than girls, a difference that is stable over the complete first cycle.

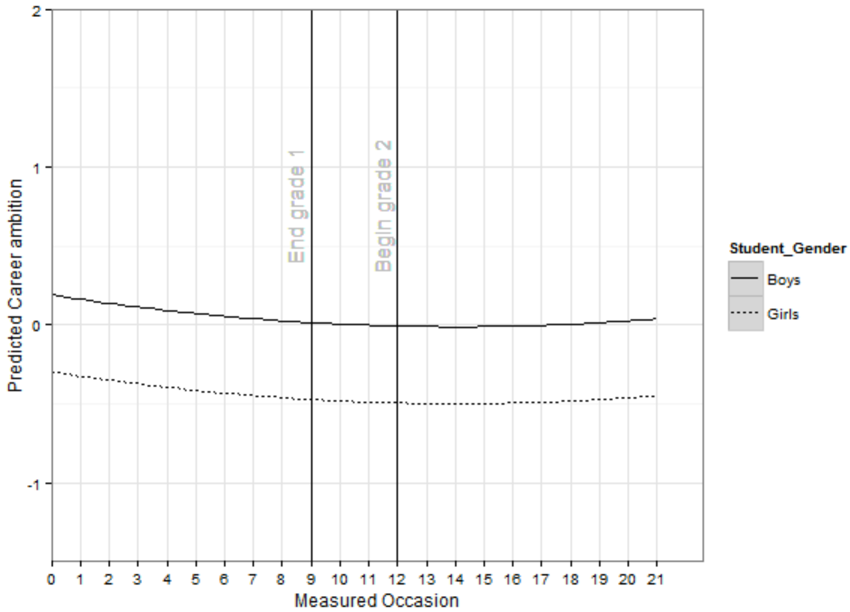

Figure 2. Evolution of predicted scores (based on the final model) for Career aspiration for boys and girls

The difference between students with or without a technological curriculum option is large: students with a more technological curriculum option score 0,588 SD higher than their peers with other curricula. This effect is even one third of a standard deviation stronger in the second grade as expressed by the significant interaction term between technical curriculum and second grade (0,319). Given this outspoken interaction effect we did some additional analyses focussing on the question whether students' evolution in career aspirations is dependent on technological and non-technological curricula. From which we learned that there is a significant difference at the start of first and second grade between students with or without a technological curriculum option. The interaction effect between technological curriculum and measurement occasion was statistically significant but very small. As such we can conclude that students with more technical curricula tend to lose their career aspirations for a technological job a bit more than their peers with a non-technological curriculum. But this loss in career aspirations during the academic year is completely compensated during the summer holiday as the interaction effect between technological curriculum and second grade is strongly positive significant. This difference in evolution between students with and students without a technological curriculum is visualized in Figure 3.

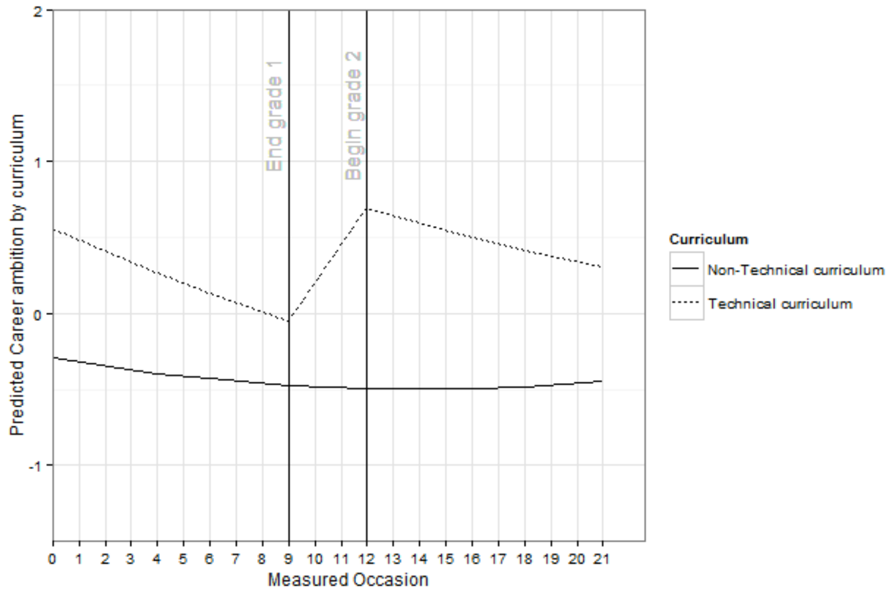

Figure 3. Evolution of predicted scores for Career aspiration for students with and students without a technological curriculum,

Gender Perceptions

Finally focussing on the results for the variable Gender perceptions (see table 2) we can conclude that students' perceptions about technology as a subject for boys and girls is largely stable. The effect of measurement occasion is not significant. It appears that boys' and girls' perceptions differs at the start of secondary education: boys score 0,290 higher. Given the significant negative interaction effect (-0,257) between gender and second grade we can conclude that this initial difference in the first grade is strongly lowered in the second grade. This trend is visualized in Figure 3. Based on this interaction effect we can also conclude that for girls there is no difference between first and second grade: the feeling about technology as a career option for themselves, as well as for boys, seems to be a very stable attitude (Fig 4).

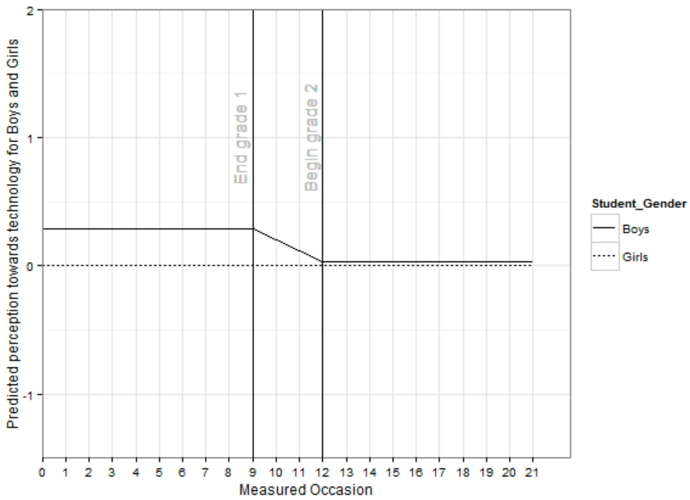

Figure 4. Predicted perception towards technology as a subject suitable for both genders

Conclusions, discussion and implication

The central question of this study was whether the attitude towards technology and towards technical studies or professions evolves through the first cycle. In line with Sorge (2007) we conclude that the evolution of the attitude of the students regarding technology does not evolve as a linear regression. Therefore it is inadequate to measure only at start and finish of a cycle when one wants to describe students' evolution.

We can't confirm with Skryabina (2000) who found a decline in interest and this fall was specially marked for girls, this is not the case for students' attitude towards technology as there is only a very small difference between boys' and girls' attitude evolution in the first cycle of secondary education.

As this research was set up as a large scale quantitative study, more in depth qualitative research could provide useful answers to new emerging questions. Similar longitudinal research on students' attitudes about school subject, and mainly in the domain of STEM, could provide comparable data about the evolution of students interest and career aspirations.

Between 12 and 14 years, there is still a change in students' interest in technology. The presence of technology at school does not simply provide a rise in interest as one would hope for. Whether the decline would have been larger without is not to determine from these results. We do know that a decline in interest in school subjects is not abnormal at this age. Hadden and Johnstone (1983) found in their research that such a decline in interest for technology was stronger than for other subject areas. We note on the other hand that students are evolving differently during the summer holiday than one would expect from the overall results. This is an indication that what happens during school time does matter.

In line with research from de Vries (2005) and Mawson (2010) we found that boys are more interested in technology than girls at the start of the first grade. Boys are also more excited about a technical career than girls, as previously stated by Weinburgh (1995). Girls don't see themselves (yet) as technicians as we found in their perception about technology as a subject for both genders.

In the first grade we see a steady decline in aspirations, although the decline is stopped in the second grade and even increasing a little at the end of the second grade. A reasonable explanation would be that high expectations at the start of secondary education are quelled to some extend in the first grade, and more realism comes in place. At the end of the second grade these students in Flanders have to make a decision again about their future study. This might be the reason students are thinking about their future career again, and technology steps in as one possibility. How and why students choose a technological study in the second cycle of secondary education could also be a subject of future research.

Overall we can conclude that if the goal of technology education at school maintains to promote ‘a larger number of students in technological oriented studies and professions’ there is still much to do. The unequal decline in interest throughout the school may also point to a difference of what happens during the lessons. This appears to be insufficient to determine ones attitudinal evolution with two measuring points. Because we now that interest in technology evolves far from linear, making statements and drowning conclusion from a single measurement on attitude has to be done cautiously.

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How secure are design & technology trainee teachers in their understanding of designing, as portrayed in the latest national curriculum documentation?

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Abstract

This paper reports on the first of two stages in a small-scale research project that set out to examine how secure Design and Technology (D&T) one-year Postgraduate Certificate of Education (PGCE) trainees (*n*=14) believed they were in their understanding of designing and how confident they were in their ability to teach pupils to design. Data were collected using two questionnaires. The first was given to the trainees on the first day of their PGCE and the second at the end of that programme.

The paper begins by discussing the position of designing within D&T, an aspect of the subject that has been at its heart since the introduction of National Curriculum (NC) D&T in England in 1990. It then focuses on how 'designing' is portrayed within the 'designing and making' element of the Programmes of Study (PoS) for D&T (DfE, 2013). The two publications written by the National Curriculum Expert Group (NCEG) for D&T (NCEG, 2013) and the Design and Technology Association (Green & Robson, 2013), which set out to provide support materials to help teachers understand the slimmed down PoS are discussed.

The paper then describes the research project in terms of the sample and the chosen methodology. The timing and content of the first questionnaire is explained. Questionnaire results in terms of weaknesses found in design skills, understanding of designing and terminology used in the latest PoS are examined. The research informed inputs provided for the trainees as a result of the identified weaknesses are also highlighted.

Keywords

Designing, national curriculum, initial teacher training, research active curriculum

Introduction

The research reported in this paper concerned finding out answers to the research question: How secure are a cohort of PGCE D&T trainees in their understanding of designing and how confident are they in their ability to teach pupils to design, as portrayed in the latest NC D&T PoS?

Literature review

Much has been written regarding the importance and centrality of designing and making in the school-based subject of D&T within English schools since its inclusion in the first NC for England in 1990 (e.g. Atkinson, 2009; 2011; 2012; Atkinson & Sandwith, 2014; Lawler, McTaminey, de-Brett & Lord, 2012; Spendlove, 2013; Stables, 2012). Recently explicit support for the subject from within and outside of the D&T community was widely reported when it seemed possible that D&T's very position as a NC subject might be in doubt. This was followed by vociferous debate over the backward looking curriculum proposed in the 2013 draft D&T NC (Green, 2013) leading to the publication of a much improved final version for implementation in 2014 (DfE, 2013).

In the latest PoS 'designing and making' continues as the central theme around which all activities occur.

Through a variety of creative and practical activities, pupils should be taught the knowledge, understanding and skills needed to engage in an iterative process of designing and making (DFE, 2013, p.2).

However, this latest PoS is extremely slimmed down. It is only three pages long instead of the seventy pages found in the first PoS in 1990, which was also supported by the underpinning philosophy found in the Interim report and the non-statutory guidelines. The latest PoS does set out the essential, core knowledge, understanding and skills that pupils should learn. It states that designing and making should be carried out in a range of contexts such as: "engineering, manufacturing, construction, food, energy, agriculture and fashion" (DFE 2013, p.2), implying that pupils must design and make in each of the traditional material areas associated with D&T, although it does not explicitly state which materials pupils must study.

Within the document, D&T is broken down into two elements: 'Designing and Making', and 'Cooking and Nutrition'. In terms of the content of 'Designing and Making' that is provided in four sub-sections: Design; Make; Evaluate; Technical Knowledge. This paper focuses on the content of the 'Design" sub-section. Listed under 'Design' are the various stages/aspects of designing. Similar to the other sub-sections the how, why and what should be taught, is missing. This has lead to concern that teachers will find the PoS difficult to put into operation (Green & Robson, 2013). In an effort to overcome this problem two publications have been produced. The first published by the D&T NCEG aimed to clarify the distinctive nature of D&T in the classroom through six principles and examples of classroom activity to meet those principles (NCEG, 2013). The second produced by D&TA provided an interpretation of words and phrases to be found in the PoS, and advice on how the new requirements could be implemented (Green & Robson, 2013).

The PGCE teaching team agreed that if teachers were find the new PoS difficult to put into operation (Green & Robson, 2013) then trainees at the start of their teaching career would also find the new PoS unhelpful in developing a sound D&T philosophy when compared to the support provided in earlier PoS. They were also uncertain that the two publications referred to above (NCEG, 2013; Green & Robson, 2013), were enough to overcome the problem. This became the starting point for the small-scale research active curriculum project reported in this paper.

Methodology

Sample

The sample was the full cohort of fourteen trainees (one male; thirteen female) on a one-year D&T PGCE programme in a university in the NE of England. They entered the programme after studying various undergraduate (UG) honours degrees associated with D&T and had achieved results ranging between 1st and 2.2 classifications (see Table 1). All UK Universities split the results for undergraduate honours degrees into the following classifications: 1st; 2.1; 2.2 and 3rd class, the exact mark boundary associated with each classification varies between Universities).

Sample Code	UG Degree Subject	Classification	Approx final Mark
010	Illustration	1	70 - 100
014	Media	1	
005	Applied Art	2.1	60 - 69
006	Media	2.1	
007	Interior Design	2.1	
011	3D Design	2.1	
012	History Modern Art	2.1	
001	Graphics	2.2	50 - 59
002	Textiles	2.2	
003	Textiles	2.2	
004	Graphics	2.2	
008	Architecture	2.2	
009	Graphic Art	2.2	
013	Product Design	2.2	

Table 1. UG Degree Subject and Classification achieved for each member of the sample.

Research Instruments

Based on the author's numerous past research projects concerning the activity of designing within D&T a questionnaire was developed to establish how secure the trainees were in their understanding of designing and how confident they felt about teaching pupils to design as portrayed in the latest PoS (DFE 2013). This was given to the trainees on day-one of their PGCE programme. The questionnaire was broken down into demographic information, Likert-type-scale questions regarding their own design skills (see Table 2) and their confidence to teach pupils to design. Followed by questions asking for definitions of design related terms taken from the latest PoS - terms describing the design process as: iterative; formulaic; and cyclical, and other expressions including: open-ended design briefs; user values; creative risks. Green & Robson (2013) and the PGCE teaching team deemed the understanding of these terms was essential if the NC was to be interpreted as intended (Green & Robson, 2013).

It is proposed that a second questionnaire will be given to the trainees at the end of the PGCE programme. This will chart any changes in understanding of designing and how they intend to teach pupils to design after research informed inputs, based on the data from the first questionnaire, have been carried out. Data from the second questionnaire will not be ready to report in this paper.

Results

Results from questionnaire

Design expertise

When asked how much designing of functional products, as apposed to designing per se, had been a part of their UG degree, five trainees stated that it had occupied a major part of their programme, three had spent half their time designing functional products, five suggested it had only formed a minor part of their activity and for one trainee, designing functional products had not been included at all.

Development of design expertise post-UG programme

The development of design skills post-UG degree had been limited as only three out of the thirteen trainees that had had paid employment between UG and PGCE programmes had used their design skills during that time.

Strands of D&T the trainees wished to teach post-PGCE

The questionnaire offered six specialisms for trainees to choose when indicating what they hoped to teach post-PGCE: Resistant Materials; Electronics; Food Technology; D&T-Graphics; D&T-Textiles; Art-Textiles. Trainees were able to select more than one specialism. The majority chose either D&T-Textiles (n=8) or D&T-Graphics (n=8). Four were interested in teaching Food Technology, two selected Resistant Materials, no one chose Electronics. Five of those who selected D&T-Textiles also selected Art-Textiles.

Perceived design skills

Trainees were asked to rate their own skills in terms of fourteen skills associated with designing (see Table 2), using a six point Likert-type scale (excellent skill; very good skill; good skill; moderate skill; poor skill; no skill). The mean score for the whole group was 3.080 (maximum score per skill 5: minimum score 0).

When the total sample's mean score for each skill was placed in Rank Order (RO) (see Table 2) it indicated which aspects of designing achieved high, and which achieved low mean scores. Trainees believed they were good at collecting research and using it, also developing a chosen idea, whereas using 3D modeling to develop thinking both early in the process and during the development of a chosen idea came at the bottom of their skill set. When the data for individual trainees was scrutinized in terms of the design skills that had high Standard Deviations (see Table 2) they indicated that some trainees struggled with these design skills even more than the group low mean score suggested. This dataset informed the selection of relevant skill inputs for the cohort to help overcome the identified weaknesses.

RO	Design Skill	Mean	Std. Dev.
1	Collecting Appropriate Research	4.000	0.784
2	Producing evidence of the development of chosen idea	3.857	0.864
3	Explicitly showing the use of research that influenced thinking during design activity	3.786	0.802
4	Generating a range of creative early ideas	3.714	0.825
	Annotating design activity with both descriptive and analytical evaluative thinking		0.914
	Producing innovative creative final products		0.611
7	Analysing the requirements of the brief	3.571	1.158
8	Identifying design criteria that need to be met by the solution	3.500	0.139
9	Using appropriate CAD software to aid designing	3.071	1.385
10	Sketching ideas in a manner that communicates thinking to others	3.000	1.240
11	Identifying open ended design tasks/problems	2.929	1.385
12	Using appropriate software (spreadsheets, databases) to aid designing	2.857	0.139
13	Using 3D modelling to aid design thinking early on in the process	2.641	1.336
14	Using 3-D modelling to aid the development of chosen idea	2.571	1.222

Table 2. Rank order list of mean scores for the total sample for each design skill

Each trainee's mean score for the combined design skills was calculated (see Table 3). The results indicated that eight trainees achieved a mean score higher than the group mean and six trainees achieved a mean score lower than the group mean. Scrutiny of the UG degree data indicated that the type of degree studied was not the factor causing the difference, as similar subjects had been studied across both groups. However the data did indicate that the eight who achieved higher mean design-skills-scores, qualified with higher UG degrees.

It was decided that the split of trainees into two groups, Group A - the eight trainees with mean design-skill-scores above the mean and Group B - the six trainees with mean scores below the mean would be used where appropriate in the remaining analyses.

	Rank Order Mean score	Code	Mean Score
GROUP A Above Mean Score for design skills	1	011	3.929
	2	014	3.500
	3	003	3.357
		005	
		006	
		008	
		010	
	8	001	3.286
Group Mean Score 3.080			
GROUP B Below Mean Score for design skills	9	007	3.000
	10	004	2.857
	11	009	2.786
		013	
	13	012	2.786
	14	002	2.071

Table 3. Rank order of mean score for all design skills combined for each member of the sample

Enjoyment of designing

The questionnaire asked trainees how much they enjoyed designing (very much; moderately; not very much; not at all). Twelve of the fourteen trainees enjoyed designing very much. The trainees in Group A indicated greater enjoyment than Group B although the difference was small. The questionnaire also asked whether the trainees enjoyed designing more than making, enjoyed them equally, or enjoyed making more than designing. Two-thirds of Group B enjoyed making more than designing. In contrast no one in Group A, enjoyed making more than designing. Six of them enjoyed designing and making equally and two enjoyed designing more than making.

Relationship between teacher beliefs, skills and confidence to teach

The trainees were asked three questions in terms of being a good D&T teacher. Group A indicated a stronger belief in the two statements 'teachers need to understand how to design' and 'teachers should be passionate and enthusiastic about designing'. On the other hand, Group A agreed less than Group B with the statement 'teachers must be excellent designers themselves'. The result for Group A supported the author's belief that it is not necessarily those who are excellent designers who can teach others to be excellent designers; it is those who truly understand the activity (Atkinson 2009; 2011; 2012). Group B's scores for these three items were a concern, especially when added to their significantly lower mean score (Group A 3.125; Group B 2.250) when asked how confident they were to teach pupils to design. This data informed the teaching team as to which trainees might require extra support to develop their understanding and confidence.

Understanding terminology used in the latest PoS

The final section of the questionnaire asked trainees to define terminology used in the latest PoS. Firstly they were asked to define three types of design process (iterative; formulaic; cyclical). Only three trainees (all from Group A) were able to provide satisfactory definitions for any of these terms.

No trainee defined 'an iterative design process' accurately, five gave incorrect definitions such as:

"A free/creative way of designing"
"The process, which leads up to designing"

The rest provided no definition at all.

Five trainees were unable to define 'a formulaic linear design process', seven gave incorrect definitions such as:

"A process of design using technical drawing and mathematical processes"

and two trainees provided a definition, which indicated a limited understanding of the term:

"That it follows the design process religiously without deviating – in a line"
"A design process, which follows a strict process of development"

In defining 'a cyclical design process', two definitions closest to being correct were:

"Design process using a 'cycle' of steps – research to ideas to analysis then back to more research if required"

"That the process goes through cycles of design, coming up with a solution, evaluating and starting again"

Otherwise there were two incorrect definitions and nine trainees were unable to define the term.

When trainees were asked to define 'open-ended design brief', three trainees gave acceptable definitions:

"A brief, which can be taken in a number of different directions to allow a variety of outcomes"
"A brief where no specific outcome is anticipated"
"A brief with no set end product"

Seven provided definitions that indicated a limited understanding of the term, although there were still four trainees who provided incorrect definitions such as:

"The outcome from the brief doesn't necessarily have a finished product"
"A continuous brief that is ongoing and can be developed further"

In terms of the statement 'D&T teachers should get pupils to think about 'users' values', the data indicated better trainee understanding. Ten trainees understood the statement, another three presented definitions that were partially correct and only one trainee suggested an incorrect definition. However, when asked to define what values the statement could be referring to, only six trainees were able to suggest the types of values that Green & Robson (2013) indicated were implied in the PoS. Three trainees provided partially acceptable suggestions, four gave incorrect suggestions such as *'materials', 'questionnaires', 'primary research'* and one student provided no suggestions at all.

When asked the meaning of 'Teachers need to enable pupils to take creative risks' five trainees understood what was implied. For example:

"Allowing pupils the freedom to create for themselves and not just be told what to do is important for pupil growth and confidence"

The remaining nine trainees provided partially appropriate definitions, describing more what creative risks were than making reference to teachers 'enabling' that risk to take place. For example:

"No right or wrong ideas"

"Pupils need to take creative risks so that they can design something that is different, something which they may not have tried before, taking risks is a learning curve"

As with the earlier sections the data collected from the definition section enabled research informed inputs to be developed to enhance the trainees understanding of these and other ill-defined terms in the latest PoS.

Conclusion

Data collected so far has indicated that there were weaknesses in the design skills of a number of trainees, also in their understanding of designing and how confident they were to teach pupils to design. Their knowledge of terminology used in the PoS was also poor. However, the data has enabled research informed inputs targeted at the identified weaknesses to be carried out. It is hoped that by the end of the programme the results of the second questionnaire will indicate that the trainees concerned in this small-scale study will have developed a deeper understanding of designing and how they will teach pupils to design and that they will feel secure in using the PoS to provide pupils with high quality D&T education which as the PoS states *"…makes an essential contribution to the creativity, culture, wealth and well-being of the nation"*(DfE, 2013, p.1).

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Facts for youngsters – contextualised technology or fragmented artefacts?

A study on portrayals of technology in picture books from a gender perspective

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Abstract

Technology is a field with strong connections to the female/male dichotomy and children's gender stereotyping starts as early as the age of two (Berner, 2004; Nisbet, Pendergast & Reynolds, 1998; Turja, Endepohls-Ulpe & Chatoney, 2009). According to the Swedish Curriculum for the Preschool, the preschool should strive to ensure that children ”develop their ability to identify technology in everyday life, and explore how simple technology works” (Lpfö98/2010, p. 10). The preschool also has a goal to actively counteract traditional gender roles and patterns (Lpfö98/2010, p. 4). An important part of children's activities in preschool relates to picture books. A government investigation states that the preschool, through its activities (among them ”reading aloud”) is an arena where societal norms can either be preserved or challenged (SOU 2006:75). Books about cars, airplanes, boats etc. often serve as an introduction to human applications of technology. Based on these, children start to identify and categorize the technologies they encounter in everyday life.
The aim of this study is consequently to investigate the technological content from a gender perspective in a selection of picture books, more specifically; how do the books content preserve or challenge preschool children's view of technology and gender? Preschools use books from libraries in their daily activities, therefore the empirical material in this study is derived from the library section ”facts for youngsters”. A thematic analysis was employed to discover the dominant themes within the books. The result of the study shows that there is a focus on how separate artefacts function but no detailed explanation on how these artefacts are connected or what kind of implications they have in a societal context. There also seems to be an emphasis on traditionally masculine coded technology. This study will serve as a basis for a comparative study between two preschools, one where gender and technology is a prioritised goal and one where it is not.

Keywords

Technology education, preschool, picture books, gender, Sweden

Introduction

The world of today is an increasingly technological one. To navigate their day-to-day life citizens need technological skills in the form of a highly developed technological literacy (Rohaan, Taconis, & Jochems, 2010; Turja, Endepohls-Ulpe, & Chatoney, 2009). Without this knowledge the citizens will not be able to make deliberate democratic choices (Kierl, 2006). The Swedish preschool curriculum stresses the importance of technology education. The preschool should strive to ensure that children ”develop their ability to identify technology in everyday life, and explore how simple technology works” (*Läroplan för förskolan Lpfö 98*, 2010, p. 10).

Axell’s international research overview shows that research on technology education for younger children still is in its infancy (Axell, 2013. See also Fleer, 2000; Roden, 1995; Tuja et al., 2009; B. Mawson, 2010). Axell identifies different areas in need of development, this study takes its starting point in one of these:

> There are differences in girls’ and boys’ attitudes towards technology and how they tackle technological tasks in preschool. Preschool teachers should work actively to counteract gender patterns regarding technology (Axell, 2013, p. 31).

Children’s view on gender forms early in life, somewhere in the interval of 2 through 5 years of age (Lyon, 1991;Trepanier-Street & Romatowski, 1999; Turja et al., 2009). Teachers and media (i.e. literature) are two of the elements that influence preschool children in their understanding of what society deems as appropriate behaviour for males and females (Crisp & Hiller, 2011; Oskamp, Kaufman, & Wolterbeek, 1996). Children’s literature is a primary way for one generation to transmit cultural values to the next one, the content in these books has a capacity to colour children’s view of their understanding of the world and themselves (Crisp & Hiller, 2011; Gooden & Gooden, 2001; Hellsing, 1999; Kåreland, 2013; Reynolds, 2011). According to Trepanier-Street and Romatowski (1999) children’s literature can be a powerful instrument for influencing children’s view about gender. If a stereotypical view on gender is conveyed (as documented by Axell et al., 2014; Hamilton et al., 2006; Martin & Siry, 2009) it will socialize children into traditional roles and limit their interest in other activities that may also suit them (Gooden & Gooden, 2001; Oskamp et al., 1996). A government investigation states that the preschool, through its activities (among them ”reading aloud”) is an arena where societal norms can either be preserved or challenged (SOU 2006:75). Reading aloud has a long tradition in Swedish preschools and is often done by using books from public libraries (Kåreland, 2005; Simonsson, 2004). Therefore the empirical material in this study derives from the library section ”facts for youngsters” and “technology for youngsters” originating from four different public libraries in three Swedish cities. In total, 180 books have been the subject of analysis.

Literature addressed to younger children is generally not incorporated in research on the relationship between literature, technology, society and culture and thus explored limitedly (Westin, 2003a; 2003b). The aim of this study is consequently to investigate the technological content in a selection of picture books from a gender perspective.

Methodology

Like all texts, children’s books are culturally coded, consciously as well as unconsciously, both implicitly and explicitly. Cultural codes regarding gender may be so deeply ingrained and pervasive that they are not recognized by those who hold them (Ross Johnston, 2011). To reveal the dominant themes within the books in a way as objective as possible, we employ a thematic analysis. Thematic analysis seeks to unearth themes at different levels and the aim is to explore the understanding of an issue, rather than to reconcile conflicting definitions of an idea (Attride-Stirling, 2001). The thematic analysis in this study includes 1) Coding the material, ie. identifying the technological content, 2) Investigating in what context the technology is presented, 3) Analysing and identifying themes, 4) Summarize patterns found in the material and discuss the themes identified in relation to gender.

As the empirical material consists of picture books, there are further methodological aspects to consider. In picture books the message to the reader is mediated through an interaction between text and pictures. Therefore, the analysis is performed out of a holistic interpretation of image and text (Hallberg 1982; 2008).

Technology in facts for youngsters

Our examination of the picture booksshows that a large number of them are written for the purposes of naming, labeling, categorizing and giving information about technological artefacts. How technology is portrayed in the books can be classified into three main themes: *The autonomous technology*, *The triumphal progress of technology* and *Humans in a technological context*.

The autonomous technology

Our examination of the empirical material shows that the dominant theme among the picture books is motorized vehicles, i.e. cars, airplanes, tractors etc., and this applies to both books written for the youngest and the somewhat older preschool children (ages 3-6).

The books aimed at the younger age group deal almost exclusively with traditionally masculine coded technology. Furthermore, humans are frequently excluded and artefacts are presented without any illustrated context. Motorized vehicles are brightly coloured and set against a small backdrop (i.e. water around a boat, clouds around a plane) or no backdrop at all, the main focus is on the artefact itself. If humans are presented, they are passively standing by, observing the machine performing the task, or acting as a kind of helper. This can be interpreted as if the technological artefacts operate with a mind of their own: technology is autonomous. This message is often enhanced by the text. Angela Royston's picture books, for example, contain passages like: "Lube trucks deliver oil to where oil is needed" and "The excavating arm is digging large pits".

In the books catering to the older age group, the focus on traditionally masculine coded technology is still present. However, the artefacts are presented with human or animal attributes (anthropomorphism). For example, an engine can be described as "being alert" or as if it is "roaring". Metaphors deriving from nature are also common in these books. In *Gary Gadget's Best Cars* (Johansson & Ahlbom, 2004) a disc brake is likened to a "lobster claw". The message in these books can be interpreted as if the vehicles have a will of their own and act without human control. An example of one of the few books where traditionally feminine technology is highlighted is *Bruno the Tailor* (Klinting, 1996), in which the male lead character is sewing an apron.

Generally in all of the books there is an excess of male characters. For example, in Dreer's *Oh! Les belles motos* (2003) there are about 30 male characters, but only a handful of females. The females in the book take on a passive role, standing by watching the males riding the motorcycles.

Another common artefact that is shown in the books is robots. Contrary to motorized vehicles, robots are presented as a creation of human ingenuity and focus seems to be on the relationship between Man and machine. The anthropomorphic technology is still present though. In Riddell's *Wendel's Workshop,* the inventor, Wendel, invents a mighty robot that cleans incessantly. Soon Wendel finds himself thrown onto the scrap heap by the robot. The story shows how wrong things can go if humans lose control of their technological creations. In Skåhlberg's and Dahlqvist's book *Cax – the thirteenth robot* (2012), not only is the robot alive – all kinds of artefacts are anthropomorphic. In *Robots*: *What they are, what they do* (Berger,1995), the reader is informed that robots "can do some things better" than humans. For example: robots can work without food or sleep, they never get bored, cost less than humans and so on. In the books both female and male robots are shown, though male ones are more prominent than female ones, as well as gender neutral robots.

In summary, the autonomous depiction of the technology is of two kinds. In the books that cater to the youngest, technology is portrayed as autonomous but not in an anthropomorphic way which is the case in the books for slightly older children. The autonomous and anthropomorphic technology can be interpreted as a way to create an affinity between readers and the technology. The child is supposed to identify with technology and relate to it (Schwarcz, 1966). This may not be achieved by the books for the youngest children where the autonomous and context free technology conveys a picture of there being a distance between humans and technology.

The triumphal progress of technology

As Edgerton (2006) notes, the description of technological development is seldom communicated from a global perspective. The history of technology is mainly portrayed in an innovation-centric way, including only the small number of places in the world where the newest inventions and innovations are concentrated. This narrow view is also mediated through the picture books. In Bergenholz's *What cars*

(2008) the reader is informed that: ”Nowadays almost everyone has a car. Some even have two.” A generalized statement considering that a majority of the world's population does not have a car at all.

The historical aspect is a recurrent theme in the picture books. Modern technology is colourfully illustrated whereas the technology of the past is often illustrated in black-and-white. The message is clear: everything has gotten better. In the past, people had to rely on themselves or animals like horses and oxes. In Bingham’s *Tractor: Machines at work* (2004) the reader is told that harvesting used to be a hard and time consuming work but nowadays you just use the tractor, the working horse of today. In the same book, under the headline ”Spraying or not” the reader is informed that the crops are sprayed ”to grow better”. The pictures show how easily the pesticides can be spread over the fields, by just one man and a tractor. There is also a picture from an ecological farm showing eight men working behind the tractor, lying on their stomachs and picking weed. The work on the organic farm is presented as requiring more manpower, and also as being time consuming.

The neglect to describe consequences for the environment is also a common theme in the books. This is especially true for picture books about motorized vehicles. If the exhaust gases are mentioned at all it is only as a notion:”cars pollute the air”. Statements in line with ”back in the day cars emitted a lot of pollution but today we have ways of fixing this”, conveys an over reliance on present and future technology. Technology's dual nature is not recognized and it is primarily the benefits of technology that is highlighted. A handfull of books promote recycling or reusing, but this is only implicit in the texts. However, in Koivisto’s book *Children’s Energy Book* (2007) energy is described as ”[…] a force that allows us to live, grow, play and work. […] all energy on Earth has its origin from the sun”. This book is the only one that problematizes the use of fossil fuels and uranium, it also suggests what a family can do in everyday life to save energy.

In the few instances where military technology is mentioned, it almost exclusively occurs without references to consequences for humanity. The human interaction, if present, is done using a sketch of a white generic male. An exception is the *The Violence Book* by Stalfelt (2005) in which the reader sees soldiers shooting at each other, people with severed limbs, bombs falling on cities etc. The impact on humanity is described in an explicit but at the same time humoristic way.

To sum up, just a few of the picture books raise awareness of environmental or societal issues related to technological applications. A majority of the books imply that the most efficient and easiest way of getting things done is to use machines, machines with a heavy impact on earth’s resources. They indicate that methods of the past or methods used in third world countries are inefficient and backwards. This can be interpreted as saying that poor countries need to learn from the richer ones, which includes the use of big and expensive, resource-consuming technology.

Humans in a technological context

In the books where humans are more frequently active, technology is not autonomous. It is portrayed as a result of human will to fulfill needs and wants. The systemic notion of technology is common in these books, i.e house construction, energy systems, public transportation, etc. This theme is only found in the books aimed at ages 3-6. An example of interaction between humans and technology appears in *Avions et fusséss* (Bessard, 2012). The different components of the airport are described, as well as how they are connected. The pages are filled to the brim with different passengers and the employees working at the airport. Questions about how to use the airport as a passenger are asked and answered, as well as questions regarding personal safety.

Descriptions of vocational roles and the technology that is linked to these are common in the books aimed at ages 3-6. These roles are often illustrated using a female character in a traditionally feminine coded occupation and a male character in a traditionally masculine coded one. In *The house across the street: How to build a house* (Sunesson & Agdler Suneson, 1995) a multitude of people are shown in a plethora of traditionally masculine coded occupations. Almost all of these characters are male. In *Avions et fusséss* (Bessard, 2012) there are more male pilots than female ones and the security staff is exclusively consisting of men. On one page the reader is encouraged to ”find-three-irregularities”. In the picture a stewardess, draped in a pink garb, is positioned in the pilot’s seat, while the pilot (a male) is chilling-out, reading a book in first class.

Males and females are also described differently. An explicit example is *The ice cream family* (Kåberg, 2011). Three grown-up siblings working in the factory, a sister and two brothers, are described. The brothers are shown shoulder to shoulder. They are in charge of the production and are also the ones who come up with new ice cream flavours. The sister is shown with her daughter and her father (the boss at the factory) and the text is indicating that she is the mother of the next generation of ice cream makers.

This is in line with Nikolajeva's (2004) dichotomies of how males and females are usually described in children's literature: males as active and independent, females as passive, caring and dependent.

Concluding discussion

Previous research shows that there is an emphasis on artefacts and the making of artefacts in technology education. As technology is not placed in a broader context, the connections between artefacts and humans as well as what kind of implications the artefacts have in a societal context are disregarded (Klasander, 2010; Mawson, 2007; Siu & Lam, 2005; Svensson). This theme also pervades the children's literature in this study.

Although books aimed at younger children cannot contain advanced technological concepts, there is a risk that the lack of context may prevent the children from discovering that technology is part of a larger whole. The books convey a message that technology has a life of its own and is not linked to human activity, knowledge and volition, i.e. something humans create and use to satisfy needs and wants or to solve problems. A majority of the picture books, particularly those aimed at younger readers, fail to create a connection between the machine and human intentions. On one hand the books can be interpreted as if they want to present technology as value-free and as neutral as possible. On the other hand, they miss the opportunity to connect technology to everyday life, i.e. tie technology to the societal and environmental settings in which they operate. But even if technology is presented in a context it is not value-free. From a gender perspective, the message in the picture books is clear: men are both the source of technological development and the users of technology. Male and female characters are often presented in a stereotypical manner and there is also an over representation of male characters. In the few books where the stereotypes are challenged, there still exists an implicit gender normative notion. An example of this is *Bruno the Tailor* (Klinting, 1996) in which the male character is making an apron. To do this he has to use his aunt's sewing room, indicating that this is a feminine coded domain. Another example is the book *The house across the street: How to build a house* (Sunesson & Agdler Suneson, 1995). In the book, Engineer Air (a woman) is in charge of making sure that the house will be able to ″breathe″. She has a traditionally masculine coded occupation but her role is described as caring, in line with a female normative role (Nikolajeva, 2004).

As Bjurulf (2011) states, technology education should be conducted on the basis of a holistic approach to learning. When technology is put into a broader perspective, it can contribute to children's understanding of the world around them. For many children, learning about the world starts with picture books which also often work as an introduction to human application of technology. As gender is something that is mainly socially and culturally created, reading aloud can stimulate the children to develop an awareness of gender and how gender patterns are created (SOU 2006:75). After the examination of about 180 picture books, our conclusion is that, while these may serve as a basis for an introduction to technology, there is also a risk that they will conserve gender patterns. The way technology is presented in the books, with a heavy focus on males and masculine coded technology, is not in accordance to the preschool goal of giving both girls and boys "the same opportunities to develop and explore their abilities and interests without having limitations imposed by stereotyped gender roles" (Lpfö s. 4). As technology is presented in a gender normative way, it will be up to the preschool teacher to problematize the relationship between technology and gender presented in the books.

Our conclusions will serve as a starting point for a study with the aim to examine how preschool teachers deal with messages about technology in picture books in relation to the curriculum. Two different preschools will take part in the study, one where gender and technology is a highly prioritised goal and one where it is not.

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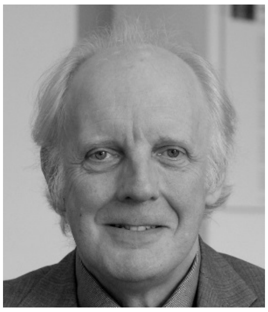
Pupil visions of a robot future



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Abstract

This paper reports a small case study of a short scheme of work in which pupils aged 12 years reveal their beliefs about robots and their views on the way robots will impact on human life in the future and their concerns as to whether this impact will be beneficial or disadvantageous. The scheme of work was developed with a view to provide pupils with technological perspective concerning a disruptive technology in this case robotics. The study raises questions as to the extent of explicit teaching that might be required to support pupils in this sort of critical pedagogy.

Keywords

Design & technology education, robotics, curriculum development, critical pedagogy

Introduction

The current design & technology curriculum for 11-14 year old pupils in England (DfE 2013) has several requirements relevant to this paper. It requires that pupils should be taught:

– to investigate new and emerging technologies,

– to understand developments in design and technology, its impact on individuals, society and the environment, and the responsibilities of designers, engineers and technologists To apply computing and use electronics to embed intelligence in products that respond to inputs [for example, sensors], and control outputs [for example, actuators], using programmable components [for example, microcontrollers].

The guidance for the proposed GCSE in Design & Technology (DfE 2014) indicates that examination specifications must require students to demonstrate the ability

– to investigate social, ethical, cultural, environmental and economic challenges, in order to identify opportunities and constraints that influence the design process,

Candidates must also have knowledge and understanding of:

– the functions of mechanical fittings and devices, power sources and discrete and programmable components and how they can be applied to products,

– new and emerging technologies, including their impact on industries, society and the environment.

For teachers developing a design & technology curriculum a consideration of robotics would meet these requirements to a considerable degree although it must be noted that these general statements would need detailed interpretation with regard to teaching robotics.

It is both relevant and noteworthy that the impact of robotics on society has recently become a matter of concern. Nesta (2014) has just published a significant monograph concerning visions of a robot economy commenting on the economics of a robot future, technological possibilities, robots of the past and future and the relationship between robots and justice. Academics have claimed that robots will 'steal 50% of human jobs in the near future' (International Business Times 2014) and Illah Nourbakhsh (2013) has written a series of short stories describing dystopian futures in which the use of robotics has unintended consequences to the detriment of humans. Hence this paper considering pupils' views on robots is timely.

Theoretical background

This paper builds on a previous publication concerning the teaching of disruptive technologies, including robotics, in school (Barlex, Givens & Steeg, 2013) and is the second of two papers describing a case study of pupils aged 12 years considering the social impact of robots. The first paper (Barlex & Steeg 2014a) considers the pupils' views of robots in the world as revealed by their initial drawings of robots and their responses to a questionnaire. Scrutiny of the initial drawings revealed that the overwhelming majority of pupils saw robots as a 'metal man'. The questionnaire revealed that in line with this view of robots the overwhelming majority of pupils saw robots tackling tasks as a human might as opposed to a non-humanoid purpose designed automated machine. In considering the appearance of robots the pupils favoured an appearance that whilst derived from a human face was not so similar as to invoke an uncanny valley (IEEE 2012) response. This paper will consider the extent to which these pupil views on robots were changed by the opportunity to study robots in the context of their current real world applications and possible future uses.

Methodology

This research took place at a new school in West London that opened in new premises with a single year group of 170 pupils aged 11 years in September 2013. It has an unusual curriculum. The school day starts at 8am with English, Mathematics, Science, Languages and Humanities lessons taking place in the morning. The afternoon lessons are longer and given over to a 'creativity and curiosity' curriculum allowing students to immerse themselves in practical subjects such as Sport, Art, Music, Applied Science and Creative Technologies. It was in response to pupils' work in applied science and creative technologies that the school developed in collaboration with the researcher a series of lessons concerning robots during which the research could take place. These lessons, each 50 minutes in length, took place during the first week in July 2014 as follows:

Lesson 1 – introduction in which pupils drew a diagram of what they believed a robot to be like, viewed examples of current robots and discussed what they are doing now in the world

Lesson 2 – administration of the questionnaire designed to elicit pupil views on robots

Lesson 3 – independent research on robots and how we might use them in the future

Lesson 4 – creative writing/drawing task describing how humans will use robots in 50 years time

The researcher collected samples of work from 80 pupils that they had produced during lesson 4. Of this sample 27 were written accounts, 49 were annotated drawings and four were short comic strips. The responses in the written accounts were categorised in terms of the useful tasks the robots might perform (shown in Table 1) and the disadvantages that might result (shown in Table 2). The responses in the annotated drawings and comic strips were categorised according to the form of the robot and the types of activity the robot performed as shown in Tables 3 and 4 in the results section. Note that some of the robots described performed multiple functions. In some cases pupils used annotations to comment on the benefits and disadvantages of using robots. These are summarized beneath the relevant table.

Results

Of the 27 written accounts 12 were creative in the sense that that they involved writing a fictional account of life with robots in the future using the story to make comments as to the benefits and disadvantages of life with robots. The remaining 15 were in the form of reports commenting on the benefits and disadvantages of life with robots. Table 1 and Table 2 show an analysis of the comments. Table 1 indicates pupils' views on the useful tasks that the robots might perform i.e. the benefits of robots. Table 2 indicates pupils' views as to the disadvantages of robots performing such tasks.

Useful tasks	Frequency
Domestic duties	13
Medical applications	6
Homework	5
Warfare	4
Care and companionship	4
Industrial cleaning	3
Transport	3
Retail	2
Personal grooming	2
Human enhancement	1
Exploration	1
Home repair	1

Table 1 Pupils' views on the useful tasks that the robots might perform as described by creative writing

Comment	Frequency
Encourage laziness	11
Unemployment	7
Loss of life through programme malfunction	5
Dependence	4
Poor health	3
Lack of purpose in life	3
Loss of knowledge and skill	1
Demise of money	1
Extinction of the human race	1

Table 2 Pupils' views as to the disadvantages of life with robots as described by creative writing

Robot Form	Tasks performed	Number of responses
Humanoid	Domestic duties	16
	Police/security	7
	Manufacturing	3
	Entertainment	3
	Homework	2
	Exploration	2
	Transport	2
	Companionship	1
	Care	1
	Santa Claus substitute	1
		Total responses 38
Animal of some sort	Police/Security	2
	Exploration	1
	Companionship	1
		Total responses 4
Non humanoid	Domestic duties	13
	Transport	5
	Police/security	3
	Warfare	2
		Total responses 23

Table 3 "How humans will use robots" as described by annotated drawings

Nine pupils made comments as to the benefits and disadvantages of robots in their annotations. Overall they noted the initial benefits of robots completing domestic tasks that many humans find unrewarding i.e. the removal of drudgery and tasks that require repetition. However they all expressed reservations with regard to this practice becoming widespread. One pupil wondered how humans would cope if the robots broke down. Other pupils took this further arguing that as robots took over more and more human tasks humans would lose the ability to do things for themselves, become inactive and unhealthy and lose their sense of being responsible for themselves. One pupil saw this as ultimately leading a decline in the human population. Only one pupil commented on humans losing employment; the use of flying robots leading to human pilots losing their jobs. Only one pupil considered the possibility of robot revolution – in this case a cleaning robot using hot wax as a weapon against its human owners. One pupil commented on the advantages of a pet robot – it could not die thus sparing the owner the experience of grief and the cost of replacement.

Robot Form	Tasks performed	Number of responses
Humanoid, essentially a 'metal man'	Homework	2
	Domestic duties	3
	Personal grooming	1
		Total responses 6
Mechanical arm (1)	Manufacturing	1
		Total responses 1

Table 4 "How humans will use robots" described by comic strips

One pupil noted that as robots did more and more for humans, humans would be unable to look after themselves and the human race would slowly die out.

Discussion

Prior to this study all the pupils had experienced a short course concerned with programming a simple Lego buggy as part of their creativity and curiosity curriculum. This is typical of the response of many schools to teaching those elements of robotics that are seen to meet the curriculum requirements outlined in the introduction (DfE 2013, DfE 2014). Commentators have noted that while such activities are without doubt useful there is a bigger picture to be considered. It is important that pupils understand that there is much more to robots and robotics than they might realize from their basic work in building and programming (Barlex & Steeg 2014b). It is clear from pupil response to the activities in lessons 1 and 2 of the study that initially they show a very limited and limiting view of what a robot might be (Barlex & Steeg 2014a). The purpose of the additional lessons 3 and 4 was to give the pupils the opportunity to find out for themselves more about robots and consider in more depth the social implications of robots on the way humans live. The teaching was deliberately not didactic and the pupils had more freedom than is usually the case in their science lessons with regard to required learning outcomes. They were asked to carry out some 'creative writing and/or drawing' which could take the form of stories, diary entries, comic strips or annotated sketches. The creative writing in most cases did not contain any illustrations of the robots being described or descriptions of the appearance of the robots considered. Hence these did not reveal the extent to which these pupils were still limited to viewing the robot as humanoid. However the annotated drawings and comic strips reveal that this view of robots is still retained by a majority of the pupils (44 illustrations out of 72 illustrations were still 'metal men'). This is not particularly surprising as this stereotypical view of robots is reinforced by many forms of popular culture and such views are not easy to change. Of the types of task that pupils thought robots could perform the most popular by far was domestic duties in both the written and visual responses (38%), followed by police/security (10%) followed by transport (9%) followed by homework (8%), then medical applications (5%) with the remainder of task types scattered across a wide range of activities but each selected by only a very few pupils e.g. manufacturing, entertainment personal grooming, warfare, care, companionship. The popularity of domestic duties is perhaps not surprising as the pupils have little experience of environments outside their home and would focus on how robots might help in that situation. It is noteworthy that in none of the accounts did the pupils use any numerical data to indicate the extent to which robots are currently being used and how this might increase in the future but perhaps pupil understanding of 'creative writing and or drawing' does not include the use of number.

Of the 27 pupils who produced written accounts 18 identified disadvantages with regard to the impact of robots on human life. These are shown in Table 2. The most frequently cited disadvantage was that robots would encourage humans to be lazy (31%), followed by unemployment (19%), followed by loss of life through programme malfunction (14%). Increased dependence, poor health through inactivity and a lack of purpose in life followed closely with just one pupil identifying each of the following: loss of knowledge and skill, the demise of money, and the extinction of the human race. A similar set of disadvantages emerged from the comments within the annotated drawings and comic books. Given the pupils' somewhat limited view of the scope of robot activity as evidenced in Tables 1, 3 and 4 they see a wide range of disadvantages. It appears that although the pupils can see the initial benefits of the tasks they identify for robots to carry out they are also aware of their potential to have a detrimental effect. In all cases the pupils saw the robots as replacing the humans that would normally carry out a particular task. They did not see robots and humans in a collaborative relationship. Hence although their initial thoughts were that robots carrying out tasks instead of humans would be a good thing, they quickly revised their opinions and saw a future in which this took place as being dystopian.

I think the reaction of the pupils to this unusual approach to teaching about robotics has some interesting implications for curriculum development in this area. The approach adopted by the teachers were, for them, highly experimental and an opportunity to move away from an approach which was concerned primarily with the transmission of knowledge. Hence they devoted a considerable amount of time to enabling the pupils to explore their existing understandings of robots and their beliefs about their current and possible future uses. They deliberately allowed the pupils to make their own value judgements and in the light of these critique the impact of robots on humans. This approach is very much in line with critical pedagogy (Friere 2013) which allows pupils to recognize connections between their individual problems and experiences and the social contexts in which they are embedded. In this particular case the pupils are speculating as to what the problems might be for humans in the social context of robot activity. Making this demand on pupils is not something to be done lightly and I wonder if some preliminary teaching about robots and some scaffolding of their explorations might not have paid dividends without depriving the pupils of ownership or the critical thrust of the endeavour.

Developing an agreed definition of a robot that reflects current reality and possible future developments would seem an important first step in developing a robotics curriculum. Hawes (2014) provides a very basic definition of a robot as "a machine that automates a physical task". This is useful as it indicates that the machine will do something in the real as opposed to a virtual world but it makes no reference to the form that such a machine might take. Hence this definition can move pupils away from the 'metal man' perception. Nourbakhsh (2013) extends this as follows:

> In robots we have invented a new species that operates as a living glue between our physical world and the digital universe we have created. Robots can operate in the real world and at the same time can be fully connected to the digital world.
>
> Adapted from pages xiv & xv Robot Futures 2013

Deliberately teaching pupils about the different types of robots and their capabilities would be useful. Providing pupils with examples of robots deploying these capabilities in different sectors of the economy would widen their view. And it would also be useful if this sector deployment were treated quantitatively across time. This would indicate the rate at which the adoption of robot 'labour' in various sectors was taking place. This focused teaching would put pupils in a far more informed position from which to speculate about impact. In terms of scaffolding their explorations it would be a fairly simple matter to provide some 'questions for consideration'; for example:

– Who wins and who loses when robots carry out this or that task?
– Where might robots and humans work side by side?
– What is the relationship between robots and humans when they collaborate?
– What is the relationship between robots and the humans they might care for?
– Who decides when a robot takes over a task that is done by a human?
– What criteria do they use to make this decision?
– Who decides on what a robot can or can't do?

It would in no sense deprive them of the opportunity to be critical. Rather it would empower their ability to critique from the perspective of their own and their family's values. It has been argued that the teaching of robotics needs to be related to the teaching of Artificial Intelligence and the Internet of Things, putting all these technologies in the context of 'disruptive technologies' (Barlex, Givens & Steeg 2013) but this is beyond the scope of this paper.

Conclusion

This small case study has explored a short scheme of work in which pupils reveal their beliefs about robots and their views on the way robots will impact on human life in the future and their concerns as to whether this impact will be beneficial or disadvantageous. It was in effect an exercise in critical pedagogy and in considerable contrast to the pupils' usual curriculum experience. The study gives pause for thought with regard to the way engaging pupils in this sort of critique should be supported by explicit teaching of relevant subject knowledge, in this case the different types of robots, their capabilities and deployment in various sectors. Future developments in robotics education carried out by the author will take these findings into account.

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Focusing on a specific learning content in primary technology education

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Abstract

In this paper, we discuss findings from two previous studies in technology education using the Learning study model and the Variation theory of learning. The Learning study is a collaborative approach where teachers and researchers work together in the classroom with the aim to enhance students' learning concerning a specific content. In a Learning study, focus is on a specific "object of learning", i.e. what the students are expected to learn. The aim of this paper is to show what knowledge concerning specific objects of learning in technology education is generated in a Learning study and to discuss the potential contribution of this knowledge to technology teaching practice. We will provide examples from two Learning studies conducted in primary technology education in Sweden. The findings from the studies are of two kinds; identified aspects of the object of learning that are critical in order to learn, and aspects that could be referred to the teaching of the specific content.

Keywords

Design-based research, learning study, primary school, technology education, variation theory

Introduction

The need for research into the relationship between teaching and learning in technology education has been highlighted by several scholars (e.g. Jones, Buntting & de Vries, 2011). In order to arrange for learning teachers need to address *what* it is that the students are expected to learn. Our point of departure is that learning is always about *something* (Marton & Booth, 1997), in other words – there is no learning without something being learned. However, *what* the students are supposed to learn is not often made explicit in the technology classroom (Bjurulf, 2008; McCormick, 2004). This fact can be understood in the light of the lack of teachers' traditions for elaborating upon the objectives formulated in the technology syllabus (Jones & Moreland, 2004; Kilbrink et al, 2013), as well as teachers' lack of articulated knowledge concerning subject specific capabilities in general (Carlgren, 2011). In order to study the relationship between teaching and learning and to understand how teachers' actions in the classroom affect students' learning, a theoretical framework is necessary (Nuthall, 2004). The so called Learning study is a way to explore specific objects of learning, i.e. what the students are supposed to learn, as well as how teaching can enhance this learning, using the variation theory of learning as a theoretical tool (Marton & Lo, 2007)

The aim of this paper is to show what knowledge concerning specific objects of learning in technology education is generated in a Learning study and to discuss the potential contribution of this knowledge to technology teaching practice. We will provide examples from two Learning studies conducted within technology education in a primary school. Each example will focus on a specific content, that is to construct a linkage mechanism allowing for transfer and transformation of movement, and to make strong constructions using hands-on material.

The learning study

A Learning study is a kind of design experiment inspired by the Japanese Lesson Study (Marton & Lo, 2007), with the major focus on exploring a particular object of learning. The object of learning refers to a capability that the students are expected to develop during one or a few lessons, for example the ability to discern a solid construction or the ability to construct a mechanism (Marton & Tsui, 2004). A group of teachers collaborate with a researcher in a process of cyclically repeated steps investigating the most powerful way to teach the specific object of learning (Marton & Pang, 2006). The Learning study model is illustrated in Figure 1.

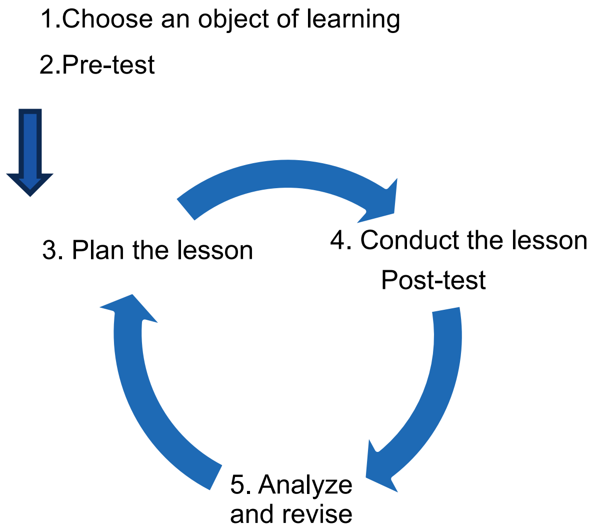

Figure 1. The Learning study model

A Learning study starts with agreeing on an object of learning, this is usually something considered to be difficult for students to learn. The next step is to design a pre-test to map students' prior knowledge. Based on the result of the pre-test, the lesson is designed and then carried out by one of the teachers with a group of students. The lesson is then analysed as well as the students' outcomes. Based on this information the lesson is revised. In the next cycle, a teacher teaches the revised lesson with another group of students, and the procedure is repeated (Pang & Marton, 2003). In a Learning study a theoretical framework, the variation theory, is used as a tool for designing lessons and analyzing teaching. Pang and Lo (2012) emphasize the focus on a specific object of learning and the use of variation theory as important foundations in a Learning study.

Variation theory

The variation theory is a theory about learning (and teaching). The theory was developed from the phenomenographic research approach by Marton and his colleagues (Marton & Booth, 1997; Marton & Tsui, 2004). From a variation theory position learning is defined as a change in which something is seen, understood or experienced. Learning is understood as a process of discerning new aspects of an object of learning in new ways. In order to discern something in a certain way, variation is needed; that is, when certain aspects of a phenomenon vary while other aspects remain constant, those aspects that vary are discerned. For example, one could not discern colours, if blue was the only colour that existed in the world. To give learners the opportunity to discern certain aspects, teachers structure the lesson in terms of patterns of variation and invariance (Marton &Tsui, 2004). Variation theory has proved to be a powerful tool for teachers when analyzing the object of learning as well as when designing the lessons (Pang & Lo, 2012). Thereby the so called *critical aspects* can be identified for specific groups of learners, that is, aspects that are necessary to discern in order to learn what is intended, but which are not discerned yet by the learners.

The learning study processes

In this section we will present the two studies (the authors of this paper participated as researchers in the respective study) and their findings separately, and then discuss the studies together. The analytical focus in the two Learning studies was slightly different. Therefore, the presentation of the results below also differs between the two studies. However, the mutual focus in both studies is on objects of learning in technology education.

Study 1: A learning study about constructing a specific linkage mechanism

The object of learning of this study was to construct a specific linkage mechanism allowing for transfer and transformation of movement (see Figure 2). The learning study was conducted in collaboration with two primary school teachers and two classes in primary education; a preschool class (25 students) - a voluntary school form following the national curriculum, which a majority of the six-year-olds in Sweden attend - and a class in grade 1 (24 students, aged seven), in total 49 students. The Learning study lasted one semester and was conducted in a total of four cycles. During the pre- and post-test the students were asked to assemble pieces of card with paper fasteners and string to a linkage mechanism that transferred and transformed the driving motion. In the lesson the students were given non-figurative teaching material. The lesson was designed in a way that would give students the possibility to discern the identified critical aspects.

Pre- and post-tests, and lessons were videotaped by the researcher using a handheld video camera, with the aim of capturing as much as possible of the students' working processes. Students' final products were collected as well, resulting in a total of 24 models from the pre-test and 21 models from the post-test.

During the Learning study process, much of the video material was analysed collaboratively in the team. The video films from the pre- and post-test were analysed using variation theory (Marton & Booth, 1997; Marton & Tsui, 2004), based on students' difficulties in constructing the mechanism. The learning difficulties were interpreted in terms of aspects necessary for knowing how to construct the mechanism that were not discerned by the children, the aspects were thus identified as critical aspects. Students' practical handling of the material, their conversations and the final models were analysed. The analysis of the pre-test showed that constructing the linkage mechanism posed difficulties since just one pair of students managed to assemble the parts in a way that allowed for transferring and transforming movement. During the Learning study process, the students improved their way of constructing. Students' ways of constructing were analysed iteratively and systematically in relation to the object of learning, thus contributing to identifying, refining and articulating the aspects to be discerned.

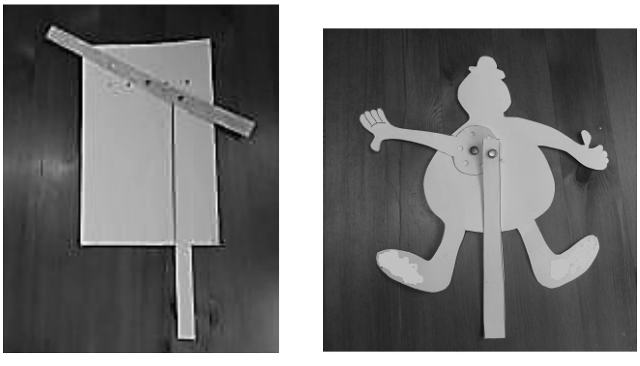

Figure 2. The linkage mechanism

The main findings in study 1 were some identified and refined aspects of the object of learning, describing what one should know in order to grasp the specific object of learning. These aspects of the object of learning included:

– *Separating the two joints in terms of position*

In order to be able to construct the linkage mechanism, the students had to discern two joints and attach them in various points.

– *Separating the different characters of the joints in terms of moving and fixed joint*

The students also had to discern the difference between the two points in terms of attachment to the base.

– *Position of the moving joint in relation to the movement*

Additionally, in order to transform the movement, the moving joint had to be attached on the opposite side of the resulting movement.

In addition, some aspects that seemed to be critical for the teaching were identified, such as the characteristics of the teaching material used and the lack of subject specific terms introduced. In the study, the teaching material used was card, which posed certain difficulties in order to discern the attachment points. To find out how this factor affects students' ways of constructing linkage mechanisms, further research is needed, possibly focusing on three-dimensional materials. The terms that were used during the lessons were terms commonly used in science education; pivot point and attack point instead of fixed joint and moving joint. However, a need of specific technology terms related to constructing the mechanism emerged during the Learning study process.

Study 2: A learning study about making strong constructions

The study was conducted in collaboration between two researchers, one preschool teacher and two compulsory school teachers. The learning study lasted for one semester and was conducted in a total of three cycles. All three cycles were conducted in a preschool class and in each cycle between 5 and 8 students from the preschool class participated. The specific object of learning in this study was the ability to use framed structures as a solid construction.

Data for the study 2 was generated by documenting pre- and post-tests and research lessons. The pre- and post-test involved the pupils in building models of bridges with the hands-on material 4DFrame (see Figure 3). Pupils worked while sitting together in a classroom, followed by individual interviews. Between the pre- and post-tests a teacher in the project held lessons aiming for the students to learn about the object of learning. The lessons were videotaped. This was repeated in all the three cycles. Furthermore discussions between the teachers and researchers were audio-recorded.

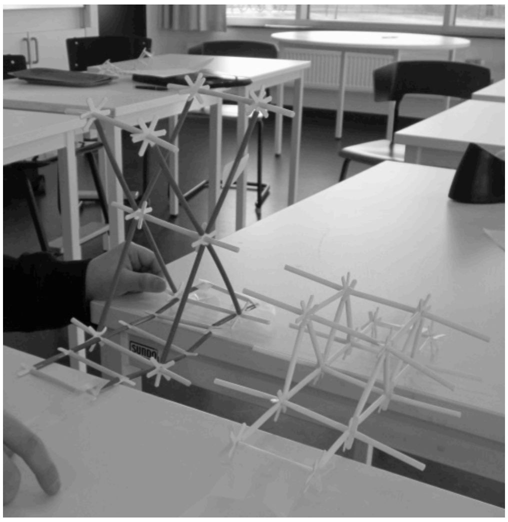

Figure 3. Examples of students' bridges

The main finding in study 2 was that the object of learning had many dimensions that needed to be taught. The use of framed structure as a solid construction needed to be taught in relation to:

– *Shapes*: In order to understand the framed structure as a solid construction the pupils needed to be able to understand shapes like triangle and square. Those shapes were also varied in order to give learners the opportunity to discern certain aspects concerning those shapes. In the research lesson, the framed structure was related to the shape of a triangle.

– *Compounding*: In order to visualize the object of learning as the ability to use framed structure as a solid construction in own construction, it was important that the students compounded the hands on material in a solid way. In the first learning cycle, some of the constructions with framed structure were less solid than constructions where the students had used squares in their constructions, because they had not compounded them good enough. This did not help the students to understand the object of learning.

– *Concepts* like strength and compounding: The teachers write in their analysis of the second lesson that it is important to use proper terms in relation to their object of learning "to use words as *strength* and *compounding* is necessary in relation to our object of learning". They noticed that this was initially avoided in the lessons. It was discussed that this was avoided in order to let the pupils think for themselves and not to put the words in their mouth, but in the third cycle of the Learning study the teachers consciously repeated the central words related to the understanding of the object of learning. In the tests of the students' bridges, it was more important how the students had compounded the hands-on material, rather than what shapes they used, which also was confusing in relation to the understanding of the object of learning.

– *Discern* solid constructions versus ability to *use*/compounding for strength: There was a difference in the *ability* connected to the learning object related to what the students was expected to learn. In the pre- and posttest the students were expected to *use* the framed structure in their own constructions, but in the lesson it was rather a focus on *discerning* the framed structure in finalized constructions. There was a difference in the level of abstraction, that was complicated for the students to handle, and this difficulty was highlighted during the Learning study process.

– *Context* in relation to the object of learning: In the first cycle, the object of learning was embedded in a learning context that was familiar to the student, but the focus rather got on the whole context than on the specific object of learning the students were intended to learn. The context rather confused the understanding of the object of learning in the specific research lesson.

Discussion

The aim of this paper was to show what knowledge concerning specific objects of learning in technology education was generated in a Learning study and to discuss the potential contribution of this knowledge to technology teaching practice. Since the analytical focus was slightly different in the studies, the presentation of the results and findings were different. However, there are some similarities between the results in that both studies showed that the process of working in a Learning study contributes to the understanding of the different objects of learning in technology.

As in previously reported Learning studies (e. g. Pang & Lo, 2012), these studies show benefits of focusing on specific learning objects in a systematic and iterative way in the teaching-learning situation in the classroom. In this way more detailed and nuanced knowledge can be generated, and this can help teachers to design teaching that enables students' learning of the specific contents. By analyzing students' learning difficulties, in order to grasp the specific object of learning, aspects necessary to discern from the learners' perspective were identified (Marton & Booth 1997; Marton & Tsui, 1994). Moreover, some aspects that could be related to the teaching situation specifically were identified.

The two common findings from the two Learning studies were related to the subject-specific concepts in technology education, and the character of the teaching material. First, the importance of using subject specific terms in teaching technology is also highlighted by Anning (1994), Chatoney (2008), and Jones & Moreland (2003). Although the object of learning in the studies focused on practical handling of specific materials in terms of constructing, and in that way this could be considered as tacit knowing, we argue that the use of specific terms in a teaching situation (while constructing) will help students to discern the aspects necessary for learning. Secondly, this study highlights the importance of students being able to handle the material used in the technology teaching in a way that it is made possible to learn what is intended. Problems with handling the material could obstruct the students from seeing the intended learning object. Therefore, it is important to use material that is familiar to the students or to put some time into learning the material itself before using it as a learning tool.

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Transfer of “knowing that, knowing how and knowing with”: the development of expertise

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Abstract

The aim of this paper is to contribute to knowledge about transfer in technical vocational education. This will be made by describing and analyzing teaching and learning with focus on different types of knowledge, theory and practice and the development of expert skills. There are two different empirical data sets. Several semi-structured interviews from informants teaching and learning in technical vocational education were collected by one author (Kilbrink, 2013b). Secondly some observational studies on expert teachers and follow-up stimulated recall interviews were done by the other author (Björklund & Stolpe, 2010; Evans, 2008). Both these sets of data has been analysed with a focus on different types of knowledge, theory and practice and the development of expert skills. From those two empirical examples we can see that the three aspects of knowing; *knowing that, knowing how and knowing with* all appear in the empirical data and could be used to understand the development of expertise.

Keywords

Knowing how, knowing with, transfer, vocational education

Introduction

Transfer is important in education, but transfer can be conceptualized differently and appear in different forms in education (Kilbrink, 2013a). The aim of this paper is to contribute with knowledge about transfer in technical vocational education. This will be made by describing and analyzing teaching and learning with focus on different types of knowledge, theory and practice and the development of expert skills. Ryle (1949) differentiated between *knowing that* and *knowing how*. Bransford and Schwartz (1999) added the concept of *knowing with*, how an expert uses his experience to observe and understand. These aspects of knowing may if they are integrated lead to a deep understanding facilitating transfer into new situations (Bransford, 2000; Kilbrink, 2013a). Marton (2006) also emphasises variation and differences between situations. Kilbrink (2013) used the concept of *transfer* in the meaning of building further on previous knowledge in new situations in an on-going learning process. In many areas of vocational education there is a large gap in the teaching of theoretical and practical knowledge.

Theoretical framework

Dual system-processing is a psychological model of two different cognitive systems for observing, reasoning, making judgments and taking action (Evans, 2008).There is a distinct difference between rapid, automatic and non-conscious processes in the implicit memory system and a slow and deliberate explicit memory system. Additionally, neurophysiological research has identified two biologically separated memory systems in the human brain, namely the non-declarative and the declarative memory systems (Squire, 2004). Merging psychology and neurophysiological research allows for the idea of two separate systems for memory and learning to be strengthened, namely the dual memory system model (Björklund, 2007, 2008). Björklund has proposed the use of "implicit" and "explicit" memory systems as synonyms for Squire's non-declarative and declarative systems. The explicit memory system is characterized by dealing with what is traditionally referred to as facts, events, rules and labels in pedagogy and science education (Evans, 2008). The explicit knowledge is possible to verbalize and communicate. Associated to the explicit memory system is the working memory, which is our conscious system (Sweller, van Merrienboer, & Paas, 1998). However, the explicit memory system is constrained by the limited capacity of working memory (Lieberman, Gaunt, Gilbert, & Trope, 2002; Marois & Ivanoff, 2005). Working memory may hold about five to seven units at a time and the addition of any further units can lead to cognitive load (Ross, 1969).

The implicit memory system deals with non-conscious knowledge (Berry & Dienes, 1993). Implicit memories are stored as multimodal sensory patterns of phenomena that we perceive, even non-consciously, in a specific situation – what we hear, feel, see and smell. Logan (1988) suggested that, "subjects store and retrieve representations of each individual encounter with a stimulus". It is therefore feasible to suggest that each representation is stored in the implicit memory system as a unique holistic pattern (Björklund & Stolpe, 2010). The implicit memory system will constantly perform pattern matching processes. When we re-experience a situation, the match will help us feel and act in the same way as we did the last time (Lieberman, 2000). Hence, we will experience a feeling of familiarity with the situation. Pattern matching is an automatic and rapid process which can impact behavior directly without being constrained by the processing limitations of working memory. Since the use of implicit memories should be considered as knowledge that is "hidden" from the practitioner it could be characterized as tacit knowledge (Polanyi, 1966b). Even though the process of pattern matching is non-conscious, the implicit memory system may trigger a corresponding declarable label in the explicit memory system. The implicit learning system has a strong impact on the development of skills and expertise, and it brings a new understanding of tacit knowledge, intuition and holistic-pattern recognition. What Polanyi refers to as "Tacit knowing" is implicit learning, and this explains why *"we can know more than we can tell"*. The Dreyfus model of novice-expert development can be explained as a slow change of utilisation of the two memory systems. The rule-following novice uses explicit memories and the expert has access to and uses a large library of implicit memories. The function of the implicit memory is to let the individual recognize habitual, dangerous or rewarding situations therefore it is important for the learner to be allowed to make mistakes, to learn from trial and error.

Data collection

In one of the sets of data interviews with informants from two three year technical vocational educational programmes at upper secondary school were conducted – the Energy and the Industrial programme. In the Energy Programme, trainee plumbers were educated and the program-specific lessons included heating and sanitation. In the Industrial Programme, future industrial workers were educated and the program-specific lessons concerned for example welding and turning. From the two programmes, students, subject specific teachers and workplace supervisors were interviewed. In the interviews, a narrative approach was used, focusing on human experiences of different situations (Clandinin & Connelly, 2000; Polkinghorne, 1995). In order to construct the narratives, different question areas concerning transfer and learning in different arenas were used as a point of departure in the interviews.

Secondly some observational studies on expert teachers and follow-up stimulated recall interviews were done by the other author. This data was analysed using a psychological model, the dual system model (Björklund & Stolpe, 2010; Evans, 2008).

Both these sets of data has been analysed with a focus on different types of knowledge, theory and practice and the development of expert skills. Thereafter we have related them to the different aspects of knowing, knowing that; knowing how and knowing with.

Aspects of knowing

The different aspects of knowing, knowing that; knowing how and knowing with will be described with a point of departure in empirical examples from the two sets of data.

Knowing that

There seem to be two ways to achieve the transfer from learning in school to successful use in the workplace as described in the literature (Björklund, 2013; Kilbrink, 2013b). Either the training in school has to be very practical and almost identical to the workplace situation or the student has to get a theoretical, more general, understanding of the principle behind a certain process (Judd, 1908). In the data material we found several examples of both approaches to education. The idea that theory always comes first, that practice is seen as applied theoretical knowledge, is common among students but also teachers. For example, the teacher Ivan from the Industrial programme teaches the basic knowledge students need for working in the industry at school and believes that they will develop their knowledge further at the workplace:

> *They [the students] get a basic education, with different industrial courses, in order to be able to further develop at their workplace learning ... so they for example should be able to run a CNC-machine. So I give them the theory at school, how a program looks and why it looks the way it looks.*

Ivan also mentions that there is more to know if something goes wrong, more than just how to start a program. Both supervisors and pupils also emphasise that it is pointless "just standing and watching someone press the button" (supervisor Ingemar) if they do not learn the processes behind the buttons. A student mentions that it can be hard to have time to learn about those processes at the workplace:

> *I wanted to know what was behind all those buttons. Why this and that. It is not hard to do, to push a button all the time, but it is, what is behind it, what could you learn more? [Interviewer: Why would you like to know that?] My reason for that is that I could then go to any working place and do it, but it is much easier to learn just one thing and just learn to perform one work at one workplace. (Student Ibrahim, 3rd year)*

As per the above quotation, according to Ibrahim, knowing about the processes behind the buttons may help him to adapt to other and different workplaces. Another student emphasises the importance of learning both at school and at the workplace, in order to understand the theory behind what they are doing. He likes to:

> *prepare himself with some kind of theory, sort of. If I would do a four week long job, then it would probably would be nice with a week at school first and thereafter do the four week job at the workplace if you were able to get to know what it could be about. Then you could be prepared and know what is going to happen, so that you can follow. (Student Emanuel, 2nd year)*

As the Dreyfus brothers (1986) indicate in their model about the development of expertise, a novice will try to understand, try to find rules and is looking for structure in a complex environment. Using the dual system model we would say that novices are using their explicit memory system to observe, assess, take decisions and act deliberate and consciously (Björklund & Stolpe, 2010).

Experienced teachers and supervisors seem to have a different approach to teaching; they acknowledge the need for experience, practice and knowledge that can't be learned from books or even by narrative. Furthermore, practical experiences are also important to the students. The students appreciate how they build further on and deepen their knowledge during the educational programmes:

> *Well, you can more or less keep an eye on if you get it right, and then practice makes perfect, so if you have done many times, then you are much better at it, then you know that it can usually be right. /…/ they know how their tool works after they have done it a lot and it is much like that, and then it can be, it has to do with experience, so that's what you should think about. (Student Edward, 3rd year)*

Edward emphasise the workplace learning as the main learning arena, and refers to the school as the learning arena where he learned the basics.

Knowing how

The teachers Ivan and Erik are reflecting on teaching in their different professions. They talk about how important it is for the students to practice and to let them do mistakes and to learn from them. Erik also says that skills relating to the profession, like welding, are something that needs to be maintained - you get "rusty" if you don't keep on doing it. Furthermore, they also relate to tacit knowledge:

Ivan: But it is like any profession, some has talent for it directly and others can learn, and there is also someone who… it does not work, has not got the motoric skills or what do you say [Erik]?
Erik: /…/ It is, I call it tacit knowledge, you show and... I feel like this, the more you work as a teacher, the more you understand that you have to teach the basics. /…/. There is so much they have to learn before [they can do their internship]. Sure, they could do their internship directly without knowing anything, but at the same time it is good to have some skills before. [Interviewer: What do you mean by tacit knowledge?] Things that are not in the curricula, things that can only emerge when you keep on working. Things that, like a feeling is hard to describe.

Knowing how, as Ryle defined it, is something that doesn't come from theory but from practice. It is a result out of repetitive training and deliberate practice. Using the dual system model this is explained as implicit memory learning, making the knowledge tacit in two ways: you can´t see your own expertise and if you do, implicit knowledge is not possible to define in words.

Knowing with

The two teachers also talk about how different senses are involved in the skills related to the professions. This is "knowing with" and also an effect of implicit learning. Erik and Ivan talk with a researcher (N) about welding:

Erik: It's harder than to learn how to walk.
Ivan: No, you have to get a feel for it, there are these welders working for 25 years, it has become second nature to them.
Erik: when they have been doing it for a long time, yes.
/…/
Erik: Yes, you are using many senses actually... It's sight and hearing and smell too...
Ivan: And touch ... thus dexterity...
Erik: Yes, above all sleight of hand but also the skill to see and...
/…/
Ivan: You are watching the flame, depending on whether it is oxy-fuel welding or if it's a stick welding or MIG the flame should look different and specific and also sound in a specific way.
Erik: We are only using the oxy-fuel welding, looking mostly for the melting, although also the flame, and if you are listening for a special sound when you weld, then you can hear when it's right, we hear directly when it is right or not right, when you have that skill you can weld! then ... when they stand and listen when I'm welding I try to make them recognize that special sound.
N: Mm. But it sounds like a formidable educational challenge for students to learn this when there are so many senses involved, so how ..?
Ivan: Everyone doesn't learn, I'll tell you. Everybody will not become welders

A similar example of "knowing with" comes from the other study when a university teacher, John, was taking his biology students out on an excursion. During the morning they had taken samples of soil, identified plants, measured trees and many other things. At this specific moment the group had arrived at a peat bog. They had been asked to put on their rubber boots and John encouraged them to walk out on the quagmire, to make them 'feel the grounds tottering beneath their feet'. He did not hesitate but walked causally, knowing exactly where to put his feet without getting wet. The students on the other hand often failed to establish a 'safe' path and some of them began to sink, getting their boots full of water. Afterwards, at the debriefing, John tried to teach them how to walk on a peat bog "And if you listen, you can feel … hear water oozing between … these floes of moss, or bog, or moss, or peat bog. And you could tell from the vegetation where you could walk or not." In this episode John showed typical expert skills, observing, assessing and acting in a complex environment almost automatically and he was asked: How do you know where you could walk or not? He answered: "The vegetation tells you where to put your feet. Sedges indicate that it's dryer. And then one recognizes what kind of moisture there is". This illustrates an analytical, conscious answer upon which John attempted to explain his skill. Asked to be more specific, John then continued: "It is trial and error. You may probe and you will see. From experience you know where you cannot go because you will sink. It's obvious". John had walked on peat bogs many times before and when he relived an earlier experienced situation, it may have helped him make the correct decisions. He was not able to transfer his own knowledge to the students, partly because his skills were tacit, hidden from himself, partly because they couldn't be expressed verbally.

Discussion

Some authors propose that no implicit knowledge should be trained. The identified problems with expertise in a field show that specific knowledge of instances will obstruct transfer. General knowledge, rules, principles and a reflective stance should be promoted, that is, the use of the explicit memory system and working memory. But many studies have shown that explicit memories fade away and are forgotten in relatively short time. This would mean that rules, theories, algorithms and names, important for explicit problem solving will not be there when needed. Observational skill and attention if consciously controlled by the explicit system, are very prone to choking, furthermore the narrow field of view utilised by the explicit system will make it hard to find relevant clues in a complex and noisy context. Deliberate evaluation of a situation using a logical, analytical method will be slow and restricted by the limitations of working memory. In every situation where speed is important the explicit system will therefore tend to be slow. Military trainers have abandoned this analytical type of decision making training and are focusing on the implicit memory system training intuitive thinking: Recognition Primed Decision making (Klein, 2004; Thunholm, 2003). Several studies have shown that explicit knowledge and skills are very sensitive to stress and the load of multiple tasks. Masters (1992) and other researchers have even shown that declarative and explicit knowledge could be disadvantageous to actions usually controlled by the implicit system. Verbal overshadowing may also disturb our perception and assessment skills (Fallshore & Schooler, 1995; Melcher & Schooler, 1996)

Implications and conclusions

If training has a goal of making the learner proficient in a real world workplace he or she must be able to cope with a complicated and noisy environment and to act fast and with precision. Furthermore, if we want them to be able to cope with stress, to build a good sense of self-efficacy and being intrinsically motivated, we do not have any alternative but to train them into expertise in the specific tasks and situations. In accordance with Marton's (2006) variation theory we can make the students recognise many different instances in various problem situations. This will give them a large library of implicit patterns and an ability to react in different situations. If the individual learner is going to be a supervisor or teacher he or she has to be given complementary explicit knowledge and most important of all a metacognitive knowledge of his or her own tacit skills. Training of implicit knowledge is done in deliberate practice characterized by well-defined tasks, informative feedback, repetition, self-reflection, motivation, and endurance (Moulaert, Verwijnen, Rikers, & Scherpbier, 2004). Implicit memories consist of multimodal sensory experiences hence training should be full of practical work and the learner should be exposed to many sensory based stimuli, preferably in a realistic workplace setting.

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The digital pedagogy and the teachers of technology education

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Abstract

This paper analyses the relationship between teachers of technology and digital pedagogy. Corollary to the development of technological possibilities which are evolving and becoming more widespread in society, the use of ICT is also progressing in the French education system. Many incentives lead teachers of all subjects to use ICT for teaching but teachers of technology education are concerned in two ways. Teachers of technology education are teaching technology but how do they integrate digital technologies for teaching in their teaching practice. ICT is considered here as an instrument for teachers' work. How they use it can highlight the educational value of these tools in the teacher and student relationship. The role of mediating artefacts in teachers' activity shows that the use of digital pedagogy is not very highly developed compared to its integration into other subjects. A questionnaire on the use of ICT helps to highlight some aspects of this role in teaching. Responses through the affordances perceived by teachers and the motivation, lead to an understanding of the role that ICT plays as instrument in educational activity and especially for teacher of technology education.

Keywords

ICT, activity, digital pedagogy, teaching, technology education

Introduction

Despite numerous incentives to use digital tools, uses are only gradually increasing within the education system. The institutional wish to integrate digital tools in the French education system is obvious, yet this has not been particulary well implemented in classes, including technological education (Karasavvidis, 2009). Our contribution is committed to the understanding of the instrumental genesis at work in the teachers' activity. One of the challenges of the research is to identify instrumental genesis (Rabardel, 1995; Rabardel & Waern, 2003). It is to move from the point of view of teachers and consider the use they make of the tools. The massive introduction of materials or the institutional recommendations most often imposed top-down without many more objectives specific to learning, or accompanying it. The role of digital tools as a mediator of the teaching activity is analysed in the light of the theories of activity and in particular from the point of view of perceived affordance (Greeno, 1994) by teachers and their pedagogical or didactical intentions. They determine the role played by ICT in their teaching.

Theoretical approach of the use of tools in education

Activity and didactic intention

Conceptual frameworks provided by the theories of activity (Leontiev, 1972; Vytgotsky, 1985) for analysing digital tools as an instrument of teaching activity. The activity is a dynamic hierarchical structure of relationships between the subject and the object (Leontiev, ibid.). The activity is oriented towards a pattern that precedes activity (Vygotsky, ibid., p. 261) and forms a whole in which the actions are directed towards a subordinate, higher level goal. Like any activity, a the training activity is characterised by what it is used for. The teacher pursues a goal or several goals that give meaning to what (s)he is doing (Leontiev, ibid.) Luria, 1979; Galperine, 1966; Vygotsky, ibid., p.150). Thus the teacher has to act, in order to make sure that the students are in a position to acquire the requisite knowledge and skills.

The didactic structure (Johsua & Dupin, 1993) consists not of three interlinked aspects - the teacher, the student, and the knowledge or the “sum of the binary relationships” maintained therein (p. 6), but the ternary relationship maintained by these three elements, which occur only "in reference to the problem of knowledge permits one to solve". (p. 261). For these authors (p. 260):

A didactic situation is in evidence whenever a teacher intends to teach knowledge to a pupil, and socially defined mechanisms are set up in order to do this.

Thus, the intention to teach, making a studentlearn, is a necessary condition of educational situations, it is essential as a motive for allowing us to consider education as an activity in which the teacher is responsible for passing on the knowledge that is pivotal to these situations. The teacher "has the responsibility of organising educational situations or practises deemed favourable to learning" (p. 249).

The teacher’s activity is geared towards the students’ learning and development. Reasons and goals then determine the teacher’s choice and (s)he subsequently provides the appropriate means to achieve this aim.

Instrumental genesis and affordance

Artefacts, whether material or symbolic (tools and signs), are mediators of activity (Vygotsky, 1985). Mediation by the tools is involved in an activity, both for what it allows and by what means, what it makes possible, and what it limits (Leontiev, 1972). The role of mediator, both as an intermediary and a means of carrying out the action, is considered in terms of the potential offered by digital tools for teachers. These are artefacts among others that the teacher has at his/her disposal to accomplish the activity (Verillon & Andreucci, 2006). The tools have the potential to act that can be socially shared. This potentiality, as accurate as it may be in the minds and actions of designers only translates into power to act (Rabardel & Pastré, 2005) through the actions of the person that claims ownership of them. This praxeology takes into account knowledge of the tool, or the artefact in Vygotsky (ibid.), the mediating artefacts: tools and signs in Engeström (2008), or even the instrument in Rabardel. In the works by these different authors, we find an anthropocentric approach in which importance is attached to the tool as a mediator of the activity. Typically in Rabardel approach, the tool becomes an instrument in the way it is used by the subject, even when this may differ from the originally intended use. Thus, the objective of the activity determines this instrumental Genesis.

The potential of a tool is not intrinsic, it depends on the subject’s knowledge of the tool and the meaning given to its use. Affordance reflects the perception of the properties attributed to objects and which condition their use (Greeno, 1994; Gibson 1977, 1979; Leplat, 2000, pp. 75-76; Norman, 1988, p. 9; 1993, p. 105; Rabardel, 1995, p. 124; Veillard & Coppe, 2009). What ICTs can do, their actual affordances (Conole & Dyke, 2004), or in other words the potential they offer in terms of mediation between the subject and the object may not be fully perceived because of their diversity and the extent of the range of the possible. The perceived affordance translates the relationship between subject and object in a context where the conventions and codes culturally and socially determined codes condition the use of an artefact (Andreucci, 2008).

> *“The presence in a situation of a system that provides an affordance for some activity does not imply that the activity will occur, although it contributes to the possibility of that activity”. (Greeno, 1994).*

The use that teacher makes of the tool in his teaching activity stems from, at least in part of the affordance ways in wich the tool may be used.

Methodology

Analysis of the integration of digital tools in the work of teachers is based on the role assigned to the tools in the theories of activity. Processes implemented are explained by the use of tools and the implementation of means for using them, but what conditions make the integration of digital tools in teaching practices effective? Understanding said practices, knowing them, and accompanying them is a challenge for researchers (Thibert, 2012).

To analyse the integration of digital tools in education referring to the theories of activity and in order to understand how digital tools are involved in the development of the conditions of the study, we asked teachers about the reasons for their choices and their didactic intentions. These are the affordances that they perceive which make instrumental genesis possible. An online questionnaire to teachers yielded more than 800 responses (805) representing 16 subjects including 656 responses from the Academy of Aix-Marseille. Out of 25 questions, 6 were open questions asking teachers to give information about a specific digital tool they were used to using in the classroom and in particular to say why they chose it. What is their educational objective? When they use this tool? How do they use it? What they ask students to do or observe and how they present it to students, whether they make comments, etc.

We analysed the 35 responses from technology teachers (E1-E35; 34 from the Academy of Aix-Marseille and one from the Academy of Bordeaux) by focusing our analysis on the 6 open-ended questions.

Results and discussion: the teaching functions of digital tools

Semiotic functions of knowledge representation

Digital tools facilitate other ways of passing on knowledge which can be given to students. Or, at least, there may be more ways of exhibiting this knowledge, ways which may be more varied or more easily accessible.

The functions of digital tools can be linked to library resources that make knowledge accessible in various forms (text, drawings, graphics, photos, videos...). Thus the semiotic representations of knowledge can take the form of multimedia documents via different sensory channels (auditory, visual, etc.), different codes or languages, different types of speech, structures (linear, nonlinear) documents, etc. Half of the digital tools chosen by teachers are representations of objects for technical video or 3D animation impossible to achieve without digital tools. These tools (sweet home 3D, E drawing, googlescketchup...) are chosen because they are widely used in technology studies. The teacher E17 states that "3D modeling plays a big part in my teaching" or "because it works well with objects whose operation is difficult to explain without a video" (E34). Teachers can distribute various teaching aids (texts, drawings, graphics, photos, videos …) which facilitates the *monstration* (Johsua, 1989).

Beyond the educational variety of media (E10: "prolong the experiments", E12: "revisiting the notions") or proximity to real things (E32: 'show the reality of the system'), the teacher also has the ability/opportunity to put knowledge into play which is important in the choice of digital tools. Knowledge and power to take action are inseparable and they are in fact situations referring to the problem that knowledge helps resolve which justify the use of digital tools, as the teacher who said "synthesize and extend the experiments to solve the problem: how to move a load heavy? '' says explicitly (E10) and as shown by the responses of other teachers when asked what educational objective is associated with the choice of the digital tool mentioned therein:

E 13: "making a digital model of a volume"

E 17: "identify the different parts of a bike"

E 31: "introduce to students the notions concerning the automated systems"

E 34: "to understand how parts fit together".

With digital tools, limits to what can be used are minimalised to allow for different representations of knowledge to be used (for example photos, movies, animations, simulations, ...) to allow the didactic detour that is necessary for the understanding and the transformation of that which is real (deconstructions, explanations, actions,...).

Study help functions

All teachers are generally equipped with digital tools for their own private use. This is a consequence of the development of technology that is constantly evolving and becoming more widespread in society, and in particular from the point of view of knowledge (greenhouses, 2011), but what they use professionally is apparently limited to class preparation (Cerisier & Popuri, 2011). This is not the case for the teachers who took the survey. They all use at least one digital tool in class. It is important to consider the role of tools in terms of how they are used to help students to understand the activity in which these tools are used. Given that some teachers do not abstain from using digital tools in their teaching practices, but merely use them in advance in order to prepare, it would be all the more interesting to look at how teachers make use of digital tools in classroom situations.

Like all teachers, technology teachers can invoke reasons to use digital tools that relate to aiding study. Also, during class time, they may wish to focus on their contribution to the teaching situation and supporting students through their own actions without resorting to outsourced teaching functions in digital tools.

The outsourcing of functions in the tools follows the laws of evolution ranging "from the abstract to the concrete" (Perrin, 1991, p. 386; Simondon, 1989), from a composite solution to an integrated solution (Deforge, 1985).

Teachers use digital tools in didactic situations to assist students in their learning process. They highlight the opportunities that other means do not offer (E34: ' operation is difficult to explain without') to promote learning face-to-face as well as distance learning, synchronously or asynchronously (tutoring, FOAD,...) and in particular the interactive nature of the tools (E29: "for its interactive side").This regulation or checking of student activity takes place as part of setting up the study conditions for that activity whereby students can adapt knowledge (data logging, experimentation, simulation,...). The link between the task prescribed by the teacher and the one actually achieved by the students reveals the tension between the logic of teaching and learning (see figure 1).

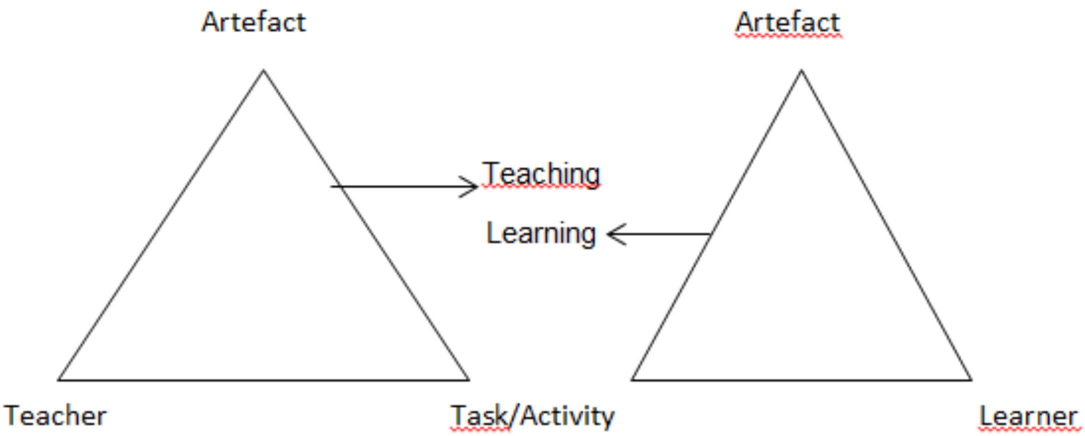

Figure 1: Activity of teacher and student in interaction

The use of tools and the teacher's actions go hand in hand. Teaching conditions are transformed by the use of digital tools.

Teachers divide up the roles that they keep for themselves and those played by tools. This is clearly shown in the organisation of teaching practices, as different teachers explain:

> *"...from a game situation, the student must conduct an investigation around the computer, [...] After the activity, there is a dialogue to talk about the difficulties and new things that the students encountered. This is a means of consolidating knowledge" (E12)*
>
> *"Assist the student (who may feel very alone or isolated) in his/her private study. Develop learners' ability to work alone and also collectively" (E22)*
>
> *"Make the link between experimentation and implementation of technical objects in order to understand a mechanical principle. Watch the video and record the steps that have been tested; compare the simulation with real objects" (E10)*

In this division of functions, teachers must fully review the scenarios they plan by integrating all dimensions of education including the collective dimension (14 teachers mention it) and change their working practices.

Digital objects and technological learning

The development of the study conditions is not the sole reason that teachers in technology use digital tools. By integrating more and more knowledge, the potential of tools extends their scope for transformation of the real and thus problem solving. Indeed, they are even the object of learning targeted by technology teaching. Thus the digital tools put forward by technology teachers who responded to the questionnaire are rarely digital tools exclusively used for teaching, such as the "Discovering ICT" application with the adventures of Globert (http://www.cite-sciences.fr/au-programme/lieux-ressources/carrefour-numerique/planete01/sg.html mentioned by teacher E 12) or a serious game of media education “2025 Exmachina” (http://www.2025exmachina.net/ mentioned by teacher E13) so that, with the exception of the Digital Work Space mentioned by teacher E22, most of the digital tools put forward, which are basically software and particularly office automation software (mentioned by several teachers: E4; E9; E 27,...), are also objects for learning about technology. Technological knowledge through the building of rapport with tools. This praxeology is pivotal to technology education.

Widespread use of the projector

The use of projectors by teachers has been widespread for many years now. Although it is not the object of project specific equipment, the video projector is needed in schools. Today, it is considered to be a fundamental piece of equipment according to the Profetic (MEN, 2012) survey conducted among 3270 teachers in France, 71% of whom have a projector available in their school, should they need one.

Through more flexible management of teaching aids, teachers find ways to increase their teaching scope in terms of displaying things (space, time, choice of materials) with projectors - hence no longer relying solely on handwriting - in the here and now. Used with a computer, the projector is a mediator, an intermediary and a means for teachers to make knowledge available to learners in a teaching situation. Several teachers explicitly make reference to this. For example: “presentation of the tool in the Beamer class-group” (E27), “presentation of the software using a projector” (E24), “design examples using the projector + group questions” (E6) first, demonstration on the video projector» (E29), “I show the video to the whole class, using the projector” (E14)...

The use of the projector is a resource (Adler, 2010) for teachers, a way for them to plan and put their teaching into practice, and a time – saving device that makes their activities more efficient (Clot, 2008, p. 17). The evolution of teaching practices is backed up by the use of video projectors in the classroom. The projector has great potential, and can be used by teachers in order to communicate with all of their students at the same time, thus allowing them to progress with their learning as a group. The projector makes good use of space and time, more so than the blackboard, and paradoxically in this case, leaves no trace of written preparation and presentation. Contrary to things that are written on the blackboard, information on the projector that is prepared in advance and written or modified during the class can be stored, even though teachers can add further information in what is an interactive classroom environment. Teachers can also easily show or delete documents without tedium. The use of the projector, which tends to become automatic, is testament to its instrumental genesis in teaching activities.

Conclusion: opportunities and potential for use of digital tools in education

The ever increasing variety of different uses of digital tools in teaching practices is clear for all to see. Innovation cannot be decreed and it's not so much the invention or the provision of new tools that accounts for their use in practice. This integration is based on external tool functions and their contribution to the teacher's individual actions. Thus, the use of digital tools increases teachers' power to act (Clot, 2008). However, despite significant incentive policies (UNESCO, 2011) related to the sometimes massive broadcasting of material, a lag persists between prescribed and real integration of the use of digital tools in teaching activity.

Technology teachers relate to the technological tools as objects in teaching their subject. Knowledge related to tools that is taught to solve technological problems. However, the instrumental genesis of tools in the teaching activity of technology teachers and their intentions reveals the role of tools in technology teaching situations. To assist in the study of what they must learn and enhance their motivation, teachers choose tools that will be welcomed by students, but the functions selected by teachers can be explained mainly by the instrumental approach (Rabardel, 1985). It reflects the effectiveness expected from the use of the tools in terms of the teaching-learning process. It is the potential for tools to be efficient in the teaching learning process which is important for teachers.

Their willingness to integrate digital tools into their teaching explains their use in regular tool situations, when these constitute resources that increase their capacity to act. The increased use of the projector by virtue of its becoming commonplace is an example of instrumental genesis of tools in teaching practices.

The affordance perceived of ICTs is the main reason why they are used. If teachers do not find the use of these tools worthwhile (in the syllabus or in training), then teaching activities will not be transformed, and an instrumental genesis will not occur. On the other hand, if teachers are able to use such tools without too many difficulties, they can easily be incorporated into their teaching methods.

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New paradigm in design-manufacturing 3D's chain for training

Case of design and manufacturing in a “FabLab for education”

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Abstract

We propose in this paper to show the impact of 3D Printing technology on design activity and to understand the main differences between designing a part with traditional technology and with the support of a Fablab's.

Keywords

3D Printing, design, manufacturing, learning process, training

Introduction

"The developement and use of « Fablabs » have increased tremendously over the last few years. A lot of Scientific and technological Institutions have implemented the use of Fablabs. If ‘Fablab’ quarantees a technical prototyping platform for interesting innovations and inventions then the ‘design process’ of this structure warrants an urgent attention. The integration of 3D printing technology has been greatly constrained by the production capacity due to its design process. Similarly, teachers are faced with a challenge with the theoretical aspect of the product design process.A risk of accelerated loss of skills of future generations to understand all phases of product development exists. This poses a risk for future generations to fully understand all the phases of the product development. In this renewed acceleration of the transition from idea to realization of the object, we will try to show how greatly impacts of the mental processes are very pregnants in prior to the artifacts conception. In making a quick transition from theory to finished product, we will try to show the great impacts of mental processes leading to these finished products. It's appeared relevant for us to ask some essential questions when a real industrial revolution arrives It appears relevant for us to ask essential questions when a real industrial revolution unveils. Like always, innovators jostle our certainties and the major and potential users watch unfold technology progress asking himself more or less some questions about essential changes that they impose and involve. As always, innovators jostle for our certainties while major and potential users watch the technologies involved in the making unfold without inquiring about the processes that are involved in the making of the new products. The Fab Academy is a Digital Fabrication Program like Neil Gershenfeld (1) has described it. The Fab Academy is a Digital Fabrication Program, as Neil Gershenfield(1) described it :

For education, a fablab proposes an advanced digital fabrication for students and access to technological tools and resources. For education, a fablab offers an advanced digital fabrication for students and provides access to technological tools and resources. We have developped at ESPE Aquitaine the necessary rapid prototyping facilities. We have developed at ESPE Aquitaine the necessary prototyping facilities. In our teaching in technology (design and manufacturing artifacts), we arrive to ask ourselves three questions that we seems today more matures for asking some more and more others. In our teaching in technology (design and manufacturing artifacts), there are three questions that we need to ask ourselves and others.

The simple question is: How to build an object with a part very simple, coming from a simple solution, in an minimal time? The simple question is: How do you build an object from very simple materials in a minimal amount of time ? The interest of this approach is that each students in his Fablab is a part of a globalized FabLab. The interestinmg aspect of this approach is that each student in this Fablab is part of a globalized Fablab. The local branches of FabLab work with other participating FabLabs and experts around the world via a distributed educational model where we pool our common knowledge to provide a unique, but mutual educational experience. Our students (budding designer) are in connection with other Fablabs around the world and can upload on their parts server (2) and can observe all parts that have been designed by others. For example, we can connect our proposition with the Fablab CCSti (3) and other Fablabs in the world. (4). Tout ceci est théoriquement en place et potentiellement opérationnel. However, if this system is working today, the point of interest is that we can engage our students in a collaborative design process. With this approach we can describe the thinking process that is onvolved when students design and build each part of the product. We propose in this paper to show the impact of this new technology on design activity and to understand the main differences between designing a part with traditional technology and with the support of a Fablab's. We also study the impact on design education.

An accelerating revolution

A new context is identify in Figure 1 by (Koren, 2010)

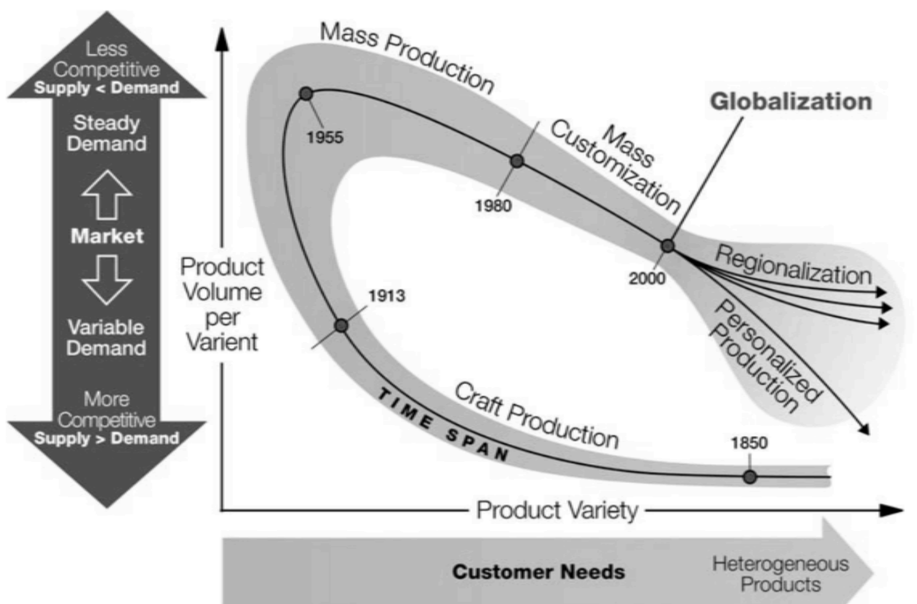

Figure 1. Evolution of paradigm in manufacturing (Koren, 10)

In september 2013, Snecma General Electic has integrated the first fuel injectors printers with 3D prints. Some time later, NASA did the same with its rocket engines.. The same year, the A350 does itsfirst flight with structured parts created with 3D printer. The 3D printing principle is based on what we call the additive fabrication. The principle is relatively simple: Create part, sometimes with complex shapes, by successive of materials layers, then have it created with volumic designer.

Saving file using a STL format allows the e printing machine to store all data to build the parts correctly. Today, the first mechanical parts made of steel are on market. The use of titanium and super 'alloy steel' has given way to a new revolution of product development. The last question that needs an answer to is the acceptable technology maturity level (RTL: Technology Readiness Level)

These are some benefits of 3D printing:

1. Mass gain of 25 to 60 per cent according to applications,
2. One mechanical part integrating multiple functions ,
3. Permission of technologic maturity level, TRL7

One of the obvious benefits is its substancial compressionof design cycles. The machinery is directly modified in its design phase because it's the 3D printing who permit parts manufacturing. (maybe several in one single printing).

The additive fabrication allows one to visualise the design process. Indeed these allow realization of design solutions and unsuspected potentiality given that the designer from the principal constrains of manufacturing.

Limitations in learning of design process of parts

In the previous introduction, we focused on accelerating design process. This acceleration although is in line with the paradigm shift from the thinking design to manufacturing, it limits the designers' conception of the processes that are involved in the design.

We have identified three major questions which disturb the design principles of our students: These are functional specifications compliance, impact of the assembling on design, impact of manufacturing on design.

We have chosen to illustrate our paper, with an example. This exercise has been submitted to our students during the primary phases of questioning around this radical posture changing. Design a machine with a rotating shaft supported by ball bearings. This proposition impose two essential things. Dimensioning of parts and the possibilities of mounting one part with the others. Fisrtly the 3D design disturbs our certainties: What are the geometric specifications that we have to give for the parts to position themselves correctly with the other parts and that they perform their functions correctly. The files transferred after design in manufacturing process of 3D additive disturbs again our perceptions.

We propose to show how S2i's students (S2i: Industry science) are led to re-evaluate their knowledge aboutconventional design phases (Assembling of a pivot connection with conventional mounting of ball bearing). They are to understand some different kinds of design phases. (development of a pivot connection by 3D printing prohibiting the assembly and disassembly). They are to analyse the design phases by a 3D virtual modeler for a conventional assembly and then the design phases by a 3D virtual modeler destinated to a 3D printing.

We show the differences and similarities of the different phases of design by developing a comparison matrix.

Question 1: compliance with functional and dimensional specification

The first question is about the the transfer of dimensional specifications in manufacturing process. We submitted some questions about designing in digital manufacturing processes. Indeed, the technological specifications and dimensional specifications from functional specifications of parts (technical performance guarantee, for example, guiding quality in rotation) are constrained only by the capacity and quality of manufacturing system which builds them. The adjustment between parts in assembling have always a sense or not? The nominal dimension that we use, seems today only the workable references. How do you think a a rotating shaft, Ø 40 H7g6, would fit in a bore? Indeed, it's not possible to identify in a 3D software, a dimensional tolerance on parts volume. This means that the quality of guiding in rotation which is normally guaranteed by the adjustment i can not be modeled in the 3D software. Gradually, we see a very significant risk: the loss of technological knowledge by young designers. Independently by the operational control of a software 3D.

Question 2: impact of assembling in design

The additive manufacturing is also involved in this transformation of the relevance of the dimensional specifications from the design phase. We can consider the design of assembling bearings. We have taken into account only the specific points in its design.

Step 1: Identification of critical points in the development of the technical solution.

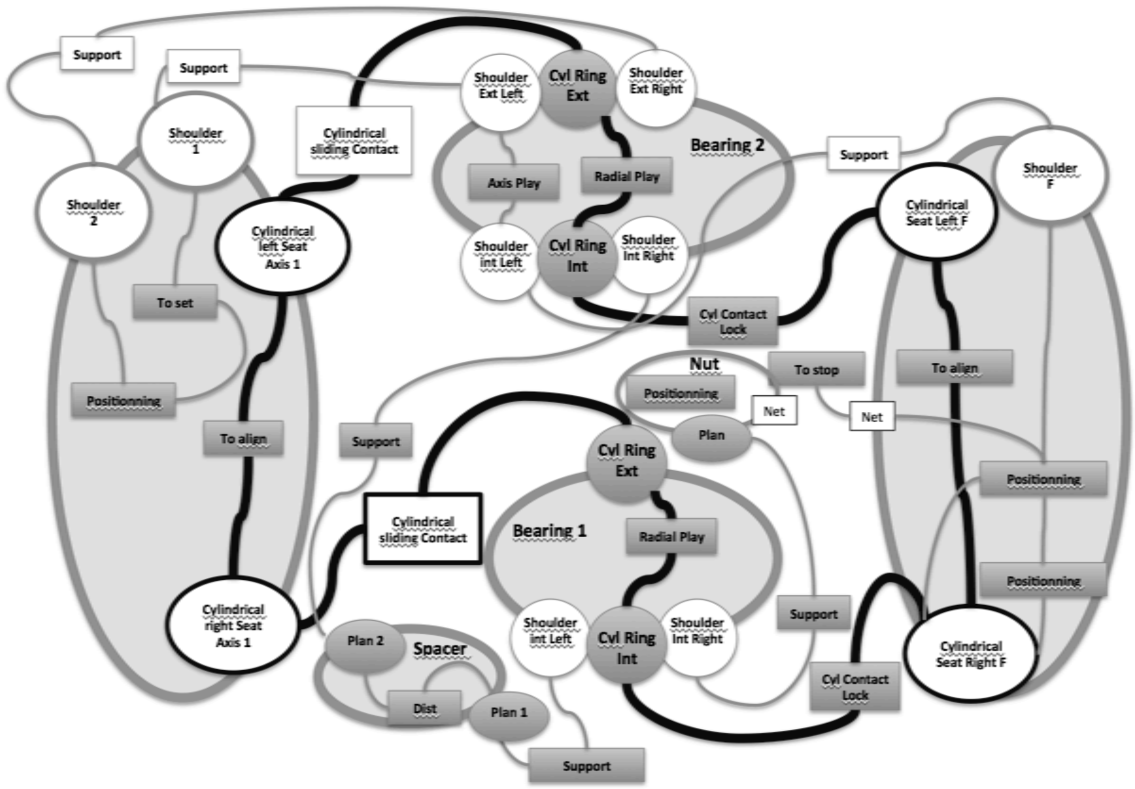

Figure 2 : Functional , structural and dimensional analysis

Step 2: Emergence of design invariants and the functional surfaces to be considered in further process. It appears that some surfaces exist only because we need to add a nut and locking washers and only for assembling reasons.

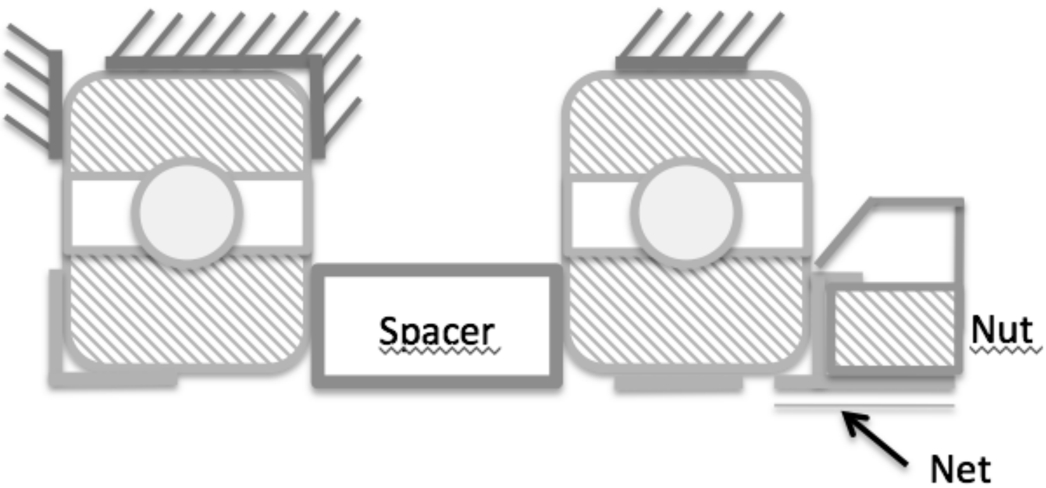

Figure 3. Result after theoric analysis

Step 3: Proposed result by a designer with 3D software help

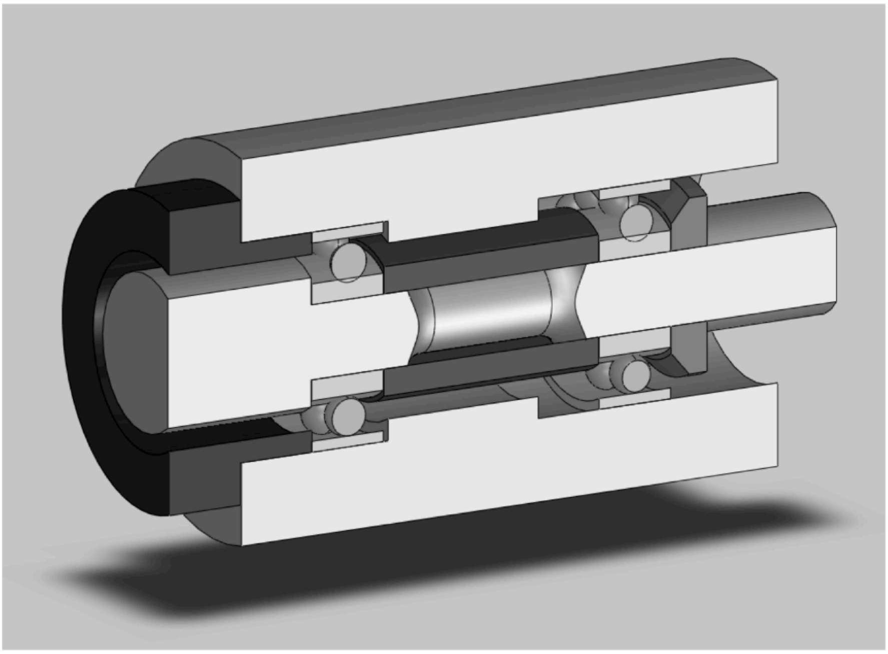

Figure 4. Result after integration in a volumic modeler

only the surfaces with an impact are a right response to design problem seen. The others surfaces are only there for force transmission, assembling, and manufacturing constraints… The acceleration of design process by digital will be able to find best perennial solution and the best efficiency solution.

To achieve this design, not only the last analysis is relevant but also the dimensional specifications. All parts are assembled with each others correctly.

Question 3: impact of manufacturing on design

The third interrogation turns around the design and assembling of the different parts of mechanism. The proposition of technical solution in Figure 4 came from 3D solver. It can be injected on 3D machine (manufacturing additive). But in this case, if we don't modify the shape, the reality, their appearance, the costs could be very high, but with a poor quality design.

In future, the possibility to manufacture with a 3D printer will place a great demand on the assembly system, which, in turn will call for the strategy to be altered. We could imagine that the parts that maintain the bearing on shaft could be directly builds by a 3D printer. We could merge all parts in one single step.

We propose to modelize this new concept of new possibilities in Figure 5, where we propose to add a technological solution matrix, the new performances of manufacturing additive. We name this new typology: integrative or non integrative specifications. Our modelization 3DPL is based on (Ponche, 2013).

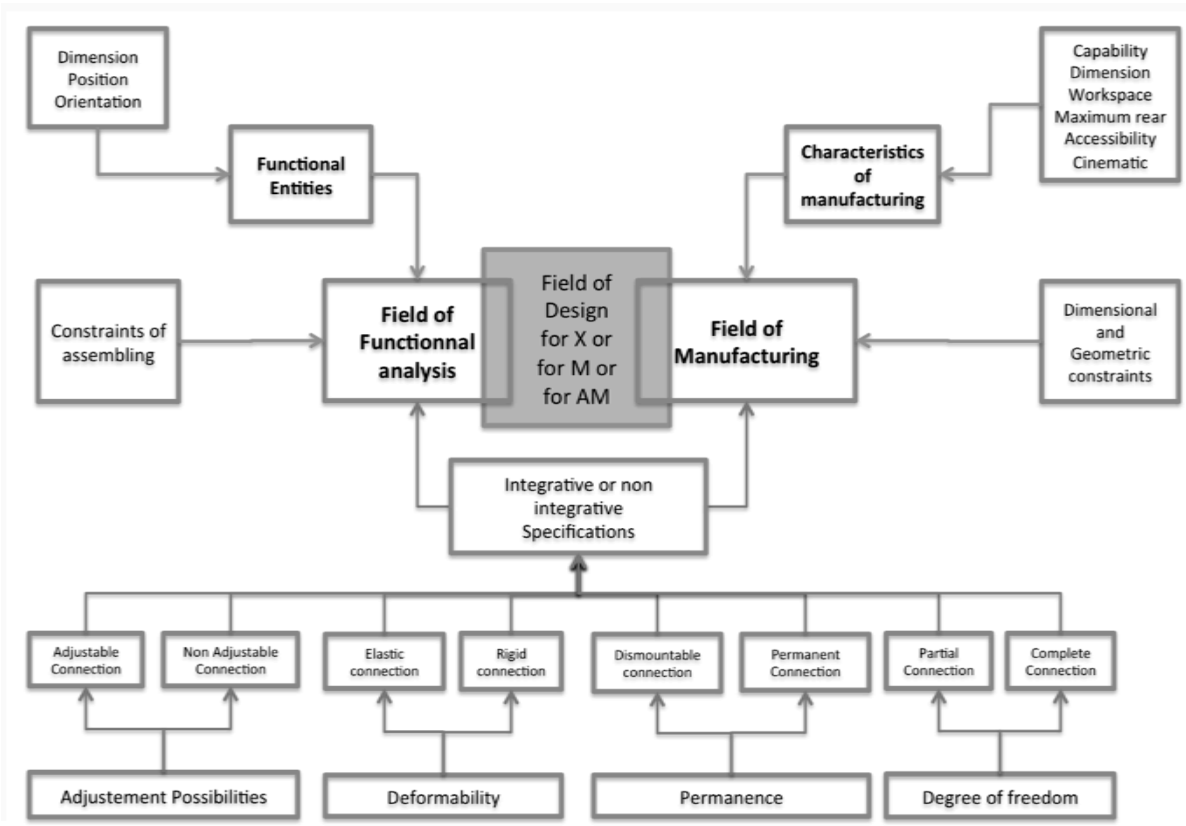

Figure 5. 3D printing model for learning, 3DPL

Conclusion

Today, the issue for teachers and researcher of design is to modelize the new design process. This new design process of integrating new possibilities where design and manufacturing are completely mixed.

We hope to demonstrate that major differences exist in the conventional design for a classical assembling and a new design for 3D printing and finally an unconventional design. A Comparison matrix of technological solutions adopted for one or other solution shows the strengths and weaknesses of different ways of thinking.

A new way of thinking appeared. This would be good for our students to address some problems and exploit the full potential of 3D printing.

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Functional analysis and its tools: how teachers use them to study technical systems with pupils 11-14 years old in France

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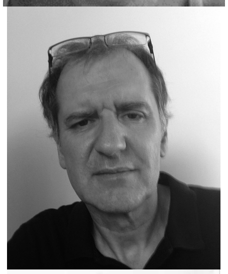

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Abstract

The study of technical systems is central to technological education. It allows us to understand the complexity of the systems in their pluri-technical dimension. In education, it generally leans toward approaches of analysis functions, structure or behavior. Different tools are associated with these methods. The implementation of functional analysis from an industrial origin focuses on several problems: the problem of transferring industrial tools to technological education, specifically concerning the knowledge involved and the references, and the problem of appropriating and transforming these tools into artifacts for teaching.

The purpose of this study, which is part of a larger research, is to identify and characterize the use of functional analysis in the declared practices of teachers in secondary schools. Using a survey, we analyze teachers' knowledge and practices regarding certain tools of functional analysis. We show that the teachers, even though they use these tools widely in secondary schools, do not claim expertise in using them. By categorizing the teachers and their responses, we try to highlight the main difficulties and find some clues that prevent functional analysis from becoming a generic method to study technical systems and becoming a constant part of technological teaching at all school levels.

Keywords

Functional analysis, technological education, technical system, teaching

Context of the study

In France, Technological Education (TE) is part of the general education. It is a compulsory subject at all school levels for pupils from 3 to 14 years old. At 15 years old, TE becomes optional and prepares for a Bachelor of Science and Technology Industry and Sustainable Development. The study of multi-technical systems is central in TE. It appears at all levels from nursery school to high school. In this paper, and in this context, we will introduce functional analysis; the type that we are speaking about deals with the technical approach to systems. As we will see later, this analysis is based on several methods, mainly for the conception or improvement of technical objects. The functional analysis and systemic approach, which form the teaching basis, are clearly confirmed as an important part of TE (Deforge, 1993; de Vries, 2005).

The system approach was developed in the USA in 1940. In France, it has been vulgarized by de Rosnay (1975) in biology, by Morin (1990) in social domain, by Le Moigne (1990), by Simon (1991) in the artificial intelligence field, and by Inhelder & Cellerier (1992) in cognitive sciences. It is defined as a dynamic and complex set, interacting as a structured functional unit and both a group of interlinked elements, in which the whole is greater than the sum of its parts (von Bertalanffy, 1968). It allows to characterize systems by specifying their boundaries, their internal and external relationships, their structure and emerging laws; it also makes apparent the socio-organizational functionality of the enterprise and makes it more fluid (Scaravetti, 2004).

Functional analysis (FA) comes from the industrial world of production and more specifically from what industrial technology classifies under the term of "Systemic and Functional Analysis" (Howard, 2007). In the industrial world of production different methods issued from functional analysis allow to understand the systemic dimension of a technical system (Zehtaban & Roller, 2012). In France, the tools associated with FA are normalized (SADT, for Structured Analysis and Design Technique; APTE®, which is a registered name for "Application aux Techniques d'Entreprise," which could be translated as Application to the Business Techniques; FAST, for Functional Analysis System Technique; CDCF, a French acronym for "Cahier Des Charges Fonctionnel," which means Functional Specifications). The tools that we introduce here are among those which we find again in TE; we will detail their uses by the teachers. They correspond to symbolic representations of the system. They come from an enterprise and allow dialog, for example, between the worker and the engineer, as both can then understand each other and communicate using a common language (Scaravetti, 2004). FA is defined as an ensemble of techniques, during the creation or improvement of a product, to identify the real needs, to quantify them, to define the true problem and to obtain important needs. FA is an approach associated with tools and elements that structured and organized the though (Scaravetti, 2004). The tools are used during the formalization of constraints and writing models. The purpose of this methodology is to obtain models that are both economic and exact (Vernat, 2004).

In a TE context, the functional and systemic approach also constitutes an important change that most likely has a positive effect upon the pupils' ability to tackle problems in a more holistic and structured way. The need to consider technical artifacts as systems rather than simple objects appears very early. These objects can be isolated without any clear boundaries (Deforge, 1993; Gilles, 1978). The systems approach has also led to a new way of designing technological education (Barak, 1990, 2007; Brown et al., 1989; de Vries, 2005; Dorst, 2006; Gartiser & Dubois, 2005).

This study deals with the eventual role of FA in teaching technology in secondary schools, and in which ways it is instrumental to teachers' practices. In France, this field of research – that is, concerning the uses of FA by teachers– has been explored in primary school by Chatoney (2003). Some empirical studies (Chatoney, 2003, 2006, 2010,) focusing on this school level indicate that FA is a structuring element for the teachers. In particular, it allows to register TE in human activities of technical objects' production, and so TE is no longer just concerned with sciences. From the point of view of the pupils, the FA locates their actions within the whole technical system; in other words, it gives meaning to the process of creating artifacts. In terms of learning, we can see all the interest of FA. However, the introduction of FA, coming from the industrial world of production reveals several problems: a problem in the transfer of industrial tools to TE, especially concerning the knowledge involved and the references (Graube, Dyrenfurth, & Theuerkauf, 2003), and a problem with the transformation of these tools into instruments of teaching. Few studies have been conducted in secondary schools, where TE still belongs to general teaching.

The main problem is discerning which references and knowledge have to be transmitted in TE. In fact, the pupils live in a world of technical systems which include multi-technological and multi-disciplinary aspects. We must teach them this complex reality, and this could be achieved with the partial or total use of FA. FA helps to take into consideration the relationship between humans and machines, and the interdependence between different functions and technical solutions, within the meaning of Simondon (1958).

Method

Sample

A questionnaire was sent to 1200 teachers in TE without any distinction between them (age, sex, experience, localization …). From the 1200 targeted teachers, 129 have answered the online questionnaire. This sample is similar to the whole population of French technology teachers, with 24 % being women and 5 % being non-titular persons. The difference between the average age for our sample, 47 years old, and the average of 42.3 years old obtained in 2003 for all teachers in France (for all subjects) is certainly due to the reduced recruitment of these last years and is not very significant, as these numbers are quite similar. With these criteria, we can advance that our sample is representative of the technology teachers' population in France.

For a confidence level of 95 % in our sample, the margin of error is 10 %. So in the following tables, every difference of more than 10 % is considered significant.

Data collection

The questionnaire is divided into three parts. The first part deals with the civil status and the kind of professional training. This part principally allows us to categorize our sample for the treatments and the data crossing. In the second part, we ask questions regarding teachers' theoretical and professional knowledge of FA. In this part, the first question is an auto-evaluation of the teachers' level of competency in FA; the teachers are asked to give themselves a mark between zero and five. Five questions concern the tools (needs diagram, inter-actors graph, functional specifications, FAST diagram) and refer to the original function of these tools. The two last questions concern FA practices and the grade level at which each teacher teaches. The third part of the questionnaire collects information about the teachers' intentions when using FA. In this part, the questions are open or semi-open. One question is about the school situation (situation of artifact conception, existing systems analysis or other) another question concerns the way in which the teachers resort to FA.

Data processing

The data obtained from closed, open or semi-open questions are both qualitative and quantitative. They are processed by flat sorting, data crossing and qualitative analysis of the open questions.

Analysis of the use of FA by the teachers

For clarification purposes, the results are presented according to two axis: the first axis concerns the teachers' ability and training with regard to tools of FA; the second one concerns the perceptions (according to their epistemological posture) of the teachers, and also concerns the use of these tools in the classroom.

Teachers' ability and training in FA

Teachers' self-declared ability: The teachers have self-evaluated their level of skill in FA, taking their level of training into consideration. These parameters have been chosen as we wanted first to have a global view for the whole group of technology teachers, in order to outline the main characteristics of FA usage. The teachers gave themselves a mark between 0 (very poor ability) and 5 (very good ability). In order to obtain significant results and to simplify the table, the self-evaluation was divided into three categories. Category one includes marks zero and one, to denote no or very little ability, the second category covers marks 2 and 3 which denote average ability, and the last category covers the highest 2 marks (marks 4 and 5 which mean that a high level of ability is declared).

Ability to use FA, considering level of training

The following table summarizes teachers' ability to use FA, considering their level of training.

Higher education	Size	Mark 0 or 1	Mark 2 or 3	Mark 4 or 5
2 years or less	19 %	8 %	56 %	36 %
3 years	29 %	2 %	53 %	45 %
4 years	9 %	10 %	45 %	45 %
5 years and more	43 %	9 %	44 %	47 %
TOTAL	129	7 %	49 %	44 %

Table 1. Level of training and self-declared ability to use FA.

This table shows that of 129 teachers, a large majority possesses a good ability with the tool: 44 % control it very well, 49 % control it imperfectly but are still familiar with it, and only 7 % cannot control it.

When we look at their level of training we notice that for the teachers with three, four or five years of higher education, the repartition is well balanced between those who declare a mark of two or three and those who declare a mark of four or five. This is not the case for those with two years of higher education, where the repartition is 56 % against 36 %, which indicates an ability not so good as that of those with three, four or five years of higher education.

It is not surprising that as the level of studies increases, so too does the level of ability; with five years of higher studies, 47 % of the teachers declared a high-level ability in FA. This indicates that the tool has to be learned and used in order to improve the teacher's ability to use it to a suitable level. Several results are surprising. 7 % of the technology teachers are unfamiliar with the tools of the subject that they teach. To this 7 %, if we add the 49 % of teachers who declare that they don't control the tool very well, it gives a total of 56 %, which becomes very alarming. It is not known whether these teachers don't study the systems, or whether they use other tools to study technical systems, as for example mind maps, energy blocks and descriptions. We also notice that the teachers who use FA do so regardless of their level of training. However, they express reservations about their ability to manage the tool as in the industrial world of production

Perception of FA by the teachers

To study the perception of FA, we have conducted quantitative and qualitative treatments on the data collected.

Quantitative treatment

First, we searched to identify how the teachers use FA. This was carried out particularly through examining the main tools of FA. We have been looking to identify teachers' effective practices when using these tools.

- Teachers' knowledge of FA tools

The following table presents the number of tools known by the teachers, among the four most widespread tools of FA (needs diagram, inter-actors graph, functional specifications, FAST diagram).

Number of tools known	0	1	2	3	4
% of teachers	14 %	11 %	12 %	17 %	46 %

Table 2. Number of tools known by the teachers.

The teachers who know all four tools represent 46 % of the total against the 14% who did not recognize any of the tools.

These results confirm that one half of the teachers in this study knows these tools, and that the other half doesn't know them or only knows a few. This can be linked with the previous results. It also poses a question regarding the way that the teachers study systems in their multi-technological entirety. One half of the teachers either studies systems differently or doesn't study them at all.

- Kinds of tools used by the teachers

The following table represents the percentage of teachers that use the different tools.

Kind of tools	Needs diagram	Inter-actors graph	Functional specifications	FAST diagram
% of teachers using this tool	56 %	59 %	77 %	57 %

Table 3. Use of the tools by the teachers.

The tools from the most to the least used are in this order: functional specifications (77 %), inter-actors graph (59 %), FAST diagram (56%) and needs diagram (57 % of users).

- Kinds of tools used by the teachers in connection with their pedagogical practices.

The next table represents the number of teachers using tools of FA among four pedagogical modalities that are frequently employed in TE.

- Pedagogical modality 1: study of existing systems (the systems are physically shown to the pupils).
- Pedagogical modality 2: conceptions of systems (the systems don't yet exist; they are designed by the pupils).
- Pedagogical modality 3: modality 1 and modality 2.
- Pedagogical modality 4: the teachers don't use FA.
- It highlights the link between the pedagogical modality adopted and the kind of tool used.

	% of teachers	Needs diagram	Inter-actors graph	Functional specification	FAST diagram
Modality 1	32 %	34 %	34 %	34 %	34 %
Modality 2	35 %	34 %	33 %	33 %	32 %
Modality 3	25 %	32 %	33 %	33 %	34 %
Modality 4	8 %				

Table 4. Distribution of the tools by pedagogical modality.

This table shows that 32 % of the teachers use FA during the study of existing systems. Inside these, of the 32 % that practice FA within modality one, the four tools are all used in the same proportion (34 % for each tool). Of the 35% of teachers who use pedagogical modality two, the four tools are used in almost the same proportions, with a small increase for the needs diagram and a small decrease for the FAST diagram. The teachers who use pedagogical modality three represent 25 % of our sample. Here, also, the four tools are used in almost the same proportions, but this time with a small decrease for the needs diagram and a small increase for the FAST diagram. 8 % percent of the teachers don't use FA. Even if the tool is recognized its utilization in the classroom is not linked with a particular modality. The teachers use FA in all cases. The distribution of the tools by modality is almost the same, one third in the conception modality, one third in the study modality, and a little less than one third for both of them combined (modality 3). The tools of the FA are, for the teachers, useful to design and study technical systems. The tools APTE® and FAST, conceived for designing, are also used to decode existing systems.

- Intention targeted in the use of the tools.

The next table represents the distribution of the teachers by their pedagogical intention: to understand the FA, understand to the system, or to understand both of them.

Intention	Understand the FA	Understand the system	Understand the FA and the system
% of teachers	26 %	22 %	52 %

Table 5. Distribution of pedagogical intentions.

Approximately half of the teachers (52 %) want the pupils to understand both the tools of FA and the system studied. 26 % of the teachers try to teach the techniques of FA and pay no importance to the system that supports the study. 22 % aim to make pupils comprehend the technical system and not the logic of the tool which allows the systems to be understood.

From a teacher's epistemological point of view, this reflects their wishes that knowledge of FA must include both the tools and the comprehension of the system.

Qualitative treatment

The treatment is based upon the answer to the following question: "Is FA essential to analyze a system? Why?"

The table represents the distribution of the 129 teachers within the answer to this question.

	Yes	No	Shared answer	No answer	Total
% of the number of response	46 %	17 %	33 %	4 %	100 %

Table 6: Responses regarding the necessity to use FA to analyze a system.

46 % of the teachers answer that FA is essential to studying a system. 17 % think that FA is not necessary. 33 % of the teachers recognize in the tool some advantages regarding pedagogical purposes.

To further enlighten the words of the teachers regarding the necessity of FA for analyzing a system, we have categorized a priori the arguments they give in their answers and justifications. This categorization is inspired by a former study on the argumentation in science lessons (Said, 2010). We must signal, elsewhere, that an aspect of subjectivity could be present during the distribution of teachers' arguments in one category or another. The crossing of qualitative and quantitative analyses reduces this subjectivity.

The main categories of arguments selected are the following: pedagogical arguments; arguments linked to the expertise; pragmatic arguments; subjective arguments.

- The pedagogical arguments come from the intention and the pedagogical choices that involve the use (or not) of FA.
- The arguments linked to the expertise are arguments based on an expert's reference (architect, other professional …).
- The pragmatic arguments come from utilitarian bases that justify the use (or not) of FA (by need or lack of need).
- The subjective arguments reflect personal resentment toward FA.
- The following table shows the frequency of the different arguments announced by the teachers to justify their opinion on whether or not it is necessary to use FA when teaching TE in secondary schools.

Categories of arguments	FA useful	FA not useful	Mixed
Pedagogic	13 %	6 %	12 %
Pragmatic	20 %	5 %	16 %
Expert	0 %	2 %	0 %
Subjective	2 %	3 %	5 %
Without argument	11 %	2 %	1 %
Total	48 %	18 %	34 %

Table 7: Percentage of teachers by par arguments type and use of the FA.

Among the teachers who consider FA as essential, 13 % have pedagogical arguments often linked to the idea of motivation (to avoid nonsense, and allow to see all the technical solutions) or to the complexity of the task (to meet the theoretical aspect of FA, in order to understand the whole system). 20 % of the teachers who agree with the necessity of FA put forward pragmatic arguments (e.g., it allows to bring to the foreground the functions of use, to enlighten the realization process of a technical object). Only 2 % of teachers suggest the necessity of FA for personal reasons purely subjective.

Among the teachers who consider that FA is not essential, 6 % have pedagogical arguments. These are often linked to the idea of complexity and abstraction of the tools (which is completely unsuitable for the pupils). 5 % of the teachers, considering FA as not essential, have pragmatic arguments linked to the utility of this method (e.g., it is not very interesting, other tools exist). Only 3 % of them see the necessity of FA for purely subjective personal reasons (e.g., I don't like this tool, abstraction). This time, 2 % make reference to arguments suggested both by experts and professionals.

34 % of the teachers have a balanced judgment regarding the necessity of FA. 12 % of this category have pedagogical arguments (e.g., concerning the method given by the teacher), 16 % have pragmatic arguments (e.g., FA allows one to have a complete vision and avoid omissions, and offers a structured framework for analyzing systems). Only 5 % of teachers argue in a purely subjective way (e.g., FA is an asset for the construction of a project). No argument refers to experts, and 1 % of teachers gives no justification.

We notice that the pedagogical and pragmatic arguments are linked together and complement each other. This explains that the pedagogical choices of the teachers are closely linked to the needs of connections between the knowledge of the industrial world and the teaching of TE.

Conclusion

Through this study, we have asked French secondary school teachers (of pupils 11 to 14 years old) how they use the tools of FA. We have endeavored to understand how and for what purpose they might use these tools. The results indicate that the use of FA is linked with their level of higher education.

They also show that, in contrast to the industrial world of production (where the use of FA is restrained to the conception of technical systems), most of the teachers use FA as well as studying existing systems than at the first step of designing. The teachers who use FA defend their practices with firstly pragmatic then pedagogical arguments, with the purpose of linking industrial references to the teaching, as well as the need to make the system more attractive and comprehensive for the pupils. If they limit the use of FA to simple systems, it's mainly because they have questions about the complexity of these tools for pupils in secondary schools.

The teachers who don't use FA see no utility and no need for such a tool. The tool seems to be complex and not very attractive and can be replaced with other pedagogical methods. These teachers have an epistemological position that separates the industrial reference from the teaching of TE. One last category of teachers uses FA in certain circumstances, depending on their needs and on the purpose for which FA will be used.

The combination and correlation between the different variables will be part of a larger work based upon a theoretical framework, not detailed here, with the purpose of specifying how the artifacts are instrumented by the teachers and used by the pupils.

This exploratory study, based on self-declared practices by the teachers, enriches the range of studies in technological education that concern the problem of reference of knowledge between technology education and his reference to the human activity in the world of production. This raises the question of the legitimacy and the existence of this teaching, and also the question of the training levels of teachers in this field.

It should be also interesting to continue this study by observing more closely the evolution of the epistemological positions, by studying the effective practices in the classroom. This would contribute to specify the field of knowledge with fine analysis of relationships between industrial's references and cultural common educational basis. It will make sense to what happen during scholar activities and efficiency of teaching and learning.

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First practical step to achieve education for sustainable development (ESD) in the context of Thailand's design education: exploring a transformative pedagogical approach

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Abstract

Literature addressing the development of ESD in both general education and design and technology education indicates that a vision aiming to inclusively empower all citizens to take charge, cooperate and create a sustainable future requires a paradigm shift in learning and teaching. This paper presents initial work for a study that explores the current practice of sustainability learning and teaching in Thailand's design education. The study intends to create a transformative pedagogical model for teaching sustainability to undergraduate design students in Thailand. Since the first step to change the dominant educational paradigm is to recognize the present through practice, the study primarily pays attention to the higher education institutions offering sustainability-related courses within their Design Departments, in order to gain insights into the pedagogical methods employed. Research data collection methods will include interviews, focus group discussions and curriculum interventions, but this paper focuses only on the development of the analysis tools for the observation of learning and teaching. Based on theories and concepts drawn from a wide range of scholars working in fields of Education (Miller, 1988; Sterling, 2001; Burns, 2011), Design (Fleming, 2013) and Philosophy (Naess, 1973), this set of tools is designed to enable the researcher to address the characteristics of the mechanistic and holistic worldviews articulated in learning and teaching. The tool set contains four key aspects to look into: 1) the general view of education, 2) the environmental ethics and the environmental education approach, 3) the perspectives of design, and 4) the model of sustainability pedagogy.

Keywords

Education for sustainable development (ESD), design education, higher education, learning and teaching observation, Thailand

Design education in relation to ESD

'Education for Sustainability' (EfS), 'Education for Sustainable Development' (ESD) and simply 'sustainability education' are interchangeable terms which describe the practice of teaching and learning for sustainability. Since ESD is most used internationally by United Nations, it is used in this paper accordingly. As stated by Daniella Tilbury and David Wortman (2004), the essential skills for ESD include envisioning a better future, critical thinking and reflection, systemic thinking, building partnerships and participation in decision-making.

> *"Design education needs to be part of the solution and not part of the problem."* (Giard and Schneiderman, 2013, p.134)

Since design directly involves production and consumption, the design practice is a subset of a bigger panorama encompassing a large number of stakeholders as well as environmental, economic, and social impacts. It is fundamental that designers are aware of this circumstance. It is obvious that sustainability is essential in design practice, and therefore, in design education. However, according to

Mafalda Casais, Henri Christiaans and Rita Almendra (2012), although sustainability in design finds much attention in the literature and in practice, the education of sustainability in design programs worldwide still lacks discussion regarding curricula and importance. Opportunities such as economic viability and environmental regeneration are slowly and awkwardly finding their way into the mainstream of design education thinking, while the inclusion of socially responsible design varies from school to school and from studio to studio. (Fleming, 2013, p.3)

Design education in Thailand in relation to ESD

As claimed by Sarakard Pasupa, Mark Evans and Debra Lilley (2012), in Thailand design education has attempted to intensify its focus on sustainability over recent years and a range of sustainable design initiatives have been carried out in order to contribute to the learning of design for sustainability. But, there is still a very limited amount of literature and learning resources available in Thai language. The insufficiency of educators with qualifications and experience concerning sustainable design also greatly contribute to this dilemma. As a result, design for sustainability is usually just an elective or optional course at the undergraduate level and only taught in a limited number of universities. Regardless of its effectiveness, lecture-based learning is mainly employed to teach sustainable design principles, in order to encourage students to implement these principles into their design ideas. In the programs that do not offer such separate course, sustainability is occasionally incorporated as an extra aspect of the studio experience.

The aim of this paper is to discuss the development of an observational tool. The tool is designed for obtaining insights into the pedagogical approaches of sustainability-related courses offered within Design Departments in higher education institutions, through classroom observation. It looks for investigating if ESD is employed for the teaching and learning of ‘Design for Sustainability’. The observational tool will be used as part of the larger study, which aims to create a transformative pedagogical model for teaching sustainability to Thai undergraduate design students. Therefore, it is of importance that this observational tool initially facilitates addressing multiple aspects of the current practices.

Although the larger study has been built upon a number of well-known literatures, including key concepts like Whole Systems Thinking (Capra, 1996, 2002), Deep Ecology (Naess, 1973) and Critical Pedagogy (Freire, 1970), Thai education culture (Komin, 1990; Mounier & Phasina, 2010) is taken into account too. The hierarchical system in Thai culture is a unique factor. Whereas the effectiveness of the transmission approach to teaching is widely put in question, teacher-centered instruction has long been a usual practice in Thailand. Buddhism also has much influence on the roles of teacher and learner, especially in terms of status and respect. Hence, it is interesting to find out how Thai cultural characteristics affect the teaching and learning of sustainability and if sustainable learning process is employed in this particular context.

Observation of teaching and learning

This paper presents the development of the observation sheet as a data collection tool to be used for observation of teaching and learning, teacher-student interactions and students' participation in their classroom activities. The observation sheet is made up of two parts, a) the space for open-ended narrative and b) the checklists for marking key concepts captured during observation. The narrative space simply allows writing and drawing for recording the teaching and learning situation. In order to design the checklists, the observation framework was formulated from a number of theories and designed systematically to observe classroom activities. It is best to make use of the observation sheet to examine each activity, instead of each session. This is because one session may consist of a variety of activities.

The observation framework

The observation framework contains four aspects concerning sustainable design education including: 1) General view of education, 2) The environmental ethics and the environmental education approach, 3) The perspectives of design, and 4) Model of sustainability pedagogy. There are tools allocated for each aspect, ranging from tool A to H. They are a collection of analysis tools in form of checklist. Each tool is rooted in different literature. The checklists were primarily built upon a conceptual continuum that spans from the mechanistic worldview on education to the holistic worldview on education. However, the model of sustainability pedagogy (Burns, 2011) also contributes to the design of the checklists and provides the structure for designing the observation sheet.

General view of education

This set comprises of tools for analysing education approaches (Tool A), for view of teaching and learning (Tool B), for view of learner (Tool C) and for teaching and learning style (Tool D).

Tool A: Tool for analyzing education approaches

This tool is built upon critical pedagogy (Freire, 1970) which efforts to foster the transition from transmissive to transformative approaches. It focuses on the educational paradigm level, pinpointing that there are three different educational positions along the continuum. The three worldviews including fragmentalism, pragmatism and holism (Greig, Pike and Selby, 1989) correspond well with the three approaches to education, which are transmission, transaction and transformation (Miller, 1988).

1) **The transmission model** highlights the teacher-centric learning as its goal is to transmit knowledge, attitudes, or skills from teacher to learner. Knowledge is considered as content.

2) **The transaction model** is more active and emphasizes on knowledge sharing. It regards learning as an inquiry process that learners and teacher co-participate in, so learning is considered both social and individual.

3) **The transformation model** engages a systemic view of education. It sees learning as holistic, participatory and practical. It is a process of increasing an individual learner's capacity for change. Knowledge is assumed to be interconnected and enriched by multiple perspectives.

Worldview: Greig, Pike & Selby (1989)	Fragmentalist /Mechanistic	Pragmatic	Holistic
	Teacher-centred <---------------------------------> Learner-centred		
Curriculum model: Bowers & Flinders (1990)	Technocratic	Academic rationalist	Critical pedagogical
Education approach: Miller (1988)	Transmission	Transaction	Transformation

Table 1. Tool A for analyzing education approaches

Tools B to D: Tools for analyzing view of teaching and learning, view of learner, and teaching and learning style

Drawn from Sustainable Education (Sterling 2001), these tools focus particularly on learning and pedagogy. With mechanistic worldview at one end and holistic worldview at the other, the tables provide a number of contrast characteristics represented through the teaching and learning situation.

Worldview:	Mechanistic	Holistic
View of teaching and learning:	Product oriented	Process, development and action oriented
	Emphasis on teaching	Integrative view: teachers also learners, learners also teachers
	Functional competence	Functional, critical and creative competencies valued

Table 2. Tool B for analyzing view of teaching and learning

Worldview:	Mechanistic	Holistic
View of learner:	As a cognitive being	As a whole person with full range of needs and capacities
	Deficiency model	Existing knowledge, beliefs and feelings valued
	Learners largely undifferentiated	Differentiated needs recognized
	Valuing intellect	Intellect, intuition and capability valued
	Logical and linguistic intelligence	Multiple intelligences
	Teachers as technicians	Teachers as reflective practitioners and change agents
	Learners as individuals	Groups, organizations and communities also learn

Table 3: Tool C for analyzing view of learner

Worldview:	Mechanistic	Holistic
Teaching and learning style:	Cognitive experience	Also affective, spiritual, manual and physical experience
	Passive Instruction	Active learning styles
	Non-critical inquiry	Critical and creative inquiry
	Analytical and individual inquiry	Appreciative and cooperative inquiry

Table 4. Tool D for analyzing teaching and learning style

The environmental ethics and the environmental education approach

Since the development of values and environmental ethics is fundamental to sustainability, the tools in this section are incorporated for analysing environmental ethics and environmental education approaches used in the teaching and learning.

Tool E: Tool for analysing environmental ethics

According to the Stanford Encyclopedia of Philosophy (1997), environmental ethics is the discipline in philosophy that studies the moral relationship of human beings to, and also the value and moral status of, the environment and its nonhuman contents. Three key concepts concerning environmental ethics utilised in this tool include the followings.

1) **Anthropocentrism** positions human beings at the centre of the universe. The anthropocentric belief is that humans possess greater intrinsic value than non-human nature. It is therefore acceptable to employ the resources of the natural world for only human ends.

2) **Technocentrism** is an environmental perspective that humans are able to control and manage resources by the use of technology. The values are explicitly centered on technology. This type of view believes that it can provide solutions to all environmental problems.

3) **Ecocentrism** is a nature-centered system of values which also recognizes non-living things, set against to the human-centered, system of values. Grounded in ecocentrism, the term 'deep ecology' derives from an essay by Arne Naess (1973) on the distinctions between 'shallow' and 'deep' approaches to environmental protection. Deep ecology calls for a more balanced and egalitarian interaction between humans and nature as opposed to the relationship of human dominance over nature, whereas shallow ecology is anthropocentric – concerning primarily with human well-being.

Worldview:	Mechanistic				Holistic
Systems of Values:	Technology-centred	Human-centred			Nature-centred
Environmental Ethics:	Technocentric	Anthropocentric			Ecocentric
		Egocentric	Shallow Ecology	Intermediate-depth Ecology	Deep Ecology

Table 5. Tool E for analysing environmental ethics

Tool F: Tool for analyzing the environmental education approach

Environmental education is a learning process that allows individuals to explore environmental issues. According to Constance L. Russell (2001), there are three approaches to environmental education. These are positioned in relation to the three previously mentioned education approaches – transmission, transaction and transformation. The table represents the contrasting views between dominant social paradigm to the new ecological paradigm, in connection with these environmental education approaches.

Worldview:	Mechanistic <---> Holistic		
Paradigm:	Dominant Social Paradigm		New Ecological Paradigm
Education approach: Miller (1988)	Transmission	Transaction	Transformation
Teaching approach to nature: Russell (2001)	Nature as resource		Nature as more than a resource, nature as home
	Nature as series of building blocks	Nature as complicated system but manageable through rational planning and the use of science and technology	All life interconnected and interdependent Biological and cultural diversity valued
Approach to Environmental Education: Russell (2001)	Behavioral modification and technofix solutions	Problem-solving Skill development Action-oriented	Personal growth and social change Development of “whole” person Commitment to social and environmental justice Collaborative, participatory
Key concept:	Economic growth / Cost effectiveness / GDP	Human well-being / Eco-efficiency / Waste management	Systems thinking / Futuring

Table 6. Tool F for analyzing the environmental education approach

The perspectives of design

Tool G: Tool for analyzing the perspectives of design

This tool places an emphasis on the creation of design perspectives through design education. Drawn from Rob Fleming (2013) and linked with environmental ethics, the multiple perspectives of design are offered in the checklist. Different design practices are positioned in relation to the value systems and worldviews.

<table>
<tr><td>Worldview:</td><td colspan="3">Mechanistic</td><td>Holistic</td></tr>
<tr><td>Environmental ethics:</td><td>Technocentric</td><td colspan="2">Anthropocentric</td><td>Ecocentric</td></tr>
<tr><td>System of values:</td><td>Economy-centered</td><td colspan="2">Human-centered</td><td>Nature-centered</td></tr>
<tr><td rowspan="3">Design Practice:</td><td colspan="4">Conventional Design <-----------------------> Design for sustainability</td></tr>
<tr><td rowspan="2">Mainstream (Economic-driven)</td><td>Design for society/ well-being</td><td rowspan="2">Eco design</td><td rowspan="2">Sustainable design</td></tr>
<tr><td>Green design</td></tr>
</table>

Table 7. Tool G for analyzing the perspectives of design

Model of sustainability pedagogy

This aspect explores Heather Burns' (2011) model of sustainability pedagogy, which is comprised of five key elements. (See table 8.) This pedagogical model reflects education as sustainability, a transformative learning process through which learners' values and perspectives change so that they are able to embrace sustainability and take action for change. The design of observation sheet follows this model as a guideline.

Element	Goal
1) Content	To increase learners' systemic understanding of complex sustainability issues.
2) Perspectives	To provide learners with opportunities to think critically about dominant paradigms, practices and power relationships and consider complex ecological and social issues from diverse perspectives.
3) Process	To enhance learners' civic responsibility and intentions to work toward sustainability through active participation and experience.
4) Context	To increase learners' understanding of and connection with the geographical place and the community in which they live.
5) Design	To utilize an ecological course design to create transformative learning.

Table 8. Model of sustainability pedagogy (Burns, 2011)

Tool H: Tool for analyzing context of the teaching and learning

This tool is derived from the fourth element of the model – 4) Context. Since the goal of this element is to increase learners' understanding of and connection with the geographical place and the community in which they live, it denotes the concept of place-based pedagogy. Unlike other tools described previously, tool H is not majorly built upon a conceptual continuum ranging from the mechanistic to the holistic worldviews on education. Instead, it focuses on the details of the context for teaching and learning.

<table>
<tr><td colspan="3">Does the session employ place-based pedagogy?</td><td>Yes</td><td>No</td></tr>
<tr><td>Dimensions to explore:</td><td>Economic</td><td>Political</td><td>Social & cultural</td><td>Ecological</td></tr>
<tr><td colspan="5">Methods used to connect with the community:</td></tr>
<tr><td colspan="5">- Observation / field note taking</td></tr>
<tr><td colspan="5">- Survey / questionnaire</td></tr>
<tr><td colspan="5">- Interview / focus group / discussion</td></tr>
<tr><td colspan="5">- Experimentation</td></tr>
<tr><td colspan="5">- Community knowledge sharing</td></tr>
<tr><td colspan="5">- Community participatory project</td></tr>
</table>

Table 9. Tool H for analyzing context of the teaching and learning

This sustainability pedagogy model regards teaching as action research, contributing to continuous development and sustainability. (See figure 1.) Using this model as a guideline, the observation sheet is designed to fit with the four out of five elements in the cycle of sustainability pedagogy planning: 1) Content, 2) Perspectives, 3) Process, and 4) Context. The 5) Design element is not included. This is because it is more practical to comprehend the design of the course by doing document analysis of the course syllabus. (See table 10.)

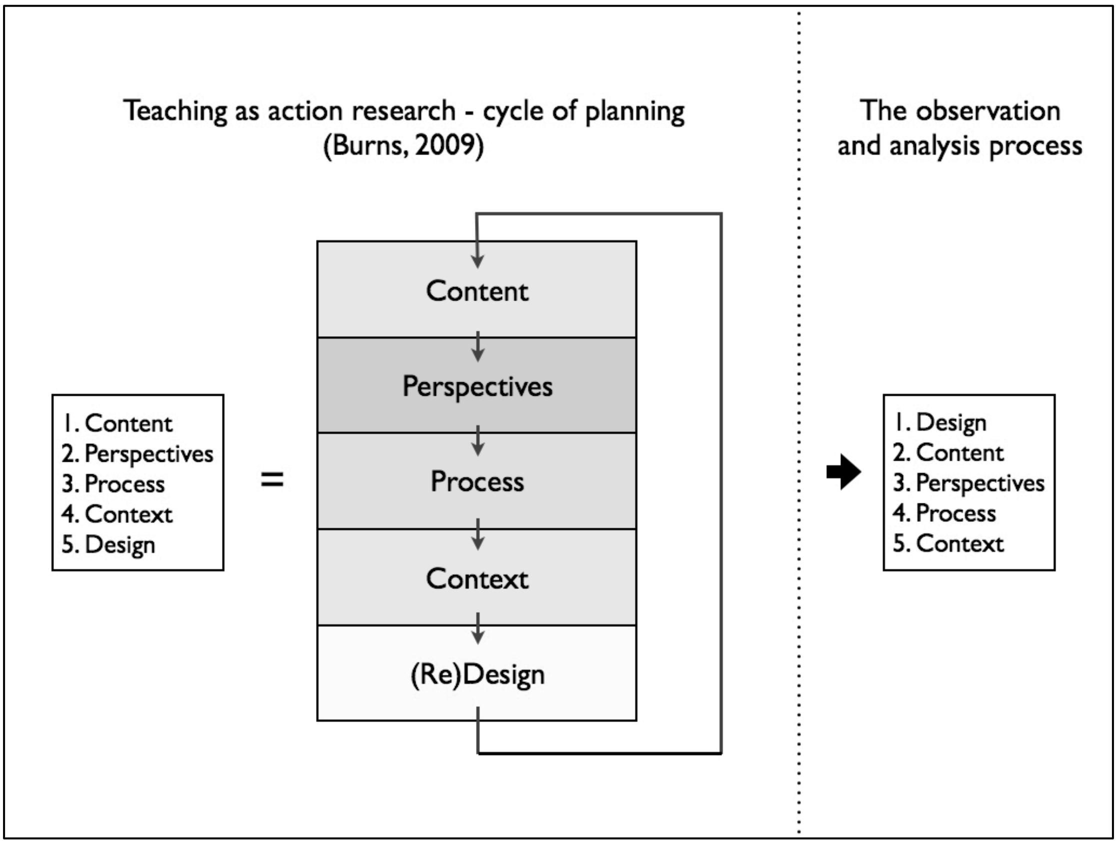

Figure 1. Teaching as action research versus the classroom observation process

What to explore	What to do
1) Design	**Before the session starts:** Document analysis using detailed course outline to understand the design of the course
2) Content	**During the session:** Classroom observation using observation sheet to understand the current practice
3) Perspectives	
4) Process	
5) Context	

Table 10. The summary of how to allocate the five elements of sustainability pedagogy model into the observation

The final design of observation sheet

The observation sheet was constructed to allow the space for open-ended narrative to sit in the middle of the template with the checklists placed along both sides. Once refined, tools A-D are grouped under the topic 'Process' (See table 11), tools E-G are grouped under the topic 'Perspectives' and tool H is under the topic 'Context' (See table 12). The final design is presented below in figure 2. One A4-size sheet is made up of two templates in total.

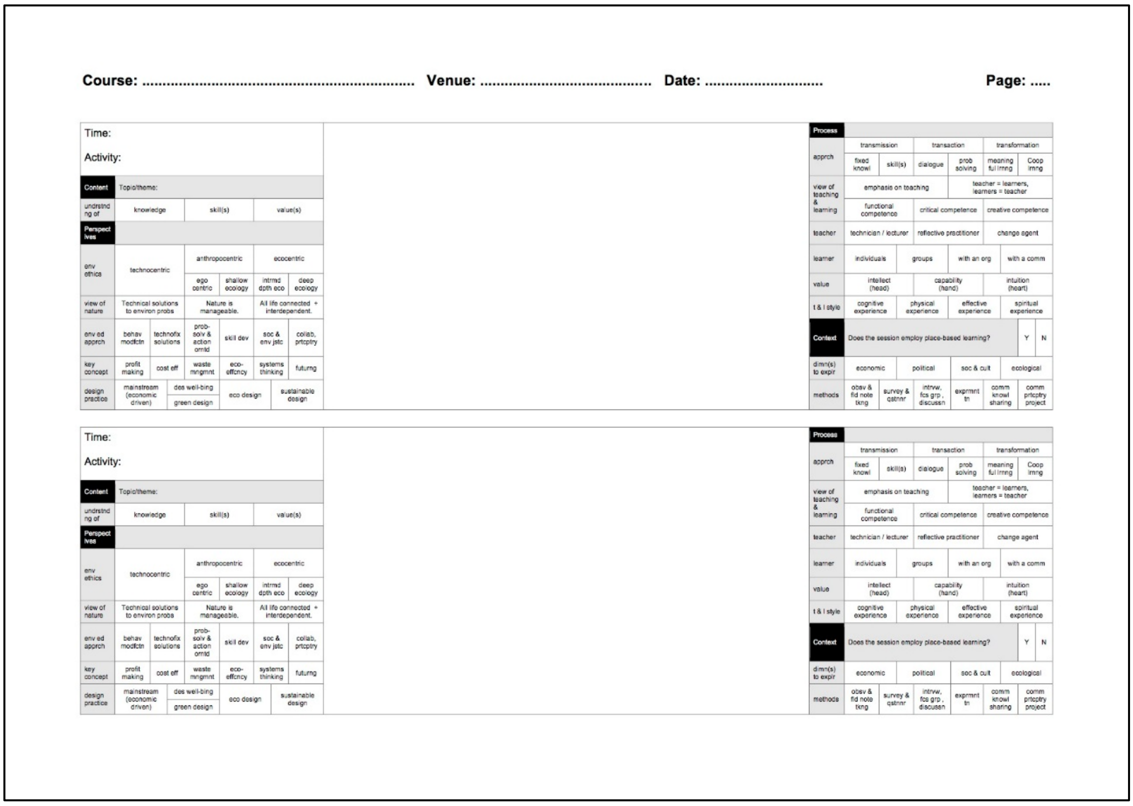

Figure 2. The final observation sheet

Time: Activity:						
Content	Topic/theme:					
understanding of	knowledge		skill(s)		value(s)	
Perspectives						
environmental ethics	technocentric		anthropocentric		ecocentric	
			ego centric	shallow ecology	intermediate depth ecology	deep ecology
view of nature	Technical solutions to environ problems.		Nature is manageable.		All life connected + interdependent.	
environmental education approach	behavior modification	technofix solutions	problem solving & action oriented	skill development	social & environmental justice	collaborative / participatory
key concept	profit making	cost effectiveness	waste management	eco-efficiency	systems thinking	futuring
design practice	mainstream (economic driven)	design for well-bing		eco design	sustainable design	

Table 11. The left-side checklist

<table>
<tr><th>Process</th><th colspan="11"></th></tr>
<tr><td rowspan="2">approach</td><td colspan="3">transmission</td><td colspan="2">transaction</td><td colspan="6">transformation</td></tr>
<tr><td>fixed knowledge</td><td colspan="2">skill(s)</td><td>dialogue</td><td>problem solving</td><td colspan="4">meaningful learning</td><td colspan="2">cooperative learning</td></tr>
<tr><td rowspan="2">view of teaching & learning</td><td colspan="4">emphasis on teaching</td><td colspan="7">teacher = learners,
learners = teacher</td></tr>
<tr><td colspan="3">functional competence</td><td colspan="2">critical competence</td><td colspan="6">creative competence</td></tr>
<tr><td>teacher as</td><td colspan="3">technician / lecturer</td><td colspan="2">reflective practitioner</td><td colspan="6">change agent</td></tr>
<tr><td>learner as</td><td colspan="2">individuals</td><td colspan="2">groups</td><td colspan="3">with an organization</td><td colspan="4">with a community</td></tr>
<tr><td>value</td><td colspan="3">intellect
(head)</td><td colspan="2">capability
(hand)</td><td colspan="6">intellect
(head)</td></tr>
<tr><td>teaching & learning style</td><td colspan="2">cognitive experience</td><td colspan="2">physical experience</td><td colspan="3">effective experience</td><td colspan="4">spiritual experience</td></tr>
<tr><td>Context</td><td colspan="8">Does the session employ place-based learning?</td><td colspan="2">Y</td><td>N</td></tr>
<tr><td>dimension(s) to explore</td><td colspan="2">economic</td><td colspan="2">political</td><td colspan="3">social & culture</td><td colspan="4">ecological</td></tr>
<tr><td>methods</td><td>observation & field note taking</td><td colspan="2">survey & questionnaire</td><td>interview, focus group, discussion</td><td colspan="2">experimentation</td><td colspan="3">community knowledge sharing</td><td colspan="2">community participatory project</td></tr>
</table>

Table 12. The right-sided checklist

Conclusion

ESD skills, including envisioning a better future, critical thinking and reflection, systemic thinking, building partnerships and participation in decision-making, are significant for the teaching and learning of sustainable design. Concerning ESD, this paper demonstrates the development of the analysis tools used for creating the observation framework and describes a method for observing teaching and learning process of sustainability-related courses in Thailand's design education. As a data collection tool, the observation sheet presented in this paper aims to enable the researcher to address various dimensions of classroom activities, from 'content', to 'perspectives', to 'process' and to 'context'. It facilitates capturing not only insights into the pedagogical approaches currently employed, but also the characteristics of the mechanistic and holistic worldviews articulated in learning and teaching. It is best to use in conjunction with the analysis of the detailed course outline, in order to understand the design of the specific course observed. The observation sheet has been used during an exploratory fieldwork in Thailand. Throughout the pilot with several groups of third and forth year Design students of leading universities based in Bangkok Metropolitan Region, data was collected through direct, passive observation. The researcher was present in the learning environment but neither interacted nor participated. As the study is ongoing and the findings are still not absolutely definite, up to this point teacher-centered instruction is found most common and the learning activities significantly reflect the mechanistic worldview in both design and education. The initial findings confirm that ESD has been hardly implemented in the selected cases. Moreover, the use of the observation sheet has been an exploration to improve tools to base a future investigation. With regards to the emphasis on the social and cultural context of Thailand and the development of the observation sheet, the researcher may consider adding in an analysis checklist in relation to the hidden curriculum. This is in order to examine how the hidden curriculum of each case contributes to both the current practice and the potential to integrate transformative pedagogy into classroom to support sustainability learning.

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Kindergarten student teachers' attitudes towards and perceptions of technology: the impact of a one year pre-service course

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Abstract

Technology education is officially part of the Israel Ministry of Education's kindergarten curriculum, but it is rarely actually implemented in Israeli kindergartens. This is due to the fact that technology education is not part of the pre-service training that kindergarten teachers receive in most education colleges and universities. In order to help kindergarten student teachers' develop their concepts, beliefs and philosophy of technology and technology education, a technology training program (seminar) was developed at Beit-Berl College.

Beit Berl's seminar syllabus is based on Mioduser's 6 Strands: The designed/artificial world, problem solving, design and making, notations, smart artifacts and the whole-kindergarten final project (Mioduser, 2009; Mioduser, Levy, Kuperman, & Rudolf, 2008).The seminar was developed and offered to students in their fourth year of training at Beit Berl. During the seminar the student teachers study the concepts and skills of technology, and its implementation in the kindergarten. Furthermore, during the second semester of the seminar the student teachers focused on conducting a small study (action research) in a kindergarten choosing one of the 6's Strands, and designed and developed a technological activity that addressed a research question.

This paper reports the findings of a survey based on the open-ended questions of the PATT questionnaire (Raat, de Klerk Wolters, & de Vries, 1987) conducted three times during the academic year (the first lesson in semester A, at the end of semester A and at the end of semester B). The findings show differences in the kindergarten student teachers' attitudes and perceptions throughout the academic year; while they were involved in a seminar in technology education and while conducting their research in the kindergarten. This paper will describe the differences in their responses at different points in time and the researcher's conclusions.

Keywords

Technology education, pre-service teacher education, kindergarten teacher, attitudes towards technology

Introduction

This paper will present the finding of a small research study related to changes in attitudes towards and perceptions of technology throughout a one year seminar on technological thinking and its implementation in the kindergarten. We will focus on: a) technology education in the kindergarten; b) pre-service teacher training in technology education and c) pre-service teachers' perceptions of technology and technology education.

Technology education in the kindergarten

Early childhood is a time in which the foundation for effective learning is built and an opportunity to teach and experience technology among other subjects. However, it is rare to find technology education in preschool and few research studies focusing on this age group have been conducted (Fleer, 1999). Technological content geared to the kindergarten level has been integrated into curricula developed and implemented in different countries (for example; in the United Kingdom, New Zealand, Australia, the United States. and various countries in continental Europe - see Compton and France, 2007; ITEA, 2000). Despite the differences between the, common sets of content categories and target skills can be identified including: technological awareness and literacy, relations with the world of artifacts in which we live, acquisition of materials manipulation skills and even design process skills (Dagan, Kuperman & Mioduser, 2012; Mioduser, Levy, Kuperman, & Rudolf, 2008).

The technology elements of the Israeli kindergarten curriculum are rarely implemented. This can be attributed to the fact that technological knowledge and relevant pedagogies are not part of most teachers' background or formal formation in their pre-service professional development. A new science and technology curriculum for this age level is currently under development (Ministry of Education, in press). Beit-Berl College decided to develop a yearlong course to address the topic of technological thinking in the kindergarten that was included in the preschoolers program.

Fleer (1999) discovered that five year old children could design, make and evaluate in an iterative process; when she gave them open-ended problems and assistance along the process. Resnick (2007), claims that a spiraling process in which children imagine what they want to do, create a project based on their ideas, play with their creations, share them with others, and reflect on their experiences – leads the children to imagine new ideas and new projects. Through this non distinct or sequential process the young children develop their creative and thinking abilities.

The Beit Berl's seminar syllabus is based on the concepts and program developed by Mioduser in Tel-Aviv University (Mioduser, 2009). This program addresses technological thinking in the kindergarten, with an emphasis on the cognitive process involved and demanded for understanding, interacting with and designing the artificial world: the human-mind-made world. It was based on a cognitive and epistemological model that enhances teaching and learning technology as a human beings' thinking and intellectual development. Thus, learning technology is learning about thinking, about learning, about the invented world, and about the results of the co-evolution of the designed and the designers' worlds (Dagan, Kuperman & Mioduser, 2012).

The program content is organized into six main strands:1) The designed/artificial world (artifacts and their use/context); 2) Problem solving (from haphazard to budding systematically in planning and implementing solutions; 3) Design and making (from free-form building to designed/reflective construction); 4) Notations (from conventional signs to computer programs); 5) Smart artifacts (from analyzing observed robot behaviors to the design of adaptive behaviors); 6) Kindergarten wide final project (Mioduser, 2009).

Pre-service teacher training in technology education

Despite the many differences in technology education training programs around the world, in various universities, and differences related to the age of the students and their intern (kindergarten, primary, secondary or high school); the programs for pre-service teacher training around the world focus on technology knowledge, processes, values and attitude on one hand and pedagogical knowledge and skills on the other hand (Pool, Reitsma, & Mentz, 2011; Baskette, & Frantz, 2013). In NZ project (Forret, Edwards & Lockley, 2013), the four key elements of technology pre-service training were: a) Philosophy of technology, b) Rationale of technology education, c) Technology in NZ curriculum; and d) Teaching technology.

Pre-service teachers need to be encouraged to dare to integrate theory and practice as a tool to deal with unanticipated situations in technology education in the classes (Koski & de Vries, 2011).

Research studies indicated that pre-service teacher training in technology education must focus on the development of teacher subject matter knowledge, the pedagogical content knowledge and the teachers' attitudes towards the subject. The studies claimed that an increase in confidence related to technology teaching combined with a more positive attitude could contribute to an improvement in the quality of teaching. (Rohaan,Taconis, & Jochems, 2012; McRobbie, Ginns, & Stein, 2000; McGlashan & Wells, 2012; Chikasanda, Otrel-Cass, Williams, & Jones, 2013; Koski & de Vries, 2011).

There is a general consensus that pre-service teacher training programs not only prepare teachers for teaching the curriculum but concentrate on building the student teachers own beliefs and perceptions.

Pre-service teachers' perceptions of technology and technology education

Volk & Dugger (2005) were interested in perceptions of technology and they compared attitudes and thinking about technology between adults in America and Hong-Kong. One of the questions in their questionnaire was "What comes to mind when you hear the word “technology?” Their findings indicated that both groups of adults think about computers first (47% HK and 68% US) and then electronics (5% in both groups). The group from Hong-Kong indicated, to a greater degree, that they also thought about "new inventions" and "advancement".

In order to teach technology effectively the teachers must develop an understanding of technology (de Vries, 2012). The goal of pre-service, technology teacher training is to help student teachers develop their conception and knowledge of technology that will influence their perceptions of technology education and shape their curriculum materials (Forret, Edwards & Lockley, 2013).

Research indicates that student teachers' changed their perceptions towards technology education and the nature of technology during their training. Initially they thought of technology as use of computers and later expanded their perception of technology to include problem solving and creativity and thinking processes (Forret, Edwards & Lockley, 2013; Baskette & Fantz, 2013; Mc Glashan & Wells, 2013).

A survey focused on the ability of one course to change students' technology literacy and their perception of the importance of technology, asked the following open-ended question: What is technology? Pre-test responses from the students included the words: computer, electronics, and cell-phones. Posttest responses included the word computers but also included statements such as: "anything that makes life better" (Baskette & Fantz, 2013).

Our study was designed to gauge the ability of a two semester course to change kindergarten student teachers attitude toward technology and perception of technology education.

Research methodology

In this paper we will focus only on the two first open-ended questions of the PATT questionnaire:

- Question 1: Please give a short description what you think technology is?
- Question 2: (added by us to the questionnaire): How would you integrate technology into the daily life of the kindergarten?

The answers to the rest of the quantitative questions in the questionnaire will be presented later on.

Many researchers around the world have used the PATT questionnaire over the years, to understand students' attitude and perceptions towards technology and validated it. (Volk and Ming, 1999; Ankiewicz, Van Rensburg, & Myburgh, 2001; Becker & Maunsaiyat, 2002; Chikasanda, Williams, Otrel-Cass, & Jones, 2011).

The research population: 23 female kindergarten student teachers in their fourth and final year of B.Ed. Degree program. This course (seminar) was the only technology course in their curriculum. 75% of the students were aged 25-30, 22% were 20-25, and 4% 35-40. A PATT questionnaire (Raat, de Klerk, Wolters, & de Vries, 1987) was administered to them three times throughout the year.

The course: "Kindergarten Student Thinking and Doing Technology" last two semesters. During the first semester the student teachers studied the concept of technology education and how they can teach it in kindergarten (The 6's Strands). Content included: Technology content knowledge, pedagogical content knowledge, and attitude and values. Some of the lessons were hands-on, learning by doing (designing), some of their knowledge they study in flipped classroom by collaborating in team work and by teaching each other's. During the second semester each pair of student teachers conducted their action research study in the kindergarten and wrote a report. Examples of research topic are:" the gender differences in building with blocks and drawings in kindergarten children aged 5" and "The differences in designing between age 4-5 and 5-6?" During the action research they have meetings with their mentor, and at the end of the year they had to present their results in front of their classmates.

Methods of analysis for the two open ended questions

1. Counting the number of words used in each question three times during the seminar.
2. Using the Wordle to presents the frequency of the use of the words in a text.
3. Using an Excel spreadsheet to compare the words,
4. Sorting all the words based on Mitcham (1994) definition of technology and compares them along the process.

Findings

The findings show the changes in the attitudes and perceptions throughout the year long course.

1. Number of words used for answering the two open questions (as show in table 1).

Table 1. Number of words used for answering the questions

Question 1			Question 2		
Pre	mid	Post	Pre	mid	Post
52	48	85	59	62	84

For the first question "What do you think technology is?", table 1 shows an increase in the number of words from the pre-test to the post-test (63% more). In the answers for the second question related to the implementation in the kindergarten; in the middle of the course, the student teachers used almost the same amount of words and at the post-test the number of words increased by 42%. We can see that in both questions the technology vocabulary of the student teachers increased.

Using the Wordle to present the frequencies of the use of words

The Wordle is a tool that presents the frequencies of words in graphical presentation. In this research we used Wordle to present the frequencies of the words used for each question (question 1 in Fig 1 and question 2 in fig 2).

Pre

Mid

Post

Fig. 1. Answers to Question 1 (pre, mid and post)

Fig 1 shows that for the 1st question "What is technology?" in pre-test the student teachers used words such as: computers, needs, development, smartphone and products. In the middle of the course they used: needs, products, making, solutions and even problem solving appeared. In the post-test they used words such as: making, improvements, problem-solving, planning, solutions and creativity. We can see that the use of technology terms and technology processes increased during the seminar.

The student teachers' answers to question 2; "How would you integrate technology into the daily life of the kindergarten?" is presented in Wordle in fig. 2.

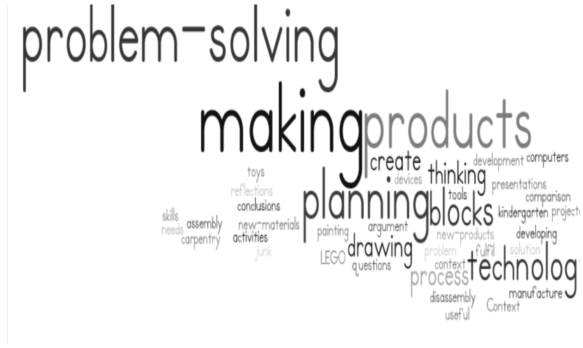
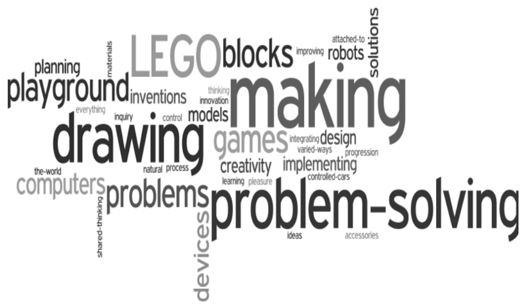
Pre	Mid	Post
		

Fig. 2. Answers to Question 2

This figure show that in the pre-test student teachers' thought that teaching technology is about computers, presentations, experience, computer games and movies. At the mid-point of the year they thought that it meant: problem-solving, making, products and planning. At the end of the year the student teachers thought that teaching technology means mostly: making, LEGO, drawing and problem solving.

The Wordle gave us a picture of the attitudes and perceptions of the student teachers as represented by their use of technology terminology and the changes along the course. But it presents the words in a size relative to the frequency of use in the same measurement it does not enable comparison between the words used.

Using Excel for compare the words used

An excel file with all the frequencies of the words used in the responses of the two questions, three times during the seminar is cumbersome and too detailed to give a clear picture. It does reflect interesting findings. For example: The term problem-solving appears only after one semester of learning and the use of it increases after the second semester in both questions. Additionally, the word "need" was used frequently in the beginning and decreased over the time span of the course. The word "computer" appeared consistently throughout the year, but it decreased in frequency over the year.

Using Mitcham categories

All the words in the responses were sorted into four Mitcham (1994) categories: 1) Artifact; 2) Knowledge; 3) Processes and 4) volitions. The frequency of the words used in each category, in the two questions three times along the process is presented in tables 2 and 3.

Table 2. Change in the Use of Words in Question 1

	Pre	Mid	Post
Artifacts	.27	.16	.18
Knowledge	.19	.06	.11
Processes	.29	.43	.49
Volitions	.25	.35	.22

Table 2 illustrates that prior to the course the students used almost the same amount of words in each category (around .25) with the exception of the knowledge category, which was lower. Over the course of the learning process we saw the following changes: the use of words that describe technology as Artifact decreased (.27 to .16 and to .18). The use of Knowledge words decreased too (.19, .06 and .11). In the Processes words we saw a large increase (from .29 to .43 and .49). The use of Volition words increased in the middle and decreased in the post-test to a level below the starting point

Table 3. Changing in the Use of Words in Question 2

	Pre	mid	Post
Artifacts	.58	.29	.28
Knowledge	.08	.11	.04
Processes	.23	.54	.55
Volitions	.10	.06	.13

Table 3 illustrates that in the beginning the student teachers thought mainly about technology as Artifacts (.58) a quarter of the words show Processes (.23) and only few used the Knowledge and the Volitions words (.08 and .10). At the mid-point more than half of the words describe Processes (.54) and more than quarter are the Artifact (.29). The knowledge and the Volition words decrease (.11 and .06). The post-test results present the same picture with only small differences in the numbers.

Findings summary

During a one year course of study and upon the conclusion of the course, student teachers used more words to describe and define technology and to explain how they will teach technology. Therefore indicating they increased their technology vocabulary.

Prior to the course the student teachers used the words "computers" and other objects. During the learning process they used an increasing number of words that describe problem solving and creativity.

From the start until the end of the course there was an increase in the use of words related to processes and decrease of the usage of words related to objects.

Discussion

The small sample size of this research study prohibits drawing definitive conclusions related to other pre-service teacher training classes. But, we can say that even a single course about technology education, over four years of studies, could create changes in perceptions and attitudes towards technology. This change in perception is proven by the increase of the use of technology vocabulary over the year long course, and the increase of the number of words related to processes.

The increasing number of processing words during the course could be explained also by the method in the kindergarten. As the student teachers understood that technology issues are integrated in the kindergarten culture it stimulated thinking and making processes (Mioduser, 2009) illustrated by the fact that the student teachers used more processes' words.

While student teachers experienced the integration of **theory** and **practice** they became **technology literate** and with that developed positive attitude towards technology and technology education (Koski & de Vries, 2011). The theory in this course means: a) learning about what technology is; b) what technology education is; c) what technology education in the kindergarten is which included d) the 6's strands. It was studied most of the time by experience it, through flipped classroom. Practice in this course means: a) experience: design; b) using systems and redesign them; c) explore and understand different control systems; d) using notations and f) exploring the artificial world (Mioduser, Levy, Kuperman, & Rudolf, 2008; Mioduser, 2009). The technology literacy presented by their ability to use technology vocabulary at the end of the course.

The kindergarten student teachers entered the Beit Berl course with a variety of views and preconceptions about technology. But, most of them thought of technology in manner consistent with what is found in other research studies for different age group students (Forret, Edwards & Lockley, 2013; Chikasanda, Williams, Otrel-Cass, & Jones, 2011; Baskette, & Frantz, 2013). In short; that technology is about computers and how to apply them in kindergarten life. As a result of their learning process during the 1st semester and even more after beginning their own research in the kindergarten; their conception, views and understanding of technology and especially technology education in the kindergarten was dramatically changed. This is illustrated by their use of the words: problem solving, design, creativity, making, drawing etc. as it was found in other researches (Forret, Edwards & Lockley, 2013; Baskette, & Frantz, 2013).

However, there is more that can be done to increase all aspects of technological literacy. Student teachers must develop the technology content knowledge, the pedagogical content knowledge and the attitudes and values as they had done during the course (Rohaan,Taconis, & Jochems 2012; McRobbie, Ginns, & Stein, 2000; McGlashan & Wells, 2012; Koski & de Vries, 2011).

Student teachers used more words in the post-test that described technology as processes and objects because they now, understood that the most appropriate way to implement technology into the kindergarten culture and with children of this age is through processes and objects.

There is significant demand for this course in the curriculum. We are optimistic that the results of this study are an indication that improvement in technological literacy can be achieved through a one-year technology course for kindergarten student teachers.

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Education for sustainable development within textile technology: a case study of two schools

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Abstract

Education for sustainable development (ESD) is an international theme for the United Nations Educational, Scientific and Cultural Organization (UNESCO). It is also a key part of the National curriculum for design and technology (D&T) in England. Textile recycling projects are a popular example of sustainable education within secondary (11-18) D&T curriculum, across the East Midlands.

However, at the last Pupils Attitudes to Technology conference (PATT27) von Mengerson (2013b) criticised the limitations of textile recycling projects and posed the need for further enhancement (p. 356). This echoed comments made by Stables (2008) who called for a need to address pupils' superficial awareness of environmental issues and Wilkinson's (2013) argument that sustainable curriculum should be enhanced through greater criticality.

This paper reports on a small-scale case study designed to shine a light on year 9 (13-14 yr.) education for sustainable development, evaluating current schemes of work (SOW) and pupils' perceptions towards ESD. As part of this research the aim was to provide guidance to enhance the critical aspect of ESD within future textile technology curriculum.

The case study is part of a collaborative action research project between a teacher educator, working in a UK University, and a secondary D&T teacher, working at a University partnership school. Findings from the case study have already been used to plan interventions and new curriculum for both trainee teachers and year 9 pupils.

The paper concludes that SOW need to provide a more varied educational experience of recycled textiles linked to the knowledge, concepts and skills associated with reprocessed materials and to draw on the pupils' culture of clothes swapping.

Keywords

Education for sustainable development (ESD), recycled fashion, schemes of work and pupil perspectives

Introduction

Sustainability became part of the design and technology curriculum in England, in 2005 (National STEM Centre, 2009) and it continues to be in the new National Curriculum (Department for Education, 2013). Internationally education for sustainable development (ESD) is a theme of UNESCO's 'Education for the 21st Century' (UNESCO, 2014). In this study we consider how this significant topic is played out in secondary schools being mindful of Stables (2008) work that identified pupils' superficial awareness of environmental issues and the need to change attitudes towards environmentalism within a school context.

The School of Education at an English university in the East Midlands was allocated in-house 'Green Impact' funding to set up small-scale research projects between initial teacher education (ITE) academics and partnership schools. The two researchers involved in this project have experience of introducing D&T sustainable development activities primarily using textiles. The most common form this takes in schools is as a textile recycling project, which, we have seen motivate pupils in relation to the concept of recycling design.

For this reason, we have approached this small-scale research project with the aim of shinning a light on current Year 9 ESD within a textile technology context, at two local partnership schools. We will do this by answering the research questions: (1) what does, ESD within Year 9 textile curriculum look like at two schools? and (2) how do the Year 9 pupils perceive sustainable development (SD) across both schools.

Literature review – Sustainable design curriculum

What does ESD look like within the D&T curriculum? We started off by looking at the current literature. To do this successfully we decided we had to review the literature in order to:

1. explore current practices and messages in other countries and subjects in order to identify significant tension related to ESD within the D&T curriculum, and

2. examine key resources currently used by D&T teachers when teaching about sustainability.

The new curriculum required pupils to be taught:

1. to be critical of the impact of products on daily life and the wider world;

2. to understand the impact of design and technology developments, on individuals, society and the environment; and

3. about the responsibilities of designers, engineers and technologists.

As has already been commented this has been a focus of the previous curriculum yet Stables (2008) and Hardy and Barlex (2013) argue it is rarely seen in schools, is superficial and a 'ritualized treatment of the 6Rs' (p. 216). Petrina (2000) proposes a D&T curriculum that includes knowledge and understanding of "resource streams" and " wakes", developing responsible designers that are aware of the cost of our ecological footprint (p. 229).

Specifically within the teaching of textile design, Fletcher (2013), argues that design education must address the issues of design for obsolescence that appears to have been built into the culture (p.140). However, as Petrina (2000) suggests the predominant pedagogy in D&T is for creating more stuff, in contradiction to the new curriculum's content. This is not unique to England and von Mengerson (2013b) writes about the popularity of recycled textile projects within the Australian curriculum, which she feels is limited and could be enhanced through skills associated with repair.

Wilkinson (2013) is troubled by her findings from a study of the Ontario school curriculum and revealing a "prevailing ideological discourse of neoliberalism that continues to prioritize values of individualism and economic competiveness" (p. 503) and calls for a more critical education. Her conclusion is that teachers need to "prepare technologically literate citizens" (p. 504). Walshe (2008) supports Wilkinson's argument and suggests that "teachers consider spending time in lessons not only understanding the complexity of sustainability, but encouraging students to make more direct links to their own lives, perhaps thereby encompassing a more political, 'who decides?' dimension to sustainable development" (p. 555). However, this can be difficult for D&T teachers and von Mengerson (2013a) argues that curriculum need to be enhanced.

There is a similar situation in geography reported by Walshe (2008) who identified that pupil's did not "explicitly consider the political aspect of sustainability" (p. 552). She also identified that pupils need to see the relevance of sustainability "for their life" (p. 553) and an awareness that sustainability was about things "lasting into the future rather than considering the possibility of changing or improving futures" (p. 554).

Von Mengerson (2013a) stresses the need "to continue clarifying sub-themes that argument the term 'sustainability'" (p. 344). This leads us to look at the resources available to help teachers with ESD. Practical Action, a non-governmental organisation, was awarded European development funding to create a framework for use in the classroom. A working group was formed in 2006 with partners from Loughborough University and the Centre for Alternative Technology. The group produced the 6Rs as "an approach to help students think about sustainability" (Practical Action, 2014) and UK examination boards adopted these in 2007. The 6Rs are:

RECYCLE: Reprocess a material or product and make something else.

REUSE: Use a product to make something else with all or parts of it.
REDUCE: Cut down the amount of material and energy you use as much as you can.
REFUSE: Don't use a material or buy a product if you don't need it or if it's bad for people or the environment.
RETHINK: Do we make too many products? Design in a way that considers people and the environment.
REPAIR: When a product breaks down or doesn't work properly, fix it.

(Practical Action, 2014)

This resource is the most common approach seen in schools and other resources are rarely used. A relatively new resource from the Ellen MacArthur Foundation provides case studies and resources relating to the circular economy (Ellen Macarthur Foundation, 2012), however, neither of the authors has seen these in use.

Methodology

Within this research we used a case study methodology to explore sustainable textile design within two UK schools. Cohen et al. (2011) describe case study research, as an investigation that reports on "real life, complex, dynamic and unfolding interactions of events, human relationships and other factors in a unique instance" (p. 289).

The research followed British Educational Research Association (BERA) guidelines for 2011 and met with the authors' University ethical clearance procedures, which included participant anonymity and data protection.

In order to explore sustainable textile design within two local partnership schools, we used two sets of data: (1) schemes of work (from both schools) and (2) focus group interviews (used with 5 pupils in each school). These are detailed below:

(1) Schemes of work. Teacher's produce schemes of work (SOW) that plan out what they will teach over the course of several weeks. They also outline lesson-by-lesson subject content. Both schools' provided SOW for their planned recycled textiles project during the teaching year 2013-2014. The SOW had been written using the National Curriculum 2006.

(2) Focus group interviews (Cohen et al., 2011). We conducted two semi-structured focus group interviews with Year 9 pupils, at both schools. We asked the pupils the following questions: (1) Did they enjoy learning about SD in textiles? (2) Do they think designers need to consider SD within textiles? and (3) What do pupils do with their clothes after they don't wear them anymore?

Due to the nature of the focus group, we do need to be mindful that "some participants may dominate the group and their behaviour may lead to a false sense of consensus" (Wilson, 2012).

Data analysis

We discussed earlier about the adoption of the Practical Action 6Rs, by D&T teachers working in the East Midlands. As early career researchers, with limited experience of coding, we decided to use a deductive method (Miles, Huberman, & Saldana, 2013) and chose to use the 6Rs as code themes for data analysis.

Findings

This section explores some of the results from the two SOW from School A and B and then combines this information with findings from the two interviews.

Schemes of work

Both SOW provided evidence of the 6Rs: rethink, reuse and refuse. However, only SOW A contained content linked to recycle and SOW B contained content about reduce. Neither school mentioned repair within the SOW.

The two SOW encourage pupils to rethink through the need to "understand the environmental impact of the products they design" (School A) and "the importance of designing and selling products that demonstrate environmental concerns" (School B).

These statements reflect the aims of the previous National Curriculum and potentially allow pupils to "design in a way that considers people and the environment" (Practical Action, 2014). However, as both SOW lead to the making of new products the aspect of rethink: "Do we make too many products?" (Practical Action, 2014) is not considered.

School A's SOW refers several times to developing pupil's skills and confidence in the "use of recycled materials". However, there is no mention within the lesson-by-lesson content of reprocessed materials (see Practical Action 6Rs definition).

Focus group interviews

The Year 9 focus groups evidenced awareness of all 6Rs. All 10 pupils (School A: A-E and School B: F-J) made reference to aspects of rethink and the majority of pupils discussed refuse and reduce. There were fewer mentions of repair, reuse and recycle.

At the start of the interview we asked the Year 9 pupils if they enjoyed learning about SD in textiles? In School A pupils enjoyed working with recycled materials, which they described as "interesting" (Pupil C), "different" (Pupil C, D and E) and "imaginative" (Pupil E). Pupils from School B struggled with the word sustainable. They didn't know what the word meant, and so the researchers explained what the word meant and the group decided to use the word environmental. During a conversation about environmental issues, pupils expressed the desire to learn about environmental issues in "more depth" (Pupil G) and find out about "the United Kingdom and what's happening round here" (Student F) as opposed to global environmental issues.

When asked if they think that designers need to consider SD within textiles, the pupils felt that designers have a duty to look after the end user and consider the environment. Pupil F talks about products that:

> like are more comfortable for other people, not just yourself? Some people wear things that they like, but other people may not like it. So you've got to try and make it blend in with how other people feel comfortable in clothes so it would be better for the population and the environment.

Pupil C talks about:

> Well, if it's more sustainable and using more environmentally friendly materials then obviously you're going to feel better with the outcome because you've used materials and you haven't just thought about what you want but thought about what's better for the environment and what's going to be better for overall.

Pupils from both groups identify the benefit of using sustainable fabrics and fabrics that are "better for the environment" (Pupil G) when designing. Pupil D talks about textile materials that are: "stronger" and Pupil C considers how:

> It's important to know how things are made and why it's important not to just use any materials and that you should think about what they're using to get the best outcome.

No pupils mention alternatives to creating products or how they judge the sustainability of a textile material. Pupils at school B discuss the different energy sources taught in Geography and how D&T can help them to use this when designing products.

When asked what they did with their own clothes after they stopped wearing them, the pupils discussed a variety of outcomes. These included: passing on clothes, hording clothes and mending clothes.

Nearly all the pupils talked about how they didn't throw clothing away, but passed clothes on to family and friends (Pupil A, D, E, and F); or gave to local charity shops (Pupil B and G); or sold via car boot sales (Pupil D). Pupil F talked about how:

> I usually - it sounds a bit daft, but usually my cousin, she's nine, but she's really tall, just like me. I pass my clothes onto her, because my clothes are still in good condition, I look after what I've got. So because my cousin's tall and skinny compared to me, I pass my clothes onto her. So when she grows up and gets bigger she can wear what I've given her, or if it's too small for her or way too big for her, I do take it to the charity shop because my uncle and my nan are doing voluntary work at a charity shop, so they take it down for me, sort of thing.

This same pupil also talked about using charity shops:

> I have, I make dyed T-shirts usually and I did buy a plain white T-shirt from the charity shop. It was a V-neck T-shirt, it was a good price, it was my size. I already had the dye and

everything to make it and then I do go around and wear it. There's nothing wrong with it, it's been washed, it's been cleaned, it's been dried, (and) so I don't see what's the problem with it. People look at it and think you got that from the charity shop, that's disgusting, you're a tramp, sort of thing. I'm like I'm not a tramp really, it's been washed, it's been cleaned, (and) you can't really say anything bad about it.

Two of the pupils spoke about how their clothes "just stay there (in the wardrobe)" (Pupil D). When the researchers talked about throwing clothes away, one pupil commented that

I think that's quite selfish actually because if you just throw them in the bin then all of the time and money and hassle to make them has just disappeared, because if you don't want it anymore then you can pass it onto someone or give it to a charity shop or someone who needs it. Not just throw all the energy away (Pupil B).

When the subject got onto mending clothes, Pupil B talked about how her "mum normally sews them back up again until I've finally decided that I can't physically wear them anymore" and Pupil E contemplated that he might mend a garment:

Depending on the size – say there was a hole in a shirt – depending on the size of a hole in the shirt I would mend it but it depends how big it is.

One pupil talked about getting their "shoes repaired once" (Pupil F) and Pupil J discussed how:

Shoes like mine are – trainer sort of shoes can't be heeled then. So I think – because you can get good ones from Clarks and stuff but if you get - shoes that you can get re-heeled are normally a lot more expensive than ones you can't.

Analysis and discussion

On examination of the SOW and focus group interviews it is clear that the pupils have a wider experience of SD than the planned SOW might suggest. We will look at both sets of data collected, against each 6R to draw out points for discussion.

(1) Recycle. Practical Action (2014) defines 'recycle' as a reprocessed material or product. For example Polartec® is a textile material reprocessed from plastic bottle waste. The SOW at School A does not include content or resources about reprocessed textile materials and there appears to be a misunderstanding about the definition of the word (von Mengersen, 2013a). An explanation for this might be, that the SOW, refer pupils to use inspiration from existing products made by Gary Harvey. Gary Harvey is a contemporary fashion designer, who uses vintage old clothing to make couture garments. The website calls his garments "Re-cycled 'Eco-Couture' Collections" (Harvey, 2014). Therefore, pupils are experiencing 'recycle' as a concept linked to reusing waste textiles. Without the experience, of learning about reprocessed materials, the pupils understanding of 'recycle' is limited.

(2) Rethink. The SOW made no mention of the rethink question: do we make too many products? This reflects Wilkinson's (2013) findings in Ontario that call for a more critical education. A point of interest, however, is the use of fair trade fashion company 'People Tree' (School A) as an example of existing products. This resource has the potential to support pupils in seeing different business models of consumption (Fletcher, 2013; Petrina, 2000).

(3) Reuse. The pupils in School A referred to the reuse of an existing product (in this case, textile waste) as a recycled material (see discussion above about the misunderstanding within the SOW). They enjoyed reusing textile waste to make their new products. One of the pupils found the reuse of textile waste "interesting" because they got to look for waste textiles within their homes, making connection with their lives (Walshe, 2008). SOW may enable the connection with the pupil's home life, through the reuse of textile waste, however, it feels like there is a missed opportunity around curriculum content linked to the pupils' culture of passing on unwanted clothes. Teachers might need to recognise their pupils' sustainable behaviour within planned curriculum.

(4) Reduce and (5) Refuse. Pupils are aware of a need to make sustainable choices about material. However, their knowledge of 'how' to make sustainable choices about materials and processes appears superficial based on the pupils' lack of understanding about the ecological footprint needed to make judgments about the sustainable credentials of chosen textile materials. This supports previous findings from Stables (2008) and Petrina (2000).

(6) Repair. The SOW includes no mention of what to do when a product breaks down or does not work properly, and how pupils might fix it. This doesn't acknowledge the responsibility of the designer (Petrina, 2000), or address the issue of design for obsolescence (Fletcher, 2013). The pupils demonstrated

some awareness of shoe repair and mending, however, this may have been linked to the socio-economic background of the pupils and would require further investigation to decide if von Mengerson's (2013b) theory of ESD enhancement through skills associated with repair is achievable.

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Designing an e-portfolio environment for assessment of a collaborative technology project

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Abstract

E-portfolios can be used to record both the development process and the outcomes of technology design projects. Preparation of an appropriate e-portfolio environment, including the choice and set-up of the software, provision of both formal and informal support, and alignment with the assessment task, all require deliberate attention to design principles. This paper draws from the literature to identify important design considerations for an e-portfolio environment being used in an investigation of the feasibility of using e-portfolios for assessing individual performance in a collaborative technology project. It explores similar e-portfolio development projects and theoretical positions to develop a set of specifications and key considerations as a framework for the current project and as a contribution to ongoing discussions in this area.

Keywords

E-portfolio design, collaboration, assessment

Introduction

An investigation into the assessment of individual performance in a group technology project required the development of an appropriately configured e-portfolio environment. The term e-portfolio refers to an electronic portfolio in which the artefacts presented are in digital form. The concept of an e-portfolio environment allows consideration of the e-portfolio itself, the context in which it is to be used, and the support materials provided. In identifying the important considerations and specifications for the design of the e-portfolio environment, it seemed likely that such information may also be useful to other people working with e-portfolios, hence this paper.

Background

The context for the e-portfolio environment design discussed here is a group design project in a compulsory first-year technology education paper taught as part of a primary undergraduate initial teacher education degree. Students work in self-selected small groups (3-4 people) to develop a response to a design problem that they have identified. The project continues through the first 6 weeks of the 12-week paper and allows students to demonstrate their growing understanding of technology and technological practice which is the learning focus of the first part of the paper. Each group submits a record of their project in the form of a portfolio. The portfolio has previously been submitted in paper form but recent developments in available software have prompted an investigation into moving from paper to digital portfolios.

Methodology

Presented here is a brief review of the relevant literature leading to a proposed set of guidelines for e-portfolio environment design. The literature is primarily from the technology education and Computer Supported Collaborative Learning (CSCL) communities. The inherently contextualised nature of the design task and of the setting mean that while some aspects of the specifications will apply across a broad range of e-portfolio environments, much of what is discussed is specific to the situation described above.

Literature review

Effective use of e-portfolios depends on resolving a number of specific issues related to the portfolio concept and to the digital nature of the environment. This section explores theoretical issues before describing two examples from the literature.

Philosophically, this research is informed by a socio-cultural view of learning which suggests that learning involves interaction with other people and their ideas through mediating tools such as language, and that it is influenced by the cultural setting within which it takes place (Wertsch, 1998). This is particularly useful in making sense of a group learning situation since the effective functioning of a group requires social interaction and takes place within a particular cultural setting. A socio-cultural view has important implications for e-portfolio design as it suggests an emphasis on supporting social interaction, joint contribution, and flexibility to allow the group to make decisions about how best to present their performance on the task.

Capability and performance

Assessment of capability in technology education requires attention to aspects of student performance that are not well captured in traditional paper and pen based assessment events (Kimbell & Stables, 2009). Portfolios have been used as a way of better capturing a broad range of elements of performance. E-portfolios extend the portfolio concept by enabling the inclusion of a broader range of forms of digital evidence including images, video and sound files, weblinks, and files from specific software packages in a range of formats (Williams & Newhouse, 2013).

In technology education an e-portfolio needs to support the presentation of evidence that clearly demonstrates what is regarded as capability. Kimbell and Stables (2008) view capability as “the power to produce change and improvement in the made world” and see imaging and modelling as central to its development. Capability requires competence, skill, and knowledge but these are not sufficient. It also requires the ability to make good decisions and to bring these together in a purposeful way.

Digital technologies

Digital technologies include any means of generating, collecting, storing, or presenting information in a digital form. They are now readily available to most people through mobile devices such as smartphones, tablets and laptop computers, and through the internet. They offer a much wider range of ways of representing technological practice with respect to both process and outcome (Williams & Newhouse, 2013). They also allow much more scope for the learner to take responsibility for the collection and presentation of evidence of their learning.

The e-portfolio is a way of collecting, selecting, reflecting and presenting digital information and takes advantage of the greater range of formats offered. Because it places an emphasis on the selection of appropriate material and on reflective commentary, the learner becomes more actively involved in the assessment process when e-portfolios are used for assessment (Barrett, 2007).

Assessment

Assessment involves the collection and evaluation of evidence generated by learners and is used both to inform further teaching and learning and to indicate current levels of performance or competence (Brown, 2008). Where it allows comparison between two instances, it can be used to comment on learning. The primary focus of assessment is the student and their learning and there is increasing recognition of the benefits of involving the student in assessment decision-making (Bain, 2012; Boud, 2007).

Assessment of performance in technology is characterised by its focus on process as well as outcome, and by its highly contextual nature. There are some significant features of learning in technology education that affect its assessment. According to Kimbell and Stables (2008) these include:

- a focus on learning in issues-rich, task-centred activities in which the learner is an active participant;
- recognising that learners will not necessarily each be learning the same things and may achieve the same result in different ways;
- viewing knowledge and skills as best learnt when the learner needs to know them and to the level needed to address the problem rather than as a defined corpus that can be generically associated with any given activity.

Procedural learning is an important part of technology education and evidence of this needs to be collected over time. Such evidence is often collated in the form of a portfolio (Newhouse, 2013). This enables the learner to take a more active role in the selection and presentation of appropriate evidence and supports a greater focus on the individual. Recent research into the use of digital portfolios (e.g. Kimbell, 2012; Williams, 2012) has highlighted the potential to broaden the forms of evidence that can be used to demonstrate developing capability.

Collaboration

Collaboration has been identified as a key skill in research into what people need for 21st century living and employment (Binkley et al., 2012; Ministry of Education, 2007). The Programme for International Student Assessment (PISA) framework for collaborative problem-solving (OECD, 2013) defines collaboration as *"the capacity of an individual to effectively engage in a process whereby two or more agents attempt to solve a problem by sharing the understanding and effort required to come to a solution and pooling their knowledge, skills, and efforts to reach that solution*." Any consideration of collaboration therefore needs to explore the nature of the group, the nature of the activity in which they are engaged, and the nature of the interactions that contribute to completion of the activity (Dillenbourg, 1999). The concept of collaboration is process oriented even though the purpose is to achieve the agreed outcome.

In recent years a growing interest in the ways in which information technologies can support collaboration has developed. Several themes emerge from this including recognition of the diversity of skills and background of participants and the need for people to develop collaborative skills as well as those needed to achieve intended cognitive outcomes (Dawes & Sams, 2004; Fransen, Weinberger, & Kirschner, 2013; Montequín, Fernández, Balsera, & Nieto, 2013; Napier & Johnson, 2007). Some of this has come from analysis of failure of collaborative projects in education (Baker, Bernard, & Dumez-Féroc, 2012; Kapur & Kinzer, 2009; Pathak, Kim, Jacobson, & Zhang, 2011). There has also been a focus on the role of design of the environment, task, and supporting tools in regulating both the process and outcomes of collaboration (Fischer, Kollar, Stegmann, & Wecker, 2013; Strijbos, Martens, & Jochems, 2004).

Technological practice is commonly collaborative. McCormick (2004) noted a lack of research in technology education into collaborative work on joint products and suggested that the use of digital technologies offers potential for both collaborating to learn and learning to collaborate in the context of design problems. Since then, there have been significant developments in digital technologies, particularly associated with mobile devices. However, few studies e.g. (Hong, Yu, & Chen, 2011) have focused on collaborative work. Most research into the use of digital technologies in design problems tends to focus on individual activity rather than collaborative activity e.g. (Kimbell, 2012; Williams, 2012). Although possibilities for collaboration in technology education have been identified (Hennessy & Murphy, 1999), they haven't been explored with respect to the use of digital technologies.

Examples

Project e-scape

e-scape is an exam management system designed to support the assessment of performance in design capability in the United Kingdom (Kimbell, 2012). It is essentially an e-portfolio that facilitates the collection and presentation of diverse forms of digital evidence in a limited timeframe. The collection of evidence is to some extent scripted through the use of specified templates. The software was aimed at supporting assessment of individual performance in a high stakes examination setting.

While there is considerable scope for inclusion of a broader range of evidence of process, student performance is constrained through use of templates and e-portfolio structure, and through time limitations. The assessment process uses the comparative pairs approach which has been shown to support more holistic judgements and to be reliable (Pollitt, 2011).

Digital representations project

This project in Western Australia (Williams & Newhouse, 2013) explored the use of digital technologies to support more authentic forms of assessment in high-stakes qualifications assessment in four areas of the curriculum that have a strong practical performance component. In the Engineering Studies example, the e-scape system developed in the United Kingdom (Kimbell, 2012) was used.

Implications for e-portfolio design

Drawing on the points raised above, the following would need to be consdiered in developing an appropriate e-portfolio environment for a group design task:

- The way collaboration is supported needs to reflect both how the e-portfolio is used and what it is able to represent
- The potential benefits offered by digital technologies should be integrated into the system
- Technological capability should be evident through both process and product
- Students should have input into assessment with respect to what is represented and how.
- Assessment needs to be authentic, reliable and valid

The e-portfolio environment

The development of a digital environment for a specific purpose can usefully be regarded as a design problem, enabling the resources and approaches of innovative design to be applied as demonstrated in a number of recent studies (An, 2013; Chen & Teng, 2011; Kirschner, Strijbos, Kreijns, & Beers, 2004; So, Seah, & Toh-Heng, 2010; Wang, 2009; Zhang, Olfman, & Ractham, 2007). The design required is complex as it needs to address a broad range of intersecting areas including the technical aspects of the technologies involved, the nature of the task(s) students are to be engaged in, and the support materials and processes that guide students in their involvement. Where engagement in the task itself requires knowledge and skills other than those the task seeks to develop or assess, then these need to also be explicitly addressed in the supporting materials and processes.

Williams and Newhouse (2013) identified a framework of four specific dimensions that would need to be satisfied in order for the use of digital technologies to be effective in assessment. This was based on the proof of concept criteria used by Kimbell (2012) in his initial exploration of the feasibility of project e-scape (described above). The four dimensions identified were manageability, technical, functional, and pedagogical. They are used here as a way of framing the development of an e-portfolio environment.

A set of guidelines has been developed as a series of key questions using the four dimensions as an organising framework. They are underpinned by the theoretical framework discussed earlier and derive from examples presented in the literature, discussions with colleagues, and consideration of my context at the time. They are not definitive but are intended as a basis for ongoing discussion and refinement.

Technical dimension

The technical dimension deals with issues about the practical implementation of the software. It addresses how the software works, where it is based, and how it is supported. It also considers the administration of student accounts and access.

Aspect	**Questions**
Server location	Will the server be located internally or externally? How many accounts can the system cope with? How secure is the system?
Accounts	How are accounts set up? How are group accounts set up?
Access	Who controls access? Will the software be continuously accessible? Is it web-based or PC-based? Does the system allow several people from the same group to access the group page simultaneously? How do students access each other's files? Can the site be accessed on multiple devices?
Storage	Is there enough storage space for what we need? How is file quality maintained?
Support	How good is the technical support within the institution?
Flexibility	How much scope is there to adapt the software to suit our needs? How much scope is there for student creativity in designing their group portfolio?

Table 1. Design questions for the technical dimension

Functional dimension

The functional dimension relates to the way the e-portfolio environment supports the intended purpose for which it is being used and so is primarily concerned with how the task itself is facilitated by the software and supporting materials.

Aspect	Questions
Nature of evidence	What evidence needs to be able to be provided?
Source of evidence	Where can evidence come from?
Task clarity	How will students know what is expected of them?
Authenticity	How will authenticity be assured?
Content decisions	How will content decisions be made and who will make them?

Table 2. Design questions for the functional dimension

Pedagogical dimension

The pedagogical dimension provides a way of considering they way in which the e-portfolio environment enacts the theoretical ideas about teaching, learning, and assessment, particularly in technology education, that underpin the task and its intended purpose.

Aspect	Questions
Socio-cultural view of learning	How does the e-portfolio environment support a socio-cultural view of learning?
Peer feedback	Are peer and teacher feedback supported?
Reflection supported	How is reflection supported?
Necessary learning supported	How will the necessary learning be supported?

Table 3. Design questions for the pedagogical dimension

Manageability dimension

Manageability addresses issues of how people might use the environment to complete the task. It considers such things as workload, timing, ease of use, and fitness for purpose.

Aspect	Questions
Student workload	Will this make more demands on student time than the current task?
Learning to use my portfolio	How long will it take students to learn to use myportfolio? What support will be provided for students to learn to work with myportfolio?
Staff workload	Will the marking take longer than it currently does? How long will it take for staff to learn to work with myportfolio?
Ease of marking	Does the group e-portfolio provide all the necessary evidence for marking?

Table 4. Design questions for the manageability dimension

Conclusions

The design of an effective e-portfolio environment is clearly complex and involves a number of interacting decisions. It is not sufficient to simply adopt a piece of software and expect it to work. The design process is context dependent as the constraints and affordances are unique to each situation. It is also iterative. Decisions about e-portfolio software and supporting materials depend on the answers to key questions but also influence some of the answers to those questions. Choices are governed by what best meets specified needs but is also moderated by considering how what is available can be tailored to what is required.

One of the main decisions is the choice of e-portfolio software which will be guided by institutional availability, how well it offers satisfactory answers to the questions, and the degree of customisation it affords. It is virtually impossible for one solution, even when custom built, to satisfy all requirements and so there will be an element of compromise. Consideration therefore needs to be given to the extent to which such compromise could be accepted before accepting or rejecting the software solution.

The tension between characteristics that are at times complementary and at times conflicting makes the design of effective e-portfolio environments challenging. The approach presented here using a series of questions is intended to provide a way to engage with the complex array of issues by highlighting key concerns and allowing them to be considered collectively. It is hoped that they will provide a basis for further discussion.

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The girls who succeed within higher technical education – why do they choose and who are they? Four profiles emerge through the use of cluster analysis

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Abstract

Every year in Sweden about 7500 students start on civil engineering programmes. About 25% are women. Previous research highlights success factors, such as strategies that help manage the transition from upper secondary school. One difficulty that arises is how female students in particular identify with the engineer role. This study focuses on the female students who succeed in civil engineering programmes in Sweden. Why do they choose? How do they succeed? By using the Bourdieu's theory and the concept of capital, the study aims to find out who the female civil engineering student seems to be. A questionnaire was constructed based on background aspects such as programme, age, earlier education, parents' educational level, parents' professions etc., but also based on aspects relating to the choice of programme, plans after taking the degree, statements about the students' interests and activities outside university, identification with the role of engineer and success factors. This web-based questionnaire was then sent out to all female students enrolled on civil engineering programmes during term 7, 2012 (about 1200 students). In total 411 students answered the questionnaire. The answers were analysed with SPSS. From the material it is possible to detect four different female student profiles: The Life-experiences-profile, The Engineer-capital-profile, the Educational-capital-profile and the Natural-science-capital-profile. There is a reproduction of traditional patterns. Children of educated people are provided with an obvious choice through the capital they possess. These active and successful forms of capital do not seem to come from earlier schooling, but instead to a greater degree from the student's home conditions. One implication is that compulsory schooling, must take more responsibility for making technology a subject that could be seen as relevant for girls with different social backgrounds, interests and lifestyles, if we really want more than 25-30% girls within higher technical education.

Keywords

Engineer capital, gender aspects in higher technical education, engineering students

Introduction

Every year in Sweden there are about 10,000-12,000 applications for about 6500-7700 Master of Engineering university places and about 50-55% of the students take their examinations. Evaluations show a higher completion rate for students with parents with a higher level of education (UKÄ, 2013). One explanation for the high level of dropouts is the problems that Swedish pupils seem to have with mathematics, according to politicians emphasising concerns over the PISA (2013) results.

About 25-30% of the students are female. In the 1990s, Staberg (1994) found that girls had negative experiences of technology education within lower secondary school and the same result recurs in evaluations in 2014 (Skolinspektionen, 2014) being viewed as one explanation of the low percentage of female engineering students.

A report from one of the technical universities in Sweden relating to students who choose to start their engineering education states that most important factors for their choice of technical education; are the interest in the specific course content, personal interest in technology and high expectations of a future career. Many of the new students say that they obtained their interest for and knowledge about natural science and technology not from school and formal education but instead from other sources such as home and friends (KTH, 2011).

Research shows that most young people actually like technology but do not see the professions of scientist or civil engineer as possible desirable careers. The students who see such a future for themselves seem to have more science capital within their families, such as science-related qualifications, knowledge, interest and contacts (ASPIRES, 2013). Kingdon (2013) finds that students in upper secondary schools on programmes preparing them for higher education have specific views of engineering courses and engineers. They state that it is important to be good at mathematics, technology and physics, to be intelligent, self-managing and autonomous, ambitious, industrious and motivated. They also stress that it is important to have the desire to be successful.

In Sweden there are political intentions to increase both the interest of students in civil engineering programmes and the completion rate (SGED, 2008). According to SOU 2010:28, this is a strategy to increase both the interest in technology and science and the number of recruits to technical universities by making changes to the current educational system, from preschool up to and including secondary school. In his study, Ahlbom (2013) found that the most important factors affecting engineering students' choices are an interest in technology, personal qualifications, influence from people outside school, expected salary and status. Both Ahlbom and SOU 2010:28 point out the important role that technology education plays in compulsory school, for example in developing an interest in technology. But the Skolinspektionen (2014) finds that merely having technology education is not sufficient. In particular, female students in lower secondary school find their technology education irrelevant and uninteresting.

One difficulty that occurs in research and explains dropouts is the issue of how a student identifies with the engineer role; students perceive science, technology, engineering and mathematics as "stable, rigid and fixed" and hence a narrow platform for developing desirable identities (Tolstrup Holmegaard *et al*., 2012). Research also shows that students who succeed in their civil engineering education have been able to achieve a kind of “engineering literacy” including ways of reading, writing, speaking, using models and tools, behaving, interacting, believing, displaying a particular world view etc. (Allie *et al*., 2009).

Female students seem to have concerns about the engineering role and, for example, adopt a "resistance" identity, asserting their difference from other females and “claimed” to be “more like boys” (Walker, 2001, p.86). Other examples are female students who express science and engineering aspirations as a possibility and who describe themselves as “not girly”, while they are described by teachers and parents as good, nice and focused on academic achievement (Archer *et al*., 2012).

Aim of the investigation and research questions

This study focuses on the female students who succeed in engineering programmes in Sweden. I am interested in why female students choose to become engineers, what has inspired them and how they identify with the engineering role. With such results it might be possible to understand how, when and in what way within the educational system young people could be inspired to choose higher education in technology.

The following research questions were formulated: Why do Swedish female students choose and how do they succeed in engineering programmes? Who are they?

Theoretical framework

Devine (2012) argues for using Pierre Bourdieu's theories (1996) as an approach to engineering education research. "His theories can provide a useful framework for further exploring the underlying reason that [...] factors occur in various students and why they affect subsequent performance" (Divine, 2012, p.2). By using Bourdieu's theory and the concept of capital, the study aims to find out who the female civil engineering student is. "Capital" in this context means different recourses and experiences (social, educational, economic etc.) in a person's life. Various capitals develop value both in the relationship between individuals in a social practice, such as different civil engineering programmes, and in relation to the overall power structure in society various capitals develops its value (Bourdieu, 2004). The study attempts to find the characteristics and attitudes that mean that the student fits in as a female student in engineering programme in Sweden; both how she makes choices and how she identifies herself within the role but also the female student's life: social background, lifestyles etc. All aspects combine to produce the basis of an analysis about what seems to emerge as "typical" and symbolic capitals (Bourdieu, 1984).

Methodology

A web-based questionnaire was constructed with a total of 148 statements based on background aspects such as programme, university, age, earlier education, parents' educational level, professions etc., but also based on aspects relating to the choice of programme, plans after taking the degree, identification with the role of engineer and success factors. The questionnaire was created within the theoretical framework and based on Bourdieu (1984) plus related studies and other studies based on questionnaires dealing with the same topic, such as the Norwegian project ViljeConValg, 2014.

This questionnaire was then sent out to *all* female students enrolled on engineering programmes in year 4 across Sweden in 2012; in total about 1200 students (80% were contacted via an e-mail including the link to the questionnaire, 20% via a paper letter presenting the link). In total 411 students answered the questionnaire.

The answers were analysed with SPSS both for descriptions and classification (using cluster analysis: hierarchical, Ward's method, Euclidean distance), the aim being to detect a variety of patterns within the material.

Within the cluster analysis, the clustering was based on answers to three specific statements/variables (whether they were inspired by parents working as engineers, inspired by parents who were not engineers and whether the topics on the courses were really interesting or not) and four clusters were created. This clustering is thereby partly in agreement with results from earlier research that show how parental education and occupations would play a role in Swedish students' choice of education (for example Broady et al., 2009). Using cluster analysis, the focus is on individuals and how the complexity created by different variables taken as a whole can describe the individuals' situation and characteristics. Individuals could be presented in different profile groups in which each profile has its own specific properties (Sjöquist *et a*l., 2010; Bergman *et a*l., 2003).

Results from the cluster analyses, four different student profiles

Student profile (1): *Life experiences group* includes 127 students with well-educated parents. More of these students have chosen biotechnology as their programme specialisation compared with the other profiles. These students are characterised by having made their choice after upper secondary school or after a period within higher education in some other programme. Slightly more of these students than the other profile groups have travelled for an extended period during a study break after upper secondary school and slightly fewer of them say that they were inspired by teachers in upper secondary school. To a large extent, compared to the other cluster profiles, these individuals emphasise that they want to do something good for society and humanity, but they do not consider the aim of graduating as an engineer, that the course suits them or that they seem to feel comfortable with their choice to be inspirational in succeeding in their studies.

A profile emerges here that identifies with an engineer role that has the opportunity to do something good for humanity, society and the environment. But the students still have doubts about whether the profession is actually the right one for them, even though they are aware of the range of possibilities within the engineer role and that these possibilities occur in different fields.

Student profile (2): *Engineer capital group* includes 59 students who specifically have parents who are engineers. More of these students have chosen technical physics as a programme specialisation. More of them have chosen a university with a good reputation and want to work as an engineer abroad. They have not been inspired by teachers or schoolwork in compulsory school and only a few of them have been inspired by teachers within upper secondary school; they have always thought that they would become an engineer and they have, for example, a facility for mathematics that has encouraged this intention. In comparison with other clusters, this group is characterised by wanting to take a course that provides jobs and a profession with many opportunities. Many of them have been supported within their studies by parents and siblings; having some fun alongside their studies has been a factor for success and they want to do something good in their professional life. They all appreciate the traditions at the university and consider that their studies are very demanding.

The profile identifies with an engineer role that provides many opportunities and possibilities to create benefits for society; the students simply consider "engineer" to be a good profession. Important strategies for succeeding with their studies are, for example, to be involved in a lot of social activities and to develop to be part of the "culture".

Student profile (3): *Educational capital group*, and includes 95 students who have parents who are not specifically engineers but who are also well-educated. More of this group have chosen industrial economics as a programme specialisation. They have always had a facility for mathematics and many of them decided to become an engineer after completing upper secondary school, although some of them made this choice early in upper secondary school. Slightly more of them interested in working as an engineer in the private sector in Sweden and have been inspired by friends who are engineers or engineering students but some of them also by teachers in compulsory school. Compared with the other clusters, these students are characterised by wanting a profession that provides jobs, and with many possibilities. They mention facility for mathematics as a success factor, they quickly got to grips with their studies and then found it easy to continue. They seem not to have time to read anything other than course literature.

This profile identifies with an engineer role that is successful within any kind of sector. This student is ambitious and performs well in her studies. She succeeds in her course by applying good study technique and great self-confidence in relation to education.

Student profile (4): *Natural science capital group*, includes 130 students. They specifically answer that they really enjoy and like the course objectives and content. Many of them have chosen biotechnology but also technical chemistry as specialisations. More of these students chose their field of study as early as lower secondary school. From early childhood they have always been interested in natural science and mathematics and more of them have siblings who are engineers. This group is characterised by people who really want to work as an engineer. They want to earn money, but they are not as concerned about doing good things for society and mankind or about working with environmental issues. They state that they found mathematics easy and that their choice has always felt entirely right. Being an engineer, according to these students, means being creative and coming up with things, and they want to solve problems and do research.

A profile emerges here of a student who within her studies is driven by a strong interest in natural science and a desire to work as an engineer or in any related field of science and technology; one who has always known that this is possible. She identifies with an engineer's role as a creative problem solver and a researcher.

Discussion

The female students who have success in engineering programmes are characterised by their possession of certain capital. They have a positive attitude to the profession of engineer and enjoy the typical traditions at the technical universities. They have found like-minded friends and seem to be aware that their aptitudes, especially for mathematics but also for natural science, give them success. They truly fit in and embrace the traditions in terms of both the educational and social aspects of their courses. They seem to value a traditional teaching context with lectures and classroom teaching. They select programmes such as Industrial Economics and Biotechnology, traditional choices for women in Sweden.

There is thus a reproduction of traditional patterns. Children of educated people are provided with an obvious choice through the capital they possess. These female students "fit in".

The culture and roles are thereby preserved. These active and successful forms of capital do not seem to come from earlier schooling systems, but instead to a greater degree from the student's home conditions. Earlier education may help to reinforce this capital, with students who already have suitable forms of capital as a result of their home background feeling even more reinforced.

Could it be interesting to interpret and describe this picture? A description of something we already know?

The results provide important confirmation of issues that have arisen in earlier research and in evaluation reports about how students with well-educated parents are over-represented within engineering programmes and how they also have a higher completion rate. Research also shows how much of an impact educational capital obtained from home conditions has on students' choices and performance. Furthermore, research focusing on female students within higher technical education has highlighted difficulties, especially with identification with the engineer role and the different strategies that emerge among female students on engineering programmes.

In this study, the four cluster profiles indicate explicit aspects beyond the statistics, such as views, experiences and strategies that seem to be fruitful in the specific field of civil engineering programmes in

Sweden. To some extent these are findings similar to those obtained from earlier research, but there are also some different results.

- **An interest in natural science from childhood and knowledge that such an interest could be used in a diversity of technical areas and thereby in professions, not merely connected to fun experiences at a science centre or short-lived activities and experiments within natural science and technology education.** Compulsory and upper secondary schools rarely provide examples of how course material relates to different professions and pathways through higher education. Such experience and knowledge is closely connected to parental education, employment and social networks.
- **Great self-confidence in mathematics throughout school and awareness of how mathematics can be a tool for pathways through higher education.** The view of mathematics currently being highlighted via reformers, schools and other actors in society about how important mathematics skills are, how difficult the subject is and how poorly Swedish pupils seem to perform, may tend to create both a rejection of and low confidence in mathematics. If a student has a background which has reinforced her mathematics skills and made visible how such skills are used and what skills are required within higher education, this will endow her with a larger amount of educational capital. The compulsory and upper secondary school systems rarely highlight the more concrete uses of mathematic skills and how they are useful and used in higher education and in professional practice.
- **A positive view of lectures and classroom teaching and an opinion developed throughout the whole educational system about how effective such teaching will be.** Educational capital like this is grounded within the student's involvement in earlier school years but will be established and reinforced by home conditions.
- **A positive view of the engineer role and an understanding that such a role has many faces.** Experience that leads to understanding of the fact that there are a wide range of possibilities within many of the different engineering professions and that an engineering education can be the pathway to something with many opportunities. An understanding that has been made visible and concretised of the diversity within engineer roles can be connected to a large amount of educational capital developed in relation to parents, siblings and social networks.
- **A view of higher technical education as a pathway to something "for me"**. Depending on interests and views, such pathways will provide the student with progress and experience, but higher education itself is necessarily not the goal. The student has the confidence to take this pathway on the basis of her own circumstances. A rational view of the programme, if required, could be provided to a greater extent by well-educated parents.

Conclusions and implications

One conclusion from the results is that, to a great extent, female students in higher technical education in Sweden represent a homogeneous group and that their interest and strategies for succeeding in higher education seem not have been established within lower years in school or stimulated by teachers there. Fruitful capital and successful strategies can instead be connected to social background and parental levels of education.

One implication is that compulsory schooling, especially the lower upper secondary level, must take more responsibility for making technology a subject that could be seen as relevant for girls with different social backgrounds, interests and lifestyles, if we really want more than 25-30% girls within higher technical education. It is likewise appropriate that teaching in primary schools and even in the natural science programme at upper secondary school level should reveal what it means to have a career as an engineer and how higher education within engineering can function and be successfully completed.

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Four teacher profiles within technology teaching

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Abstract

This study is focused on technology education within in the lower secondary school (junior high school) in Sweden. Current evaluations show that the relevance of the school subject of technology is perceived low by students. Moreover, it appears that technology teachers lack adequate competence within the subject and do not "possess" the knowledge related to technology for properly teaching this subject. Research has shown that how teachers understand their subject and how they relate to it affects how students interpret and appreciate the subject. This study aims to identify teachers' views of technology and their views toward teaching it. For analysis the research used Klasander's (2010) emphases used in teaching technology subject and DiGironimos (2011) dimensions of technology. A questionnaire was sent to 494 technology teachers with questions of methodology in teaching and definitions of technology. The analysis was done by cluster analysis combined with descriptive statistical analysis. Technology teachers were found to be a very homogeneous group, but clustering showed differences between teacher profiles. It was found many teachers could be categorized as Doer, Sufficient, Society-oriented and Flexible. However, research stresses the importance of societal connections and expression of civic responsibility in teaching. This should give the technology subject a higher relevance compared to what evaluations show. But technology teachers seem to not include ethical values, political positions, sustainable development, and historical aspects within the subject, which could be a reason why the technology subject is still perceived by students as irrelevant.

Keywords

Technology education, teachers' views, lower secondary school, cluster analysis

Introduction

The subject of technology is presented within the curriculum for compulsory schools in 2011 in Sweden and it is presented as a broad and multifaceted topic with a variety of instructional goals. The student developmental skills described in the syllabus are intended to give students the interest and knowledge to continue onto higher education with studies in technology. The subject of technology includes various technological areas which set high demands on skills for teaching it, particularly for technology teachers in years 7-9. The purpose of this study is to investigate the perceptions of teachers about technology and technology teaching among teachers who teach years 7-9.

Not all teachers who teach the subject of technology in years 7-9 have had specific training about the complex topics of technology or technology teaching. However, research shows that the students who have teachers with technology training will experience more diverse technology teaching and will better understand the goals and objectives of learning about technology (Mattsson, 2005). From being a practical workshop topic in the 1960s and 1970s, technology has become a subject with a wide-range of content in the current Swedish syllabus. How teachers choose to teach technology is therefore partly determined by when the teacher received their teacher training, together with both the extent of their knowledge of technology and other subjects they were taught.

Although the technology syllabus emphases both the purpose and core content of technology, studies show that students are taught differently depending on the teacher's view of the subject, and different teaching emphases are provided by different teachers (Klasander, 2010). The teachers' choices of content and ways of working reflect what teachers perceive and construe as “The Nature of Technology” (DiGironimo, 2011).

DiGironimo (2011) emphasizes that technology is created by people and is therefore – unlike science – influenced by human values that change over time, and political positions, as well as aspects relating to culture, gender, class, and ethnicity. Given such a broad approach, it seems clear that it is also important to examine the historical aspects of technology (Hansson, 2002). Reflection and evaluation are also characteristics of the subject of technology (de Vries, 2005; Pitt, 2006; 2011), which can create the view that the subject of technology is a "doing subject" (Mawson, 2007, 2010). DiGironimo (2011) identifies five dimensions which, when taken together, characterize the view of technology in. She asked teachers and students "What, in your opinion, is technology?" And she encoded their responses according to the framework. See Figure 1.

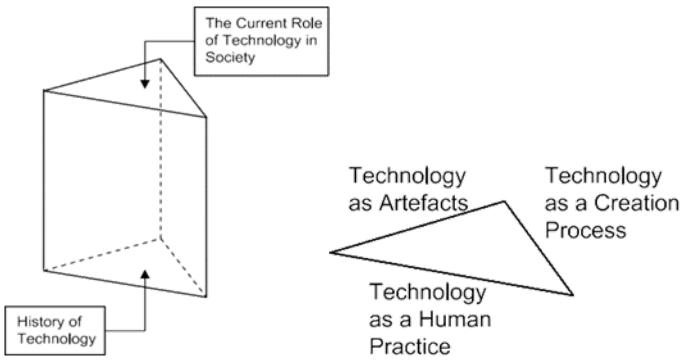

Figure 1. Top and side views of the representation of the nature of technology. (DiGironimo, 2011).

According to DiGironimo (2011), an individual's view of the subject of technology can be found within a prism. This applies to both teachers and students alike. Teaching about its content can move from one side to the other of the triangle and backwards and forwards in time (through the prism). The dimensions are as follows:

“Technology as Artefacts”

> “The products of technological innovation and the educational technology tools as computers, cell phones, graphing calculators, video game systems, and iPods. It also includes the internet, machines, cars, and factories” (p. 1342).

“Technology as a Creation Process”

> This dimension of the nature of technology encompasses what technologists (e.g., engineers, architects, designers) do. What they need to possess physically (other technological artefacts) and mentally (specialized technological content knowledge, science knowledge, mathematics skills) in order to engage in the design process. This view can represent “the methods of technology”.

“Technology as a Human Practice”

> Technology is not immune to gender, race, or class distinctions. Just as technology is not free from human involvement, technology is influenced by political, cultural, societal, ethical, environmental, economic, and personal values and beliefs” (p.1342).

“History of Technology”

Technology has always been a fundamental part of human history, but "The tendency to refer to only modern technological advances as technology is inaccurate” (p.1343). Mistakes, errors, and failures form part of the technology journey mankind has undertaken. “How humans engage in the enterprise of modern technology has and will continue to change” (p.1343).

"The Current Role of Technology in Society"

This concept is less well-defined than the other views. Technology´s role in society is complex and depends on many things including technology's relationship with other disciplines, status in the education system, and function in everyday life. The role can change from year to year or minute to minute. It means different things depending on who you are and what you tend to do with technology artefacts.

Research questions

This study's goals were achieved through the following two research question:
1. What are teacher's views of the school subject of technology in Sweden?
2. What are teaching views toward teaching technology at the junior high school level in Sweden?

Theoretical framework

We believes that different teachers describe their technology teaching on the basis of different ways of looking at the subject. Previous research (Östman,1995; Svennbeck, 2003) shows that there are patterns in the choices and objectives that characterise teaching and how teaching is described. Roberts (1994) describes the patterns used in different subject content as so-called knowledge emphases, and he believes that teachers choose to teach in accordance with these. Research on different views and values in science teaching has revealed different patterns and purposes. Similarly, there is an ongoing struggle between different traditions and visions.

Within the subject of technology Klasander (2010) found how different education emphases have been achieved differ and can cause major impacts. Klasander describes the content of the different education emphases and compares them with the emphases detected within science teaching (Roberts,1994; 2007; Fensham,1988; Östman,1995). Klasander summarises the characteristics of the respective emphases in Table 1, as below.

Design and make	Being inventive, manufacturing small products, craftsmanship, models.
The industrial phase	Preparation for working in production, industrial design or engineering. The view that nature's resources are utilitarian.
The durable development	Eco-centric. Bad/good technology is highlighted, most often as a destructive force. More descriptive than proactive.
Manage everyday	Anthropocentric. Being able to handle system-dependent artefacts. People responsible for the technical system's development on an individual level.
The civic	The role of people is important, preparedness on a societal level. Anti-deterministic
History of technology	Understand the system's growth needs, driving forces, terms and conditions are knowledge which are necessary for making decisions for the future.

Table 1. Different education emphases, found by Klasander (2010)

Methodology

The aim is to examine how teachers look at the subject of technology and inventory how different teachers look at the subject and express what content and methods they choose to teach. The analyses are related to Klasander's (2010) education emphases within the technology subject and DiGironomo's (2011) categories for different views of technology.

In order to maintain an empirical approach to the analysis, a questionnaire was developed and sent to technology teachers working with years 7-9 learners in Sweden. The questionnaire contained background questions and questions about the choice of methods for teaching, together with questions about the teacher's definition of technology, their description of the aim of technology teaching, and why they chose to teach technology. In addition, they were asked the extent to which they choose to teach according to the central content of the syllabus, the aim of the subject, and regarding the abilities that it is expected for the pupils to develop.

Of Sweden's 1624 schools, 510 schools in year 7-9 were selected. These schools were distributed across the country and different sized schools with different operating forms were studied. A web-based questionnaire was sent to 499 teachers and contained 115 questions/positions. The primary form of questioning was through closed-form response alternatives. A number of free text response alternatives were also included. The response number was 223 (46%).

The analyses were carried out qualitatively by dividing the free text response alternatives into themes and then using cluster analysis in SPSS (cluster analysis: hierarchical, Ward's method, Euclidean distance), combined with frequencies and cross tables data. The aim was to employ a variety of analyses to find different descriptions of the aim of technology teaching and if these aims are characterized for positions related to the Curriculum and comment material.

The actual clustering was based on what the teachers answered to the questions/situations as presented in in the right-hand column in Table 2. These descriptions of the content can be found in the syllabus for the technology subject in Sweden and those teachers that responded most similarly regarding extent and how often they facilitated would fall into the same cluster. Each question had been structured to relate to different dimensions within technology according to DiGironimo (2011).

Technology as Artefacts	How often do you facilitate the following in your technology teaching: The students may identify and analyse technical solutions on the basis of appropriateness and function.
Technology as a Creation Process	To what extent do you allow the students: To practically test, observe and design.
Technology as a Human Practice	How often do you give the students the opportunity for the following in your technology teaching: The students are able to undertake more in-depth consideration and more problematized perspectives. Discuss consequences of technology choices on the basis of ethical aspects.
History of Technology	How often do you consider that you facilitate the following in your technology teaching: The students may analyse how the technology has changed over time.
The Current Role of Technology in Society	How often do you consider that you facilitate the following in your technology teaching: Make the pupils aware of technology's role in society and everyday life.

Table 2. Relation between DiGironimo (2011) and questions used for clustering.

Results

About half of the teachers are women and qualified in technology, most of them uses text books and emphasises that the syllabus is important. A third of the teachers focus each lesson on making technology visible, on relevant concepts or make visible the role of technology in society. Many of them focus every now and then about technical systems, energy, technical solutions and the design process.

About half of the teachers express regarding why they chose to teach technology, that they have a genuine interest and more of them are positive to their teaching. Very few expresses that it is an important subject.

The teachers' free text responses regarding different views of technology in which DiGironomo's (2011) dimensions were used and regarding the most important aims of technology teaching that were related to Klasander's (2010) six emphases, are presented in this table and we can see how the teachers emphasises the role that technology has in society

What is technology?	(%of223)
Technology often has a role in society to solve problems	37.2
DiGironimo: The Current Role of Technology in Society	
Technology as artefacts and their function	17.9
DiGironimo: Technology as Artefacts	
Technology is what certain people work with; methods, design	23.8
DiGironimo: Technology as a Creation Process	
Technology as a human practice with ethical and cultural values	1.3
DiGironimo: Technology as a Human Practice	

The history of technology and historical technology	5.8
DiGironimo: History of Technology	
The most important aim of Technology	
Putting technology in a wider societal context	22.5
Klasander: The civic emphasis	
Management of everyday technical items	15.7
Klasander: The manage everyday emphasis	
Design and manufacturing of artefacts	10.8
Klasander: Design and make	
Technology should demonstrate manufacturing and industry	4.5
Klasander: The industrial phase	
Sustainable development and the future	4
Klasander: The durable development emphasis	
The history of technology	9
Klasander: The history of technology emphasis	
Increase interest in technology	15.7
Researchers' own emphasis	

Cluster analysis

The cluster analysis, in which four clusters were created from a total of 205 of the 223 teachers, was based on the teachers' answers regarding the extent to which the statements agreed with what and how they taught technology. From this, four profiles with different characters were developed:

Teacher Profile 1 - *The Doer*: This profile was characterized by practical construction activities. The teacher takes into account the aesthetic aspects of design, with a major focus on design and material knowledge employed together within the creative process. The function of artefacts and the role of technology are important. Construction and design take place in almost every lesson. The time allocation to technology as a subject is very important. Actual school research is considered to be essential and what the Swedish National Agency for Education emphasises is significant in the teacher's own work. They also work with the driving forces in technology and emphasize an understanding of scientific and technical principles within technology.

Profile 1 - The Doer (61 individuals)	(% of 61)
Women	49
Qualified	52
Year 1-7 teachers	7
Year 4-9 teachers	44
Subject teachers	30
Other qualification	20
Teaches Physics, Chemistry, Biology, Mathematics	46
Uses text book	30
Other teaching materials	56
Positive view of the subject	44

Teacher Profile 2 – *Sufficient unto himself*: In this profile the teacher emphasizes the importance of adhering to the syllabus, but also states that contacts outside the school and the experience of colleagues are unimportant for technology teaching. The teaching provides no opportunity for analysis, assessment of technology, or analysis of the driving forces in technology. A small amount of design work is permitted, but without material knowledge. The school's profile, if any, what the Swedish National Agency for Education emphasises, what current research is presenting and what the students do in the natural or social sciences are all considered as unimportant.

Profile 2 - Sufficient unto himself (37 individuals)	(% of 37)
Women	40
Qualified	49
Year 1-7 teachers	8
Year 4-9 teachers	51
Subject teachers	19
Other qualification	8
Teaches Physics, Chemistry, Biology, Mathematics	41
Uses text book	19
Other teaching materials	40
Positive view of the subject	51

Teacher Profile 3 – *Society-oriented*: This teacher profile involves identification and analysis of technical solutions, together with some work on practical aspects. The role of technology in society and everyday life is prioritized and examined in almost every lesson. Technology knowledge to manage everyday life and the aims related to the civic emphasis are underlined. The practical aspects are interspersed with ethics and the driving forces of technology, together with technology's relationship to sustainable development and environmental consequences. Teachers with this profile seem to be most interested in school research.

Profile 3 - Society-oriented (55 individuals)	(% of 55)
Women	58
Qualified	58
Year 1-7 teachers	9
Year 4-9 teachers	46
Subject teachers	20
Other qualification	22
Teaches Physics, Chemistry, Biology, Mathematics	47
Uses text book	33
Other teaching materials	53
Positive view of the subject	60

Teacher Profile 4 – *Flexible*: This teacher profile emphasizes all dimensions as something which is considered to take place every now and then. Teaching related to the civic emphasis is strongly underlined, sustainable development and environmental consequences equally so. These teachers also state that the students' viewpoints and ideas are important. The profile focuses on analysis, trying things practically including with models, and also focuses on technology's role in society. Aesthetics are important, as is the fact that students should obtain confidence in their ability to assess technical solutions linked to sustainable development. They value contacts with colleagues and outside the school, and feel that the teachers' own knowledge of technology affects the teaching to a very high extent.

Profile 4 - Flexible (52 individuals)	(% of 52)
Women	60
Qualified	60
Year 1-7 teachers	12
Year 4-9 teachers	46
Subject teachers	27
Other qualification	14
Teaches Physics, Chemistry, Biology, Mathematics	60
Uses text book	24
Other teaching materials	62
Positive view of the subject	43

Discussion

Societal orientation and civic knowledge are greatly valued when the teachers describe their view of technology and what is important. However many lessons contain design and manufacture without more detailed connections to technology. The teaching may, despite this, reflect a view of technology as a doing/manufacturing subject. Putting technology in a wider and more value-based context requires knowledge and interest on the teacher's part. It is possible that the teachers themselves have technology knowledge relating to design and not the same level of experience of guiding students to achieve insight into their own technology use. For example, fairness and gender are important. Even if the technology teacher group appears to be extremely homogeneous, the cluster analysis shows certain differences between different teacher profiles.

Summary

The results demonstrate consistency between how teachers say they view technology and the purpose of their teaching. Technology optimism is perceptible, as is the feeling that it is important to make visible technology's benefits to society. What does not appear to occur to any significant extent is the view of technology as designed by humans, with connections to ethics, analysis of the advantages and disadvantages of technology or cultural patterns or gender structures in relation to technology. Nor are values and politics, sustainable development or the historical dimension emphasised in the teaching. The same absence applies to aspects such as the driving forces of technology or different development phases. In practical teaching, there is a greater focus on making visible technology and technical systems, technical solutions and scientific principles, the technology area's forms of expression and design work.

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Pre-service teachers' perceptions of technology and technology education

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Abstract

Technology teachers' perceptions and understanding of the nature of technology heavily influence their perceptions of technology education and consequently shapes their teaching practice. Within New Zealand, the university initial teacher education (ITE) community has developed an agreed framework - Pre-service Technology Teacher Education Resource – to guide the aims and intentions of their technology ITE programmes. A foundational aim of this framework is to help student teachers develop their concepts and philosophies of technology and technology education, a goal that aligns with the Nature of Technology strand of the of the New Zealand technology education curriculum. In line with these aims, it was agreed that a survey of students' perceptions of technology and technology education when entering ITE programmes across NZ, and again on exit, would provide valuable insights into the impact of these programmes and this paper reports findings from two New Zealand universities. Participants were teacher trainees enrolled in compulsory, initial technology education papers at the start of their degree or postgraduate programmes. Students were asked to complete a questionnaire at the beginning of their initial paper, before any teaching had taken place, and again at the end of the paper. The questionnaires included demographic information, Likert scale items and open response questions. Quantitative data were entered into SPSS and a two-tailed t-test applied to determine whether differences between pre and post responses were statistically significant. Qualitative, open statements were coded and examined for response themes. The findings from two universities are presented and discussed.

Keywords

Pre-service teacher education, perceptions, technology education, technology

Introduction

Even for long-standing curriculum subjects it can be difficult to establish a consistent view of the nature of the discipline that is shared across the various sectors of education involved in teaching it. For a new curriculum area this can be even harder, particularly for a subject like technology that, in New Zealand (NZ) as elsewhere (Jones, 2009), has evolved from a range of syllabi and teaching approaches (Harwood & Compton, 2007).

Subject sub-cultures take time to develop but have a strong influence on teachers' perceptions of the subject and of their role and practice as teachers of that subject (Jones and Carr, 1993; Jones, 2003). Along with experiences at school and the culture of schools in which they later teach, experiences during their initial teacher education (ITE) play an important role in shaping teachers' perceptions and understanding of their subject. NZ ITE is available through a variety of registered institutions but the majority of NZ teachers train within the six main universities. The relative autonomy of tertiary institutions means that there is potential for variation in the aims and practices within ITE programmes and for this to lead to conflicting aims and practices within schools. As Elliott (2008) and Gambhir, Broad, Evans, & Gaskell (2008) have commented, there is a need for consistency in ITE both within and across institutions.

Within NZ, the university ITE community has developed a coherent approach to ITE that provides consistency in philosophy while supporting diversity in practice. The Pre-service Technology Teacher Education Resource (PTTER) framework (Forret et al, 2011) is aimed at supporting coherent understanding and purpose across ITE institutions. It represents a foundational core aimed at providing the most long-term impact on student teachers' developing pedagogical content knowledge (PCK) in technology education (Shulman, 1987; Magnusson, Krajcik and Borko, 1999). The PTTER framework for technology ITE is based on four elements: philosophy of technology - establishing philosophical foundations of technology as a field of human endeavour; rationale for technology education - examining rationale for including technology education as part of a core education curriculum; technology education in the NZ curriculum – understanding how the NZ curriculum mandates and structures technology education: and, teaching technology - understanding how to plan, teach and assess technology in the NZ curriculum. While all four elements are important, the first is seen as foundational, i.e. it is essential for teachers to have a well-developed understanding of technology (de Vries, 2012) and that this underpins the other three elements. Because of this, one of the primary goals of pre-service technology teacher education in New Zealand is the development of appropriate and consistent views of technology. However, apart from in-course assessment, there is currently no data to indicate the extent to which we are being successful. Associated with this is the recognition that students bring a variety of perspectives about technology and technology education with them to ITE programmes (Burns, 1990) and that these need to be built on to develop understanding.

The research

Following the development and use of the PTTER framework within the main ITE institutions in NZ (Forret et al, 2011) it was agreed that a survey of students' perceptions of technology and technology education when entering ITE programmes across NZ, and again on exit, would provide valuable insights into students' perceptions of technology as well as the impact of ITE programmes on those views.

The findings reported here are some of the initial results from two institutions and are part of a larger project aimed at brining together similar data from across the country to inform development of technology ITE programmes.

Research design

The research adopted a mixed methods approach using a before and after questionnaire to collect a range of quantitative and qualitative responses to questions seeking demographic information, Likert scale responses and open question responses. Students were asked to complete the questionnaire at the beginning of the paper before any teaching had taken place and again at the end of the paper, 12-14 weeks later. The same questionnaire was used both times except that the post-teaching questionnaire included additional, open, questions focused on students' experiences within the paper. . Quantitative data were entered into SPSS and a two-tailed t-test applied to determine whether differences between pre and post responses were statistically significant. Qualitative, open statements were coded and examined for response themes. The research adhered to the universities' ethical guidelines and students' responses were voluntary and based on informed consent.

Participants in University A (97 students completed the pre-course survey, 99 completed the post-course survey) were undergraduate primary teacher trainees enrolled in a compulsory, one semester initial technology education paper. Approximately 90% of respondents were females between 17 to 24 years old. Participants in University B (21 students completed the pre-course survey, 22 completed the post-course survey) were postgraduate primary and secondary teacher trainees enrolled in a compulsory one semester technology education paper. In this group approximately 80% of respondents were female and ages ranged approximately evenly from 17 to 37+ years old.

Results

Tables 1 and 2 show the quantitative results for two Likert scale questions and displays the number of respondents (N), mean value responses (Mean) and the 2-tailed, t-test significance (Sig). Significance values of 0.05 are significant at the 95% level and values of 0.01 or below are significant at 99% level or higher.

University A

Table 1: University A before and after responses showing number of respondents (N), mean response values (Mean) and 2-tailed, t-test significance values (Sig)

	Before		After		
Question	N	Mean	N	Mean	Sig
1 What do you think the subject/learning area called technology is mostly about? (1-3) 1 = no focus– marginally about, 2 = some focus, 3 = heavy emphasis					
Woodwork, metalwork, sewing, cooking	96	2.33	99	2.31	0.805
Learning about electronics and machines	97	2.40	98	2.39	0.158
Learning how parts of machines and systems work	95	2.24	98	2.42	0.056
Learning about technology over time, place and cultures	97	2.39	98	2.57	0.022
Learning about new inventions	96	2.27	96	2.47	0.015
Thinking about the impact of technology	96	2.47	98	2.72	0.001
Learning what experts in the community do in their job	97	1.91	98	2.22	0.000
Computers	96	2.68	98	2.37	0.000
Problem solving	94	2.34	98	2.85	0.000
Creativity, design & showing others your ideas	97	2.62	99	2.89	0.000
Planning and making things	95	2.53	99	2.83	0.000
Learning about resources/materials	95	2.38	99	2.75	0.000
Learning about what it means to do technology	97	2.34	98	2.70	0.000
2 Please indicate the extent to which you agree or disagree with the following statements. (1-5) 1 = Strongly disagree, 5 = Strongly agree					
Science and technology are basically one and the same thing.	95	2.25	99	2.26	0.941
Technology is a small factor in your everyday life.	95	2.00	99	2.05	0.778
Engineering and technology are basically one and the same thing.	95	2.52	98	2.47	0.698
Humans often develop new technologies to improve upon previous technologies.	96	4.21	99	4.27	0.619
The results of the use of technology can be good or bad.	95	3.91	98	4.12	0.095
Most environmental problems can be solved using technology.	95	2.72	99	2.95	0.054
Design is a process that can be used to turn ideas into products.	95	4.23	99	4.49	0.012

Perceptions of technology

In Question 2, students' responses did not change significantly except in response to 'Design is a process that can be used to turn ideas into products' where there was a significant (0.012) increase in agreement with this statement after the paper.

In the after paper questionnaire, students were asked 'Has your view of technology changed since completing this questionnaire the first time?' and, 'If yes, in what ways have your views of technology changed?' 86.7% of students replied 'Yes' to this question. The majority of responses as to how their views had changed referred to a broadening of perceptions of technology. For example, "I used to think technology was just about electronics such as computers and cell phones but now I know it is much more. I now understand that technology involves solving problems, modelling, design and much more."

"That there is so much more involved. It is how things are made and work. It makes you see the world in a different way."

Perceptions of technology education

In Question 1, students were asked what they thought the subject of technology was mainly about. Responses showed a large number of significant changes. The only items for which the changes were not significant (< 0.05) were: Woodwork, metalwork, sewing, cooking; Learning about electronics and machines; Learning how parts of machines and systems work. All responses that did show significant change indicate stronger association with technology except for computers where there was a significant reduction in association. This is consistent with their views becoming broader and is also consistent with the results reported for the same research carried out with a similar cohort one year earlier (Forret,M., Edwards, R., Lockley, J., & Nuyen, N., 2013).

In the post questionnaire, students were asked 'Has your view of technology education changed since completing this questionnaire the first time?' and, 'If yes, in what ways have you views of technology education changed?' 78.7% of students replied Yes. Responses on how their views had changed tended to echo their comments regarding how their views of technology had changed, e.g. "Its not just about modern computers and phones", "More than just making things" and "I know that it is much more than just cooking, woodwork, sewing etc,, stuff that you do in school, and has a broader context."

University B

Table 1: University B before and after responses showing number of respondents (N), mean response values (Mean) and 2-tailed, t-test significance values (Sig)

	Before		After		
Question	**N**	**Mean**	**N**	**Mean**	**Sig**
1 What do you think the subject/learning area called technology is mostly about? (1-3)					
1 = no focus- marginally about, 2 =some focus, 3 = heavy emphasis					
Learning what experts in the community do in their job	21	2.00	22	2.00	1.000
Learning about what it means to do technology	21	2.48	22	2.45	0.899
Learning how parts of machines and systems work	20	2.05	22	2.00	0.778
Woodwork, metalwork, sewing, cooking	21	1.95	22	2.00	0.740
Planning and making things	21	2.57	22	2.64	0.699
Learning about resources /materials	21	2.57	22	2.50	0.697
Learning about new inventions	21	2.29	22	2.36	0.679
Computers	21	2.24	21	2.10	0.351
Learning about technology over time, place and cultures	21	2.38	22	2.59	0.281
Creativity, design & showing others your ideas	21	2.76	22	2.91	0.278
Problem solving	21	2.67	22	2.86	0.188
Learning about electronics and machines	21	2.24	22	1.95	0.077
Thinking about the impact of technology	21	2.48	22	2.82	0.035
2 Please indicate the extent to which you agree or disagree with the following statements.					
(1-5) 1 = Strongly disagree, 5 = Strongly agree					
The results of the use of technology can be good or bad.	21	4.19	20	4.15	0.879
Technology is a small factor in your everyday life.	21	2.24	22	2.41	0.718
Design is a process that can be used to turn ideas into products.	21	4.43	22	4.55	0.637
Engineering and technology are basically one and the same thing.	21	2.24	22	2.05	0.549
Humans often develop new technologies to improve upon previous technologies.	21	4.48	22	4.09	0.235
Most environmental problems can be solved using technology.	21	3.14	22	3.59	0.072
Science and technology are basically one and the same thing.	21	2.19	22	1.64	0.035

Perceptions of technology

In Question 2, responses did not change significantly except in response to 'Science and technology are basically one and the same thing' where there was a significant (0.035) decrease in agreement with this statement after the paper. In the post questionnaire, 76.2% of students said their view of technology had changed.

Perceptions of technology education

In Question 1, responses did not change significantly except in response to 'Thinking about the impact of technology' where there was a significant (0.035) increase in agreement with this statement after the paper.

In the post questionnaire, 80.9% of students said their view of technology education had changed. Responses on how their views had changed included the following themes: a better understanding of the curriculum/technology curriculum; broader and better understanding of technology education and its components; increased sense of the creative and dynamic nature of the subject; understanding that teaching the practical elements of the subject is important.

Discussion

While in both the undergraduate and postgraduate groups there were few significant changes in their views of technology, examination of the pre and post mean scores shows that there were shifts in the level of agreement with the statements and that these changes were generally in a desirable direction towards a broader view of technology. In general, changes were more marked for the undergraduate group and this is likely, in part, due the group being much larger than the postgraduate group.

In each group, there was one technology related item with a significant change. For the undergraduate group there was a significant increase in agreement with 'Design is a process that can be used to turn ideas into products' and for the graduates there was a significant decrease in agreement with 'Science and technology are basically one and the same thing'. Neither of these are the same as the two significant changes noted in an earlier study (Forret et al., 2013). There is no clear reason for this and it would seem to suggest that more attention is needed on clarifying perceptions of technology. However, it may also reflect the resistance to change of established views that students bring with them into the course (Flores & Day, 2006; Stuart & Thurlow, 2000).

The most significant changes occurred in the undergraduate group's views of technology education with highly significant changes in nearly all the technology education related items except those most commonly related to technology. The changes are generally consistent with a broadening of students' views of technology education to more strongly consider aspects such as creativity, design, problem solving, planning and making, as important in technology education and a reduction in the perceived importance of computers and learning about electronics and machines.

Unlike the undergraduate group, the postgraduate students' only significant change related to technology education was an increase in their agreement with the item 'Thinking about the impact of technology'. At this stage there is not enough evidence to indicate a clear reason for this. It could relate to the difference in educational experience of the two groups, differences in course content and/or teaching, or simply the need for a more finely tuned data collection tool. The general similarity of mean values between both groups and the low values of some means suggests that it is not due to students coming into our courses with well-developed and appropriate views of technology.

A large majority of students from both groups indicated that their views of technology and technology education had changed during the paper. While the data suggests that the type and degree of change varied between the groups, changes are in directions that indicate a broadening and deepening of perspectives of technology and technology education and are consistent with the general intent of the PTTER framework.

Qualitative responses suggest that the postgraduate group were, understandably, more focused on the goal of preparing to teach technology with many of their responses referring to curriculum and teaching related aspects of the paper.

Conclusion

The results presented here offer a window on pre-service teachers' perceptions of technology and technology education and how these are affected by their involvement in a technology specific teacher education course. While the results are encouraging, they raise some issues that warrant further investigation. These include the way different cohorts e.g. undergraduate and post-graduate student groups vary in their perceptions and response to courses, what is most effective in bringing about change in views of technology, and what aspects of our courses are currently working well.

Although the results generally show positive changes in students' responses in line with many of the aims and intentions of the ITE programmes, further analysis will be needed to more fully examine the data and consider how these findings might inform our practice and how we might refine the questionnaire. We also look forward to combining our findings with those from other NZ ITE institutions to provide a national picture of students' perceptions of technology and technology education. Given that there appears to be little research into this area in the international literature, this should be of interest to a wider audience and there is potential for international collaborative projects in the future.

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Assessment of technology in early childhood and lower primary school using dimensions of learning

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Abstract

Teaching and Learning in technology for students aged between three and seven should be designed to build a strong base of understanding and internally driven interest and abilities related to our technological world. In this paper three dimensions of learning are explored as a tool to assess aspects of technology education in the upper early childhood and lower primary school sectors.

In the New Zealand primary sector there are times when students might have achieved at one level but are not ready to move to a higher achievement level. When teaching and assessing technology, teachers rely curriculum and supporting documentation to assist with formative assessment.

Technology education in the New Zealand early childhood sector is not as well-structured or defined as in primary, although students are given opportunities to recognise, use, make and evaluate technology across five strands in the Early Childhood Curriculum. Students are assessed in a range of dispositions but are not formally assessed in technology education. However, teachers may look for ways to extend students' understanding of our technological world.

This paper offers a way to broaden and deepen student learning without necessarily moving them to higher curriculum achievement levels by offering a tool to assist teachers giving feedback as a part of the formative assessment process in technology education. It is envisaged that this paper will precede empirical research on ways to broaden and deepen young students' understanding in technological literacy in both sectors.

Keywords

Technology education, assessment, primary and early childhood, dimensions of learning

Introduction

When assessing technology is not unusual for teachers to consider that their students are not ready to move to the next achievement level for a variety of reasons even though they have met their current expected level of understanding. Teachers therefore can explore ways to broaden and deepen their students' knowledge and understanding across a range of technology areas or contexts. The framework presented in this paper specifically illustrates how Claxon and Carr's (2010) dimensions of learning can be used to assist teachers to formatively assess students' learning in a variety of ways and acknowledges that learning for students' futures is complex and multifaceted. Claxton and Carr (2010) suggest progress can be represented as change in three dimensions: robustness, breadth and richness. This paper explores learning in technology and then identifies ways in which these dimensions might be applied to assessment in technology education in both early childhood and primary settings.

Dimensions of learning

Assessment of students' learning and development in technology involves intelligent observation of the children by teachers with the purpose of improving students' technological literacy (Compton & France, 2007). Claxton and Carr (2010) suggest that a number of learning goals, dispositions, orientations or habits are advocated by educators. They also suggest viewing these goals or dispositions as verbs rather than nouns as is the norm. They see dispositions not as 'things' to be acquired but rather a way of doing that increases in frequency and complexity which can be described with applicable adverbs. The example they cite is 'persistence'.

> In our view, persistence is not something that a learner 'acquires'. Instead we see growth as a change in likelihood that they will respond to difficulty in certain ways: by sticking with it; voicing doubt sand digging below the surface, for example. These responses are then modified by a range of adverbs: an individual engages in them more or less *frequently*, or, *appropriately*, or *skilfully*. (2010, p. 88).

The fact that these tendencies can be seen as changing over time allows us to consider what and how teachers can do to assist their students' progress. Claxton and Carr (2010) offer three adverbial dimensions: robustness, breadth and richness, against which progress can be measured. The first, 'robustness' can be thought of as a tendency to respond to learning in a positive way when conditions for learning are not as supportive as they once were. Robustness is a matter of tolerating and managing the emotions of learning. An example from my own experience is Kaleb at 2 years old unable to work the mouse on the computer to play his favourite matching game. Initially an adult needed to support him. When left alone to attempt to use the mouse he became angry gave up playing the game. I talked to Kaleb about not getting upset at failing and that trying again was a good way to learn new skills. Slowly Kaleb became more skilful at using the mouse and was able to accept that mistakes were made and try again. After while was able to work the mouse independently without adult assistance

The second dimension, 'breadth' is concerned with the understanding that what is learned in one domain can be transferred to other settings, sometimes known as knowledge transfer. For example developing skills in working collaboratively in one area slowly develops into the skill of developing collaborative skills and taking leadership roles is a range of other domains. Again let's look at Kaleb. When he first started kindergarten at three years of age he found working with other children in the sandpit difficult. Over the year he started to take an interest in what others were doing in the sandpit and then started to play with them working on the same project. The skills he learned in the collaborative work in the sandpit were then applied to building constructions from boxes and completing jigsaw puzzles with his friends inside the classroom. His collaboration was broader. Taking on a leadership role in collaboration solving jigsaw puzzles also added robustness.

"Richness' is the third dimension and involves the development of flexibility and sophistication. Let's go back to the disposition of persisting to illustrate this. Initially the skill of persistence may mean not giving up on a task, but later problem solving strategies, obtaining assistance, anger control or mood repair may be inserted and become more subtle over time. Claxton and Carr (2010) cite an example in which Sarah's learning portfolio illustrates a rich range of support she calls on to assist her in making a bag. She discovered her learning was "stretched over' peers, teachers, family, materials and resources to sustain her three month sewing project which began with a discussion with a friend whose grandmother had taught him to sew, and culminated with a the setting up of a 'bag making factory'. "She had become much more skilful at marshalling and building for herself the scaffolding she needed in order to persevere in difficult enterprises" (Claxton.G. & Carr, 2010, p. 91). These dimensions can assist in the assessment of social and cognitive dispositions of young children. The next section identifies key elements in which the dimension can be specifically applied to technology education.

Learning and assessing technology

Progress in technology is not linear, nor is it a sum of individual parts, but rather a holistic process which can be difficult to assess (Kimbell, 1997). Achievement in technology includes a students' conceptual understanding of subject matter and their ability to transfer concepts to future learning and new and unfamiliar situations (Pellergrino, 2002).

National or state curricula such as New Zealand's national curriculum achievement objectives (Ministry of Education, 2007) and the United Kingdom's Key Stages (National Curriculum website team) go some way to identifying progression in technology. For teachers to be able to have a clear picture of students' learning further support documents such as New Zealand's Indicators of Progression (Ministry of Education, 2009) maybe required. These not only identify and break down learning steps but also supply clear teacher guidance and teaching strategies. Compton and Harwood, (2005) Jones (2009) and Pellegrino (2002) suggest more research is needed around the notion and specifics of progression in technology education in the school sector.

In the New Zealand early childhood sector learning technology is not specifically identified in Te Whāriki (Ministry of Education, 1996) however it offers a holistic approach to education, teaching a range of skills, knowledges and ways of thinking that apply directly to technological thinking and doing (Mawson, 2006). Part D of Te Whāriki (p93-99) identifies the technology foundational knowledge and skills embedded in it pages. These include the capability to solve practical problems from the 'Well-Being' strand (p. 94), using materials for different purposes and recognition that different technologies may be used in a variety of settings and places in the 'Belonging' strand (p95), experiencing collaborative and cooperative problem solving and understand how technologies assist people in the 'Contribution' strand (p96), using communication technologies in the 'Communication' strand (p97) and using a variety of technologies for different purposes in the 'Exploration strand' (p98). The 'Exploration' stand also contains more specific activities and exploration directly applicable to technology (Mawson, 2003). Several learning examples are directly related to the use and construction of technology, these include: offering degrees of challenge in construction activities (p87), using technology to explore movement in objects such as wheels and pulleys and creating three dimension constructions (p91). Others are related to technological process such as using trial and error to find solutions, giving reasons for choices (p89), developing spatial understanding by fitting things together and taking things apart (p91) and exploring the nature and properties of materials and substances.

How and why students' progress in their technological thinking in the early childhood sector is less defined and structured. A framework using Claxton and Carr's (2010) dimensions may assist teachers in assessing students' understandings of technology and developing their technological literacy in both the early childhood and primary schooling sectors. Teacher knowledge of formative assessment practices will also assist this process.

Assessing technology using dimensions

The dimensions can be used to assist with the assessment of technology education in both primary and early childhood settings. Assessing Technology in primary settings occurs through a range of strategies such as observations, work samples and student portfolios of technology practice. Table 2 illustrates how the dimension of learning can assist teachers using the indicators of progression (Ministry of Education, 2009) to assess their students in technology at Level 1 of NZC (Ministry of Education, 2007).

For example in the achievement objective Brief Development the indicators of progression state that students are required to communicate the outcome they are going to produce and identify some attributes.

– To demonstrate robustness students can work towards identifying some attributes with the assistance of their teacher initially and working towards independently to identify other simple attributes.

– To demonstrate breadth students can work towards identifying attributes independently in a new context. For example they may have been taught about attributes when developing a toy and then transfer this knowledge to a new food product they are developing.

– Richness can be demonstrated through an increase in the sophistication of the range and number of attributes identified. Table 1 briefly outlines the type of thinking / activity in each dimension for each of the achievement objectives at L1 of NZC.

Table 1: Assessing technology at Level 1 of NZC using the dimension of learning

	Achievement Objectives	**Indicators of Progression**	**Robustness** Students can …	**Breadth** Students can…	**Richness** Students can…
Technology Practice	Brief Development	communicate the outcome to be produced identify attributes for an outcome	work towards identifying some attributes with less assistance and with determination	identify attributes independently in a new context having learned what they are in a previous context	identify a more sophisticated range and number of attributes for their outcome
	Planning for Practice	identify what they will do next identify the particular materials, components and/or software they might use	work towards articulating what they are going to make and some tasks they will need to undertake and what they are going to be made of	identify sequenced tasks, that need to be undertaken in a new technology context	identify several tasks to be completed and the sequence in which they need to be undertaken Identify resources and materials to be used after undertaking informed research

	Outcome Development & Evaluation	describe potential outcomes, through drawing, models and/or verbally identify potential outcomes that are in keeping with the **attributes,** and select one to produce produce an outcome in keeping with identified attributes	preserver with their annotated drawing or verbal descriptions so that others are able to recognise the intended technological outcome (TO) which relate to identified attributes	transfer drawing skills form planning one TO to another	increase the sophistication of their drawings to include a range of techniques and skills
Technology Knowledge	Technological Modelling	describe what a functional model is identify the purpose of functional modelling describe what a prototype is identify the purpose of prototyping	understand why they are developing models of their TO and therefore transfer this knowledge to their practice	having found that modelling improved their first TO, instigate the need for modelling when developing subsequent TO	use modelling to improve a wider and more sophisticated range of attributes and use a range of modelling techniques to evaluate varying aspects of their TO
	Technological Products	identify materials that technological products are made from identify performance properties of common materials identify how the materials have been manipulated to make the product	develop an increased understanding that TO are made from different materials and that each material has a range of properties	having learned that a specific TO is made of specific materials identify new materials other TO are made of	recognise a wider range of materials and that the materials TO are made of will impact on the way they work
	Technological Systems	identify the components of a technological system and how they are connected • identify the input/s and output/s of particular technological systems • Identify that a system transforms an input to an output	work towards understanding that components work together to produce a TO	after learning about one system, recognise another system 's inputs and outputs	recognise smaller and more complicated components of systems
Nature of Technology	Characteristics of Technology	identify that technology helps to create the 'made world' identify that technology involves people designing and making technological outcomes for an identified purpose	develop an understanding that some aspects of their world are made and that people design and make these TO but undertaking a process and making careful decisions	having learned at some things in one context or environment are made, recognise the made TO in another context or environment	understand that things that are made are made for an increasingly sophisticated range of purposes and there is a increasing range of factors that people who make To need to consider
	Characteristics of Technological Outcomes	identify technological outcomes in a group of technological and non-technological objects and systems identify who might use particular technological outcomes	develop an understanding of what is made and what is natural and understand that people make TO for a reason	having learned the characteristics of some made things to be able to identify other made things based on the criteria used initially	identify that some objects might be a mixture of made and 'natural' things and that some made things come from natural things and understand

		identify the physical attributes of technological outcomes identify the functional attributes of technological outcomes			that a range of people might use one TO for different purposes

In early childhood settings assessment occurs minute by minute as teachers and peers listen, watch, and interact with students or groups of students. These continuous observations provide the basis of information for more in-depth assessment and evaluation that is integral to making decisions on how best to meet students' needs. Assessment of the early childhood environment should always focus on individual children over a period of time and avoid making comparisons between children (Ministry of Education, 1996). As in the primary sector Claxton and Carr's (2010) dimensions can be used to assist teachers to assess students in and about technology and give them feedback on how to progress within each of the five strands of Te Whāriki (Ministry of Education, 1996). For example within the Well-Being strand the ability to solving practical problems can be illustrated using Robustness, Breadth and Richness.

– To demonstrate robustness students can be assisted in practical problem solving by assist students to decrease the levels of frustration and anger when initial attempts at solving the construction problem of stability when a built tower fail. Students can realising that repeat attempts may eventually lead to an understanding that a wider base assists tower stability or understanding that some ideas will not work i.e. that tall towers cannot have a narrow base.

– Breadth can be demonstrated through the transfer of problem solving skills in one context to another, such as using the knowledge of design stability gained above to assist construction in the sandpit when building a castle or playing leap frog with friends.

– Richness is demonstrated in practice problem solving to an increased sophistication in the understanding of ideas such as learning that reinforcement and structural shape along with base size also assist with stability.

In Table 2 Technology in early childhood education is further explored through illustration across the five strands of Te Whāriki.

Table 2: Progress in aspects of technology in Early Childhood demonstrated using the dimension of learning

Strands	Identified Aspects of Technology	Robustness *The children can…*	Breadth *The children can…*	Richness *The children can...*
Well-Being	solve practical problems	repeatedly attempt to construct a tower leading to the understanding that some ideas will work and others will not work.	the transfer of problem solving skills in one context to another such as building block towers to building castles in the sandpit	demonstrate increased sophistication about problem solving such as learning that ideas to assist problem solving are multifaceted, e.g. structural and materials shape assist stability
Belonging	using materials for different purposes and recognition that different technologies may be used in a variety of settings and places	understand that the first materials the use may not be suitable and exploration of a range of materials may be necessary	transferring understandings that materials have different forms and functions from one project to another for example using material suitable in one context may not be appropriate in another context	understanding that the same materials may be useful in a range of functions which may change according to the setting in which it is used for example fabric can be used to construct a garment and filter water

Contribution	collaborative and cooperative problem solving understand how technologies assist people	Demonstrate that working with others involves giving and taking understand that things help people do things they cannot do themselves. E.g. scissors can assist in separating paper	use cooperative skills learned in one contest can be transferred to other context identify that some tools have multipurpose. If scissors cut paper then they may also cut fabric (or themselves ☹)	demonstrate a range of for collaborating with peers e.g. compromise, walking away, or welcoming others using a range of technologies and beginning to look for tools that may do a specific job
Communication	using communication technologies	understand that learning to use technologies takes practice and time to perfect	understand that technologies can be used in a range of settings and that techniques used in one technology may transfer to another e.g. swiping a cell phone and a tablet	understand and demonstrate increasingly complex functions of communication technologies.
Exploration	technologies for different purposes the use and construction of technology creating three dimension constructions fitting things together and taking things apart and explore the nature and properties of materials and substances.	demonstrate determination and persistence when learning to use a new tool. use a range of materials and techniques to create 3 D constructions	discover that technologies can be used in a range of settings and that techniques used in one technology may transfer to another e.g. swiping a cell phone and a tablet use techniques used in one setting to assist with construction in another setting.	Through exploration, understand that technologies have multiple purposes and be able to use increasingly more complex technologies develop increasing complex constructions with increasing sophisticated joining techniques

Conclusion

Assessment is an aspect of technology that has been researched from many perspectives (Barlex, 2006; Compton, Harwood, & Northover, 2000; Crooks & Flockton, 2001; Fleer & Quinones, 2009; Fox-Turnbull, 2003; Hoepfl & Lindstrom, 2007; Jones, 2009; Jones & Moreland, 2001; Kimbell, 1997; Moreland & Jones, 2000). This paper suggests the use of Claxton and Carr's (2010) dimensions of learning to assist teachers in the assessment of technology in both the early primary and early childhood settings. Assessment of students' learning and development in technology involves intelligent observation of students by teachers and other experts with the purpose of improving students' technological literacy (Compton & France, 2007). It can be seen in the tables above that the dimensions of robustness, breadth and richness can be applied to aspects of technology in both sectors. The framework offers guidance for teachers by considering ways to facilitate and assist students' progress within the context of technology education. This paper does not offer alternative components to be assessed but offers a way to deepen and broaden learning for students aged from three to seven years. It specifically illustrates how Claxon and Carr's (2010) dimensions of learning can be used to assist teachers to formatively assess students' learning in technology at L1 NZC (Ministry of Education, 2007)and within the five strands of New Zealand's Early Childhood curriculum, Te Whāriki (Ministry of Education, 1996). It is hoped that this paper will precede empirical research to deepen understandings of the effectiveness of the tool presented here and to gain further insight into a tools to assist teachers to teach and assess technology to ensure solid foundations in technological literacy.

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A comparative analysis of patterns of girls' attitudes towards D&T: the case of Botswana and Swaziland

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Abstract

This paper responds to a growing concern by the author of the gender imbalance in the training of Design and Technology (D&T) teachers at the University of Botswana. Using a framework based on attitudes formation and change, a comparison of secondary school girls' attitudes towards D&T revealed a somewhat different pattern between Botswana and Swaziland. Understanding this pattern and its underlying drivers is central to providing practical evidence based option for relevant, tailor–made interventions focused towards girls to meet their specific technological education needs. Analysis of 965 Likert scale questionnaires revealed 'Support' and 'Importance' as common factors influencing girls' attitudes towards D&T in Botswana and Swaziland. However, Independent Samples t-test revealed important differences in the way these two factors play out between the two countries, thus no significant difference in terms of Support, and significant difference in terms of Importance. These results indicate that the amount of support provided [or not provided] by parents, siblings and teachers influence these girls' attitude towards the subject in both countries. So the limited numbers of girls enrolling in D&T in both countries is a sign that these girls do not get much support or encouragement to do so from all whose support is paramount. The enrolment of girls in D&T could potentially be bolstered by promoting the subject to the public and by ensuring that these girls get much social support to alleviate potential obstacles. As a socialization problem rather than a biological determination problem, and as raising issues of moral justification and problems of moral obligation, any intervention to fight the gendered nature of D&T and to promote it among girls should target not only them but their families as well.

Keywords

Design & technology, gender, attitudes, exploratory factor analysis, independent samples t-test, Botswana, Swaziland

Introduction

The University of Botswana is in partnership with the Ministry of Education and Training in Swaziland to train teachers for D&T from Swaziland. The numbers of teachers from Swaziland to the University of Botswana for training in D&T increased by 80%from two in 2007 to ten in 2013 (the agreement is to send 10 each year). This figure is an indication of the need for training of teachers in Swaziland in the area of D&T. The 48 teachers at the University of Botswana from Swaziland for example, between 2007 and 2013 were all males, compared to the 71 teachers from Botswana 12 (17%)of which were females. About 280 teachers from Swaziland are yet to be trained in this subject area and only 10% of them are females. This gender imbalance is a reflection of deep rooted stereotypical attitudes and perceptions of the Swati towards technology education. These stereotypical attitudes coupled with a male dominated teaching force compromises quality in access and participation in technical, vocational and education training as espoused in the Technical and Vocational Education and Training and Skills Development (TVESD) policy (Mamba, 2010).

With a male dominated teaching force, technology education in Swaziland is bound to face a double edged problem of gender imbalance. On the one hand would be young girls who do not take up opportunities to pursue technology education, and on the other would be a male dominated teaching force who cast an image that suggest that technology education is a masculine field of study.

The subject is relatively new in Swaziland as it is in most countries in Southern Africa. The history of D&T education in Botswana and in Swaziland is similar; i.e. the subject has evolved from craft subjects such as Woodwork and Metalwork. As a result of this history, the subject is viewed as a motor skills development practical subject suitable for less academic male students.This view of D&T as a motor skills development subject has had a major effect on the development of attitudes towards the subject the world over (Volk, Yip & Lo, 2003; Ardies,Maeyer & Gijbels, 2013; Dakers, 2006, 2007; Dingalo & Moalosi, 2003).

Theoretical and conceptual framework

Indoshi, Wagah, & Agak, (2010) developed a framework (Figure 1: see Appendix) illustrating the complex nature in which the emotional (for instance liking or disliking) component, the cognitive (beliefs) component, and the behavioral (tendency to act towards a subject) component of attitudes are formed and changed.

Using this framework based on attitudes formation and change, this study focused much on the cognitive and behavioral components of attitudes to D&T, most of which emerge as a result of environmental factors. It was anticipated that most of the participating girls [here referred to as 'Non D&T girls' (NON D&T)] would not have had the chance to experience the subject to develop any emotions towards it. Non D&T girls' attitudes were less likely therefore, to be influenced by curriculum related and administrative factors.

In Botswana (Gaotlhobogwe, 2004) and in Swaziland (Examination Council of Swaziland, personal communication, 2011), like in many other countries around the world there is overwhelming evidence that enrolment figures in D&T in general are declining. The situation is worse for girls who choose to deviate from the technological line of career as they proceed with their education (Gaotlhobogwe, 2004). Students must have reasons why they behave in a particular manner towards school subjects. In other words, factors, some of which are shown in the conceptual framework in figure 1 must have influenced their decisions to behave in that particular way towards the subject, and identifying these factors would be an important step in addressing negative attitudes towards a curriculum subject.

Various attitudinal studies on curriculum subjects agree with 'attitudes formation and change' framework above. Adeyemi (2009) discusses literature that reveals various reasons why students prefer to choose some subjects relative to others. According to Adeyemi, one study in England identified enjoyment and interest; usefulness for future; and previous performance as factors that influenced students' preference to choose subjects relative to others. The study further found that by contrast, the myths that students choose subjects because they are 'easy' or because of the pressure from friends, teachers, parents or from other sources seemed not to be influential (Adeyemi, 2009, p.102). However, according to PATT and related studies (Volk and Ming, 2009; Indoshi et al, 2010; Wagah et al, 2009) what Adeyemi referred to as myths, is reality in technology related education, possibly because of the nature of the history of technology education. Gaotlhobogwe (2004, p. 21) also indicated that "girls and boys have always settled for choices that conform to family and social norms of femininity and masculinity". As discussed earlier, because D&T is a relatively new subject, students, particularly girls may succumb to pressure from friends, teachers, and parents or from other sources when choosing the subject. Volk & Ming (2009, p. 57) observed that "the attitudes students have about technology, whether received through parents, peers, schooling, or one's daily life experience, play an important role in their ability to participate actively in their current and future technological world". More than just personal choice, the aggregate uptake of curriculum subjects can also have large effects on national economies and social development (Gaotlhobogwe, Laugharne, & Durance, 2011).

Purpose of the study

The purpose of this study was to provide a basis for comparison of patterns of girls' attitudes towards D&T between the two countries. Such a comparison provides opportunities for: information sharing; contribution to knowledge; as well as future research collaborations. In order to meet this purpose, the following research questions guided the study:

What factors influence girls' attitudes towards D&T in Swaziland?

What factors influence girls' attitudes towards D&T in Botswana?

Are there significant differences in factors that influence girls' attitudes towards D&T between Botswana and Swaziland?

Methodology

Research design

A quantitative research approach was adopted. While a mixed method design would have been the most suitable, due to cost implications it was not possible for interviews to be conducted given that the study was done in two countries. A questionnaire adopted from Gaotlhobogwe (2010) and influenced by the framework based on attitudes formation and change (Indoshi et al, 2010) was used. This questionnaire was developed for purposes of appraising girls' cognitive and behavioral attitudes towards D&T. The Cronbach's alpha coefficient for the fifteen items was .665 suggesting that the items had relatively acceptable internal consistency (note that a reliability coefficient of ≥.5 is considered "acceptable" for preliminary research (Robinson, Shaver, and Wrightsman, 1991; Peterson, 1994).

Research setting

Three high schools from each country were purposefully sampled for the study. From Swaziland schools from the following areas were sampled; Mbabani (the capital city); Dlangeni (a rural area about 40 KM from Mbabani); and Elangeni (a semi-rural village about 15 KM from Mbabani. Similarly, from Botswana, schools from the following areas were sampled: Gaborone (the capital city); Shoshong (a rural village about 250 KM from Gaborone); and Maun (a semi urban village 700 KM from Gaborone).

Participants

A convenient sample of 965 girls [age ranging from 10 -22] from the six schools completed the questionnaire. See (TABLE 1) for the distribution of the numbers of D&T and non D&T girls who completed the questionnaires in Botswana and Swaziland.

Country	D&T	NON D&T
Botswana	82	407
Swaziland	78	398

Table 1. Distribution of the numbers of D&Tand NOND&Tgirls

Data collection procedure

Ethical procedures and considerations were adhered to, to ensure that participants were protected and provided with information relating to the nature and purpose of the research, and to understand and participate without coercion. Due to cost implications data collection in Swaziland was conducted by Research Assistants (R.As) who were technology teachers undertaking training in D&T at the University of Botswana at the time. Prior to data collection these R.As were trained to conduct the administration of the questionnaires in their home country. During data collection, a briefing session with potential participants was conducted by the researcher (R.As in the case of Swaziland) with the help of resident teachers after which potential participants were given consent forms and those of their parents to complete and bring back to school the following day. The questionnaires were administered by the resident teachers in the presence of the researcher (R.As in the case of Swaziland) to only those who completed and brought back their consent forms.

Data analysis

A total of 965 (Botswana = 489; Swaziland = 476) questionnaires were analyzed using SPSS Version 21. In order to answer the first research question, Exploratory Factor Analysis (EFA) was used to reduce the number of items into a smaller number of factors for ease of analysis and interpretation (Field, 2005; Thomson, 2005). Data were factor-analyzed with Principal Component Analysis (PCA) to reduce complex data set to lower dimension that is easy to interpret from hidden data structures (Shlens, 2005*)*. By performing the PCA, data from the questionnaires was arranged and parameterized along the principal factors that describe attitudes of girls towards D&T. In the PCA objects or variables that are similar to each other have similar scores on each factor (or axis), while dissimilar ones are far apart

(Gaotlhobogwe et al, 2011). This visual understanding from the PCA provided inference on the patterns of attitudes of girls towards D&T in Botswana and Swaziland. Varimax orthogonal rotation was used on attitude to D&T questionnaires because most of the factors in this scale were not correlated (Thomson, 2005).

Independent Samples t-test was conducted to answer research questions two and three. According to (Field, 2005) Independent Samples t-test is used to test difference between two unrelated groups across the same continuous, dependent variables. Independent Samples t-test procedures were conducted to investigate differences across students' characteristics of country of origin (whether from Botswana or Swaziland) to ascertain the level of differences in factors that influenced their attitudes towards D&T. Before conducting the analysis, assumptions were assessed to ensure that the data set was suitable for Independent Samples t-test.

Results

Based on scree plots and Kaiser' Little Jiffy (eigenvalues >1), the 15 items that asked about the attitudes of girls towards D&T in Swaziland subscale converged into five factors (TABLE 2) that accounted for 52.70% of variation in item responses after extraction (see Appendix). The 15 items that asked about the attitudes of girls towards D&T in Botswana subscale converged into four factors (TABLE 3) that accounted for 47.93% of variation in item responses after extraction (see Appendix). Factor loading values greater than 0.40 showed that an item loaded on a particular factor. The five factors that influence girls attitudes towards D&T in Swaziland are shown in TABLE 2 as: Importance, Difficulty, Support, Knowledge, and pass rate (see Appendix).

The four factors that influence girls attitudes towards D&T in Botswana are shown in TABLE 3 as: Complexity, Importance, Gender and Support (see Appendix).

Independent Samples t-test was performed on the factor scores to test differences between the two countries across the two common factors [Importance and Support] simultaneously. The results shown in TABLE 4 (see Appendix) indicated no significant difference in terms of Support [t (853) = 2.220, p=0 .027], and significant difference in terms of Importance [t (853) =-7.564, p= .000].

Discussion

As the purpose of the study was to provide a basis for comparison of patterns of girls' attitudes towards D&T between the countries of Botswana and Swaziland, the findings reveal that patterns of girls' attitudes towards D&T between the two countries are somewhat different, indicating that the two countries could collaborate in efforts to promote participation of girls in the subject. Two factors [Support and Importance] emerged as common in influencing girls' attitudes towards D&T in Botswana and Swaziland. These results indicate that the amount of support provided [or not provided] by parents, siblings and teachers influence these girls' attitude towards the subject in both countries. So the limited numbers of girls enrolling in D&T in both countries is a sign that these girls do not get much support or encouragement to do so from all whose support is paramount. The enrolment of girls in D&T could potentially be bolstered by promoting the subject to the public and by ensuring that these girls get much social support to alleviate potential obstacles. Lin, Wen-huiTang, & Feng-Yang (2012) discuss a study in which women felt helpless and oppressed within their families in terms of using Information and Communications Technology. The authors report that the absence of support and help from families and the constraints these women experienced in using their home computers hindered their ICT learning (p. 80); and although they recognized its importance in the modem world and were willing to learn, the lack of support from family members left them feeling anxious and helpless (p. 81).

The limited number of girls enrolled in the subject in both countries is also an indication of the perceived unimportance of the subject to these girls. The more females take up technology related jobs and increase female role models the more the subject will be perceived as important, and then the attitudes will be influenced positively.

Differences in patterns of girls' attitudes towards the subject between the two countries emerged in five different areas. In Swaziland, the factors that emerged as having an influence in girls' attitude towards the subject and the same not having the same influence in girls' attitude in Botswana were: the perceived level of difficulty of the subject; lack of knowledge about the subject; and the low pass rate of the subject.

All of the above factors have a direct bearing on the role of the teacher of D&T. It is upon the teachers to dispel such perceptions as harbored by most girls that D&T is a difficult subject. There have been studies (Growney, 1995; Gaotlhobogwe, 2004) that have proved that girls who enroll in D&T perform the same way as boys if not better. Girls have always perceived D&T to be a difficult subject area for them. The fact that girls in Swaziland view lack of knowledge about the subject as an influencing factor is a wakeup call upon the teachers and all that are involved to promote the subject to girls. Low pass rates coupled with the perceived level of difficulty of the subject is a major drawback in attracting girls into D&T. Pass rates and level of difficulty of a subject are determined by the methods of delivery and assessment. It is important that these two processes are reviewed to align them with the needs of the girl learners. Gaotlhobogwe (2004) observed that even though there were differences in boys and girls projects in Botswana secondary schools, the difference was in the context from which projects were conceived and not in craftsmanship. However, the same study indicated that D&T was more of a right-brain dominated subject and therefore favourable to boys; and that for it to appeal to left-brain dominated learners [most of which are girls], the curriculum, its instruction and assessment procedures need to be developed to accommodate left-brain dominant talents and skills.

In Botswana, factors that emerged as having an influence in girls' attitude towards the subject and the same not having the same influence in girls' attitude in Swaziland were: the perceived level of complexity of the subject; and the gendered nature of the subject.

The perceived level of complexity of D&T is a common factor among girls; it encompasses such perceptions as feeling inadequate to perform well in a subject area that is masculine in nature. Historically, girls felt threatened by the outlook of the subject and perceive it as not suitable for them. Botswana has made tremendous strides in reshaping the outlook of D&T, for example, building multi-purpose laboratories or workshops without machinery that could otherwise be intimidating to girls. However, the results of this study show that the legendary impression made in the past will take a long time to disappear. The underrepresentation of females in the training of teachers for D&T from Swaziland is in a way exacerbating rather than counteracting that impression.

The gendered nature of D&T emerged as a factor in Botswana where the subject is more established and familiar to girls, than in Swaziland where girls lack knowledge on the subject. This does not mean that the subject is less gendered in Swaziland; perhaps what it means is that other factors are more influential or due to the lack of knowledge on the subject, girls in Swaziland do not have much information to define the subject as masculine. The lack of knowledge on the subject in Swaziland is coupled with lack of female role models from which these girls could find solace. However, according to Gaotlhobogwe (2004) and Gaie & Nleya (2007) even in Botswana where there is increased access to the subject by girls, their perceptions about it being masculine have not changed. As a result, technology related subjects in Botswana are fraught with gross gender inequalities, observed Gaie & Nleya (2007). The finding of a study by Gaotlhobogwe (2004), that analyzed D&T projects at secondary school level in Botswana revealed major differences between boys and girls projects.

Conclusions

Attitudinal studies have shown a complex interaction of underlying factors that influence patterns of attitudes towards curriculum subjects. The scope of this study would not allow all the factors involved to be explored hence focus was on the cognitive and behavioral factors which were more likely to influence NON D&T girls than emotional factors. While the theoretical and conceptual framework based on attitudes formation and change indicate a dynamic interplay of environmental, administrative and curriculum related factors, this study has revealed that environmental factors alone can have so much influence. It is therefore recommended that interventions to promote the subject among girls should target not only them but their families as well.

The gendered nature of D&T has been viewed as a socialization problem rather than a biological determination problem (Gaotlhobogwe, 2004). The same has been viewed as raising issues of moral justification and problems of moral obligation (Gaie & Nleya, 2007), this raises the problem beyond just the administrative and curriculum related factors.

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Appendix

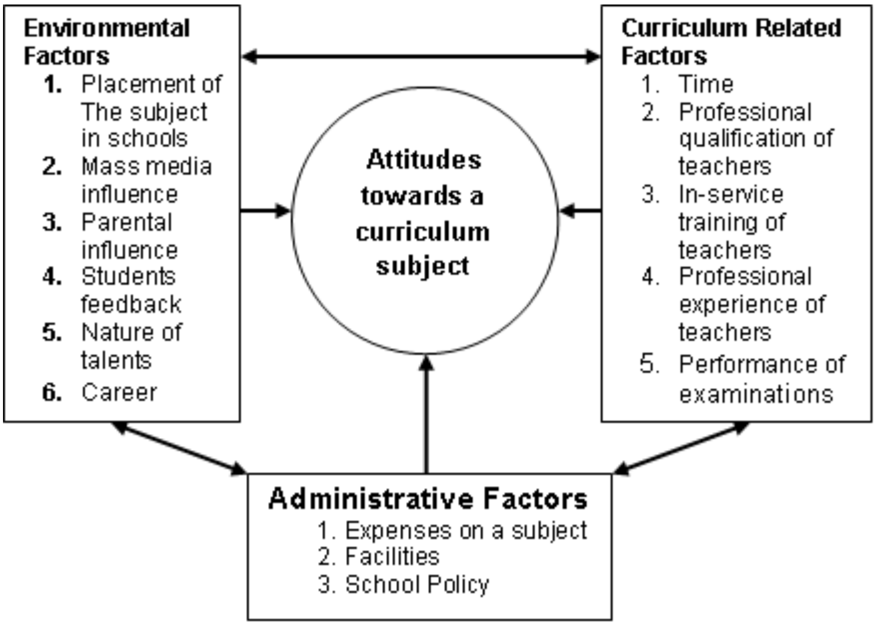

Figure 1. Conceptual framework based on attitudes formation and change (Adopted from Indoshi et al (2010).

	Importance	Difficulty	Support	Knowledge	Pass rate
DT not important for my future career	.743				
DT not important in my life	.712				
No interest in DT	.625				
Few jobs related to DT	.506				
DT is a difficult		.763			
Likely to fail DT		.749			
Lack confidence in DT		.585			
DT not suitable for girls		.444			
Lack parental support for DT			.738		
Lack siblings support for DT			.716		
Lack teachers' support for DT			.505		
Only a few girls do DT					
Lack female role models in DT				.718	
Lack of knowledge about DT				.631	
DT pass rate is low					.888

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 7 iterations.

b. Only cases for which School Ref = Swa are used in the analysis phase.

Table 2. Factor Loadings for Swaziland

	Complexity	Importance	Gendered	Support
Likely to fail DT	.763			
DT is a difficult	.717			
DT not suitable for girls	.551			
No interest in DT	.544			
Lack of knowledge about DT	.507			
DT not important for my future career		.783		
DT not important in my life		.733		
Only a few girls do DT			.747	
Lack female role models in DT			.561	
DT pass rate is low			.555	
Few jobs related to DT			.426	
Lack siblings support for DT				.736
Lack teachers' support for DT				.656
Lack parental support for DT				.611
Lack confidence in DT				

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 7 iterations.

b. Only cases for which School Ref = Bots are used in the analysis phase.

Table 3. Factor Loadings for Botswana

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Importance	Equal variances assumed	5.101	.024	-7.564	853	.000	-.491	.065	-.619	-.364
	Equal variances not assumed			-7.540	830.413	.000	-.491	.065	-.619	-.363
Support	Equal variances assumed	.170	.680	2.220	853	.027	.150	.068	.017	.282
	Equal variances not assumed			2.218	846.976	.027	.150	.068	.017	.283

Table 4. Independent Samples Test for Common factors between Botswana and Swaziland girls

The RAIFFET, a network for support and development of TVET in teacher training institutions in Africa

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Abstract

The countries' development depends largely of the development and the effectiveness of their education systems, both to promote education for all (EFA) and technology and vocational education and training (TVET) for each of them. The situation is particularly difficult in sub-Saharan Africa (SSA) and it is very difficult for many countries to provide a school that offers all children the opportunity to attend school beyond some basics. The access to primary education is not guaranteed for all, and few of them have the opportunity to receive vocational training enabling them to obtain a recognized professional qualification. The lack of qualified and competent teachers is another manifestation of the problems. Many institutional actors, including UNESCO, help foster the development of educational policies to overcome these institutional, structural and functional weaknesses. The RAIFFET was formed to make a modest contribution to this momentum by supporting the development and structuring of teacher training and education research in SSA. This paper presents some elements of understanding of the situation and the orientations of the network's contribution to this dynamic.

Keywords

Technology education, vocational training, education for all, development, Sub-Saharan Africa, educational network

Introduction

The adoption by UNO of the Millennium Development Goals (MDGs) and by UNESCO of the Education for all goals (EFA) mark an important turning point in the elaboration of a common initiative who take a great importance in Africa, specifically in sub-Saharan Africa (SSA). This policy aims to improve the lives of all people by eradicating poverty and misery in the world. The means to achieve focus largely on education becomes an end in itself: to reduce illiteracy, provide access to basic school for all, promote equity of opportunity. Through education, other objectives are targeted, such as promoting the fight against poverty, gender equality, sustainable development or partnerships for development. In Sub-Saharan Africa (SSA), despite significant progress, the situation in the late 1990s is particularly contrasted from one country to another but also internally to each of them. Several indicators show that the problems of schooling, illiteracy, gender, social, cultural or ethnic discriminations are recurrent and strain widely throughout the countries' development opportunity. Maintaining an entire segment of the population in a state of under-education in most countries forgo development capabilities that should represent a young and dynamic population.

Beyond these general objectives concerning general education, the issue of access to a professional qualification is posed. Indeed, how to think about development only in terms of general education? We see the importance of basic education for all and discrimination mentioned above are scourges which does not concern the countries of SSA. However, this basic education has little social value if it is not accompanied by a possibility of social integration. Have a professional qualification to practice a profession that allows to meet his own needs and those of his family, is essential to the success of this social integration.

Significantly, TVET is situated in a broader framework of human resource development (UNESCO, 1999) that includes the offer as well as the interaction between supply and demand (Rwehera, 2004). This offer includes various levels and fields of education and training systems of formal and non-formal, including TVET. It also includes labour supplements from external sources, including migrant workers. In fact, in the late 90s, when UNO and UNESCO formulated their global aims, TVET appears, on the one hand, firmly rooted in the ideals and objectives of education and on the other hand, generally imbued with the labour market requirements and standards in force in the work (Atchoarena & Caillods, 1999).

The school enrolment issue in a country based in part on school goals (UNESCO, 2000). The link between education for all and vocational training for each one is particular in SSA, especially where the very existence of education for all remains a goal. Under these conditions, TVET often appears as a luxury out of reach that is overlooked and sent discreetly to the business world, ordered to take charge of themselves training their employees and prospective employees. But, with informal sectors that often occupy nearly 80% of the economy of a country, this training is reduced to companionship mainly based on reproduction by imitation of the traditional gestures of the profession (Sindzingre, 2006). The institutionalization of TVET in organizations designed and planned structures and this is not an easy task in itself (Ginestié, Huot-Marchand, & Delahaies, 2012). These difficulties for financing TVET organizations and related to the structuring of TVET courses are amplified in SSA by the chronic deficit of resources needed to conduct analyses of job requirements and qualifications (R. Reinikka & Svensson, 2001).

Many actors are involved in this support to development; this article aims to present an initiative driven there some fifteen years to promote the training of teachers, researchers and managers in the areas of technology and vocational education and training (TVET) in Africa. We formed an African network of technology education teacher training institutions (*Réseau Africain des Institutions de Formation de Formateurs d'Éducation Technologique*: RAIFFET) with a mission to get closer and support the structuration of these institutions; the focus is put on the relationship between teacher training and educational research.

The context of TVET in SSA

The first weakness at the end of the nineties was a poor and unequal schooling. The great majority of countries were widely under the standards of the millennium goals, with a great diversity of situations. About 40% of kids (38 millions) did not schooled. The schooling rate was about 12% for pre-school education and 57% for primary school (Banque mondiale, 2010). It was about 24% for secondary school, 4% for higher education and 5% for TVET. The enrolment of girls is a recurrent problem in many countries. The illiteracy rate for women is almost always much higher than that of men. Similarly, access to higher education or TVET is largely reserved for men. The achievement of priorities supposes real political engagement and an adequate use of the financial means.

With 44% of young people under 14 years of age (approximately 300 million school-age children), the population in SSA is very rural and rose 2.65% per year. Urban growth is twice as important as rural progression, also reflecting a strong rural exodus. Approximately 58% of the population lives below the poverty line on less than a euro per day. If 70% of the population over 15 years of working, there are significant differences between genders and jobs are mainly agricultural (UNO, 2011).

During the first decade of the 21e century, we observe a big increase of the population, mainly in the cities (about 41%). If we observe also a significant amelioration of the health, there is not significant progress in education; 72% of young are illiterate. The most significant progresses in some countries are mainly related to the abandonment of school fees. Unfortunately, this loss of resources for schools has not always resulted in increased funding from the state. This very often leads to a deterioration of conditions in schools with overcrowded classes, a chronic lack of the most basic teaching materials (pens, copybooks, school books...), and even the lack of classrooms, tables, or chairs.

The development in SSA is too often plagued by corruption (R. Reinikka & Svensson, 2005). These are not just resources that are lost; more discreet forms of corruption undermine the effectiveness of educational systems (R. Reinikka & Svensson, 2006). The inadequacy or absence of reliable information systems (R. Reinikka & Svensson, 2011) about schooling, quality, or effectiveness of education, impacts directly the management of educational systems, leaving the door open for embezzlements and this at all levels, from ministries to teachers themselves (Ritva Reinikka & Smith, 2011). For example, many cases of fraud to examinations or to assessments are often mentioned in many countries; in some, one uses the term of sexually transmitted averages.

Qualitative studies in SSA are not many but they retell all the bad quality of teaching and the low level of students. Learn remains the ultimate goal of any school, whether basic skills of primary school or knowledge and skills acquired in TVET. Some countries have coped with the mass education while ensuring an educational level if not higher, at least the same. The huge disparities qualitatively emphasize the carelessness in the management of education. Few African countries participate in international surveys, which makes comparisons difficult. Despite this, the few data available (e.g. TIMSS[1]) are an important benchmark for evaluating the performance of African education systems; they point an extremely low level in mathematics and science (UNESCO, 2011). Few countries in SSA have the resources to support the curriculum structuring. It is not uncommon to have training programs for which the curriculum, structure and equipment were imported and appear completely inappropriate to the local context.

Teacher shortages manifested in general terms and in a particularly dramatic for some specific areas. For example, reaching a ratio of 25 students per class, within a reasonable time, supposed to recruit and train a huge number of teachers (about 4 million for EFA). Concerning TVET, SSA countries need to recruit and train one million teachers for ameliorating the very poor per pupil teacher ratio. The issue of teacher recruitment is both quantitative and qualitative (Ginestié, Balonzi, & Kohowalla, 2006). The proportion of unqualified teachers in sub-Saharan Africa is particularly critical. In addition, teachers in fragile societies work in precarious conditions; there is little means to pay them, so the job is not attractive for newly qualified graduates (Bekale Nze & Ginestié, 2011, 2012; Ginestie & Bekale Nze, 2014). To cope with the shortage of teachers, many countries rely heavily on temporary contracts for the recruitment of incompetent personnel and without training (Ginestié, 2012). In fact, the prestige of the profession is diminished and it is unfair to make them bear the responsibility for poor results of their students while the typical problem is the social status of the teaching profession, level of qualification, training, salary... (Ginestié & Bekale Nze, 2014)

The analysis of the evolution of indicators related to schooling and functioning of education systems is particularly helpful for understanding trends in SSA, during these last 15 years. The Dakar Forum (UNESCO-BREDA & WGECD-ADEA, 2010), for example, led to several important changes: i) the inclusion of EFA in the overall development of the education sector is itself an element of national strategy for growth and reduction of poverty; ii) it sparked strong international mobilization for education with a stated priority for Africa both in terms of official development assistance in cross-sectorial and budgetary choices of countries. However, despite this mobilization, the resources provided to countries are under the promises and show signs of slowing, specifically since the 2008's crisis. Enrolment rates steady progress but these rates are more favourable for boys than for girls. In the space of ten years, the number of children increased from 85 million to over 133 million. School conditions have, however overall deteriorated. The secondary school enrolment rates have also increased significantly with over 16 million new entrants. Enrolment in TVET students has more than doubled, from just over 1 million to over 2 million. The progress of TVET is obvious but not enough effective to make a real impact on the lives of disadvantaged children. The disparities between countries remain, but are less important.

The emphasis on EFA in part overshadowed a deep reflection on secondary schooling. The question that arises is that of the after primary education of these children: should they continue their education in general or technical secondary education? If the primary-secondary-university continuity is obviously logic, the fact remains: (i) that a little part of students attend school after primary school, (ii) that TVET remains, in spite of important quantitative progress, a minority in post-primary extensions, (iii) that it is still largely structured around training for jobs in the formal sector while the informal sector is widely ignored, and (iv) that the reduction of education for all only to general knowledge, does not allow countries to engage in a sustainable development processes of their social, economic environments and, ultimately, political and cultural.

The informal sector represents, in some countries, up to 80% of economic activity. It is a major part in the creation of jobs and the production of wealth in these countries. Many young people will have jobs in this informal economy, often in appalling social and professional conditions. Generally underpaid, these jobs are largely discredited, especially regarding the required qualifications. The recognition of qualifications remains a major challenge that requires their integration into a system of vocational training. Some experiments, still too few, try to link the development of training, recognition of qualifications, and structuring the informal sector (Walther, 2006a, 2006b, 2009; Walther & Tamoifo, 2009).

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[1] TIMSS: Third International Mathematics and Science Study

The traced prospects put once again highlight the need for a comprehensive approach that promotes the idea that access to a professional qualification is first and foremost the key to getting a stable and gainful employment. Thus, it is necessary to improve the poor general opinion about TVET. To do this, it is proposed that education policies take into account the national context and set up a control designed to improve equitable access to TVET (Ginestié, 2014). The creation of RAIFFET aims to make a modest contribution to this development effort and structuring through the development of teachers and trainers training.

Structuring a net for TVET

The African Network of institutions of Training of Trainers for technological education was established in 2002. It brings together initially Francophone African countries, in the sub-Saharan area as well as North Africa. At its constitution, RAIFFET relied on Colleges of Education Higher Technical Education (ENSET) legacies of French colonization, which are present in almost all francophone African countries. These institutions have all evolved since independence but they still remain imbued with the French tradition of planning and structuring training. These are all good examples of a concept of vocational training thought for a rational organization of industrial development. Teacher training is organized in a general pattern that corresponds to a conventional structure of the industry and the economy. These organizations, rather from the years 70, are poorly suited to social, cultural, economic and political of 21st century. The RAIFFET answers this concern to adapt teacher training to the issues and challenges of this new century and to include the training of these teachers in more modern outlooks, more appropriate to the real African societies. To do this, the renovation of these training institutions implies redefining their missions and engaging them in a quality and relevance improvement process of their organizations.

A few simple ideas chaired the network constitution: i) improving the quality of TVET is based on improving the quality of training for teachers or trainers; ii) the contextualization of training based on the development and structuring of educational research conducted by local teams, integrated in partner institutions; iii) the development dynamics based on the organization of an African scientific community with its own structures for exchanges and scientific debates; iv) this process must be accompanied to allow it to reach the highest international scientific level. Obviously, the situation is very different from one partner to another. Some already have education research laboratories and are engaged in this process of joint research training, others do not. In all cases, virtually all confuse education research with application of imported educational devices such as the competency approach or project approach; their models are often very old and all the time unsuited to the country's educational conditions. Many of these institutions are leaving, more or less explicitly, the low social prestige of teacher training for those better regarded of engineers or executives. Several axes organize network activity.

International conferences

The establishment of an African scientific community is organized through international conferences. To date, four conferences were organized. The central theme is based on the joint of technology education and vocational training. When the network was launched, this link does not self-evident, and training fell very often in separate organizations of general education. The RAIFFET was one of the first promoters of this integrated and comprehensive approach: indeed, how can access to a professional qualification for everyone regardless of education for all, especially for scientific and technological education. Since its creation, the network was positioned in a clear way, for a radically different conception of what was traditionally practiced in Africa, but also in many countries of the Francophone sphere.

The first conference was held in 2005 in Libreville (Gabon) on the theme "*Technology Education, Vocational Training and Sustainable Development*". It brought together seventy-seven participants from eleven different countries, including eight African countries. Sixty papers were presented and gathered in the conference proceedings (Bekale Nze, Ginestié, Hostein, & Mouity, 2006).

The second conference was held in 2008 in Hammamet (Tunisia) on the theme "*Technology Education, Vocational Training and fight against poverty*". It brought together eighty-four participants from seventeen different countries, including fifteen African countries. Sixty-three papers were presented and gathered in the conference proceedings (Bouras, Bekale Nze, Ginestié, & Hostein, 2008). At this conference, we note an increase of the African countries representation.

The third conference was held in 2011 in Saly Portudal (Senegal) on the theme "*Technology Education, Vocational Training and equal opportunities*". It brought together fifty-six participants from fourteen different countries, including twelve African countries. Twenty-seven papers were presented and gathered in the conference proceedings (Wade, Ginestié, Diagne, & Bekale Nze, 2011). These conference was initially placed in Ivory Coast, but due to political events and big troubles, we decided to move it in Senegal, very shortly before the date; it was the main reason of the few participants.

The fourth conference was held in 2014 in Marrakech (Morocco) on the theme "*Technology Education, Vocational Training and teacher training*". It brought together eighty-nine participants from eighteen different countries, including fifteen African countries. Sixty-four papers were presented and will gather in the conference proceedings (proceedings are under publication).

The next conference, the fifth, will be held in 2014-2016 in Douala (Cameroon). The theme is not defined at this moment and we expect a large opening of this conference on English African countries.

The organization of these conferences assume to facilitate the movement of African participants. The costs incurred by travel and accommodations are beyond the reach of most of them. The main difficulty is of course to ensure sufficient revenue beyond the individual contributions. The choice made is that the contribution of each African participant is minimal - 400 euros for the last conference - and that the organization supports the organisation, airfare, and accommodation. The cost for organising a conference is about € 100 000.

Mobility of researchers, teachers and executives

The life of the network, outside of conferences, develops in the organization of the mobility of researchers, teachers and managers, in the context of intra and extra African exchanges.

The RAIFFET organise also some regional seminars – in North Africa, West Africa, and Equatorial Africa – around themes like structuration of research units in education, development skills for promoting quality in education, etc. These seminars aim to federate initiatives of local exchanges between closer countries. They impulse mobility between different partners and they give opportunity to the emergence of common projects.

It is in this framework that consists UNESCO Chair "scientific and technological education and teacher training" in partnership with the Ecole Supérieure du Professorat et de l'Education of Aix-Marseille University and the Ecole Normale Supérieure de l'Enseignement Technique of the University Cheikh Anta Diop of Dakar. This academic chair is the heart of the creation of a UNITWIN network that combines ENSET of Rabat (Morocco), the University of Tunis, ENSET Koudougou (Burkina Faso), ENSET Douala (Cameroon) the University of Libreville (Gabon) and the University of Lubumbashi (Democratic Republic of Congo). The aim is to thus form a network of excellence as a support for the promotion and development of research and training in the areas of TVET and EFA. This project is largely supported by UNESCO, the Agence Universitaire de la Francophonie (AUF) and the African Development Bank (ADB).

Currently, most of mobility is financed by the European Erasmus Mundus program. These are eighty-four master students, PhD students fourteen and twenty-six faculty members or executives who benefit from these funds. Regarding the masters, students take lessons for three semester in a European university and finalize their diploma during the last semester in one of the African partner institutions. Doctoral theses are organized in co-supervision between a European laboratory and a laboratory of one of the African partner institutions. Regarding academics and executives, it is more specific mobility, in shorter time, and aimed to developing contacts between the partners. The overall project budget is € 2.8 million.

Beyond this program funded by the European Union, the different mobility organizations led to the defence of twelve doctoral theses and numerous periods of study for some master's students. These programs have a great success and they help training teachers-researchers occupying more and more important functions in their home institutions and also in the organization of education systems of their countries.

Financial resources and network structure

The main concern is of course to find the financial resources for these projects. Funding comes in part from major international organizations. UNESCO assures RAIFFET support since its start. The AUF also makes an important contribution and a timelier manner ADB supports some of the actions taken. Regarding mobility, the funding provided by the EU cannot be compared with other investments; they helped launch a large-scale plan, and have contributed to the financing of the 4th conference of

Marrakech. Obtaining such funding has educational value for African partners who are discovering the setting up and monitoring of international projects.

Another part of the funding comes RAIFFET institutions themselves, usually as part of their normal operation or in the financing of local authorities. The excellent reputation of the network proves to be an excellent business-card for local support. The bilateral cooperation agreements between countries also support a part of the network activities.

All these funds are still fragile; since the 2008 crisis, network resources have largely been cut, if we excluded the European funding. To overcome these risks of financial deficiencies, the RAIFFET is in the process of developing and implementing an original organization. Considering the potential of expertise in all institutions, and specialized in science and technology, with recognized specialists, the network has developed a set of business expertise and professional training programs for large companies are active in Africa. This is to provide high-level training in the context of a fairly simple market. The price of these courses is those usually practiced by private companies and therefore quite high. The argument for these large companies for choosing the RAIFFET as the operator, is not the price's argument, but the argument of an investment in the development of TVET in Africa. This argument is convincing enough for these companies for having recourse to the network. For trainers, they receive a fairly substantial compensation given local pay levels. The RAIFFET finds, meanwhile, a large and regular source of funding for its activities. This dynamic favours more relationships between network partner institutions and fabric of large companies located there.

A steering committee composed of the President and three Vice-Presidents - one for each region of Africa - organizes and manages the network. A scientific council led by a board of five people - all women, representing different regions of Africa - is responsible for guiding the scientific policy and facilitate the scientific life of the network. An operational strategic group is responsible for the finding of financial resources for the network activities; it is this group which notably organizes the training activities with major African businesses.

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"More sausage and less sizzle"
The effectiveness of product design experts mentoring pre-service technology teacher education students

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Abstract

The value of students undertaking authentic tasks whilst receiving mentoring from professionals has been promoted in many education contexts from K-12 and in tertiary education settings as well. So too has the use of collaborative teams since they firstly, more closely approximate the actual functioning of design practices, and secondly, because there exists a substantial literature guiding the design, implementation, and maintenance of effective teams in a wide variety of commercial and learning contexts.

This paper reports on a study of fifty-one tertiary technology teacher education students working in teams and undertaking a series of concrete invention and re-design tasks. Design experts provided advice and commentary on how to approach each design task and acted as judges of the conceptual designs. Designs were judged using Australian Design Award criteria.

The nature of the advice offered to design teams when beginning their design work, the experts commentaries on team designs, and the teams' responses to both early advice and summative commentary provide insights into how experts perceive and advise students, and how students respond to the advice and commentary they received. Advice and summative commentary provided by the experts was often ignored by the teams who addressed design problems using first principles and with limited knowledge. Design precedents and deficiencies in existing products were ignored and the prevailing state of the art was seldom used to test concept designs. These findings suggest the need to reconceptualise how advice and commentary are provided and used with student design teams.

Keywords

Expert advice, collaboration, community of learners

Introduction

Technology teacher education programs aim to provide authentic learning activities for students due, in part, to the grounded nature of the learning outcomes in school syllabi. Faculty staff teaching in these program have a wide range of knowledge and skills which are often supplemented by outside experts working in particular fields who provide advice and feedback on scheduled tasks. By working together, experts and faculty staff enhance critical engagement with design concepts and practices in a way that externalises thinking and acting processes ready for subsequent reflection. The many complex skills encountered in design therefore become embedded in the social and functional context of their use. This study explores whether leveraging expert advice and feedback using a modified form of cognitive apprenticeship (Collins, Brown & Newman, 1987) improves student outcomes. A brief outline of the modified cognitive apprenticeships is provided, team approaches are justified, and details of the study and the support platform, InDesigner, are offered. This is followed by a discussion of some of the interesting findings that emerged from the results of this study.

Cognitive apprenticeships in design

The cognitive apprenticeship approach leverages the value and status of social interactions in promoting cognitive development by having experts scaffold and mentor students during their learning. Six teaching methods within a cognitive apprenticeship approaches are described by Collins et al (1987). The first method, modeling, was reflected in expert advice and criticisms of conceptual designs. Secondly, coaching occurred through the process of delayed feedback on performance. Scaffolding occurred before during and after conceptual design development meetings. Articulation of ideas was encouraged by asking teams to annotate their designs. Reflection was required on the commentaries provided by experts on conceptual designs. This was followed by specific goal-setting activities following reflection. Setting, elaborating and reflecting on personal goals improve academic performance (Morisano, Hirsh, Peterson, Pihl, & Shore, 2010). Due to time constraints there was no time devoted to exploration, the sixth teaching method described by Collins et al.

Team approaches

A significant number of affective and cognitive benefits are claimed to arise when using cooperative or team approaches (Gillies, 2007). The advantages that accrue from learning in teams as well as workload constraints on the judges provided good reasons for using teams in this study. The benefits that accrue from using teams are dependent to some degree, on a range of factors including gender composition, ability levels, team size, and task requirements (O'Donnell & O'Kelly, 1994). Team size is commonly between four and six but smaller teams may work better if the task requires substantial discussion and elaboration of arguments and ideas. Complex tasks often require smaller teams to maximize opportunities for team members to participate and reduce wait times between contributions (Webb, 1989). The maximum team size used in this study was five members and teams were heterogeneous in nature and randomly assigned.

Despite the demonstrated advantages of using teams, they do not always function in the ways intended. Some team members may reduce effort or engage in cognitive or social loafing (Salomon & Globerson, 1989; Latane, Williams, & Harkins, 1979). Cognitive loafing occurs when one or more students are not interested in a task whilst social loafing refers to an individual who does not contribute equally to the completion of a task (the "free rider" effect). To overcome potential problems when using team approaches, all students participated in a two-week training program immediately prior to the conduct of the study. The program was based on team building activities drawn from a variety of sources.

Study outline

Study duration was three months with one two-hour session taking place each week. During session time, teams were presented with the design briefs and encouraged to use the ICT support platform, InDesigner, installed on their team computer. Seven product design expert designers provided potted advice in that platform on how to approach the design tasks. Teams could access any expert as many times as they liked. The designs used in this study were a collapsible road barrier system, an adaptable watering can, a sequence-seating problem for airports, train and railway stations, and a rope splicer.

Teams sketched and annotated design concepts on large format paper. The conversations of every team during these sessions were audio recorded and later transcribed for subsequent discourse analysis (Gee, 2005), interaction analysis (Linell, 2009), and conversation analysis (Sidnell, 2010). At the end of each design session teams were required to reflect and report on their ideas in an electronic diary built into InDesigner. At submission, students presented their final concept designs in a hard copy and included annotations to explain and detail their designs. Submissions were judged against Australian Design Award criteria and a score out of 20 was assigned each work. Teams were placed into three categories based on their scores (hi/med/lo performing) for each task. Following judging by the expert panel (a rotating pool of two designers), critiques of the key ideas for each team (N=11 teams) and the cohort as a whole were loaded into InDesigner for collective review and debate. This review took the form of a collective feedback and analysis session that occurred at the commencement of the subsequent design session. Teams then responded to the judges' comments. Following the cohort feedback, teams were encouraged to set goals for their subsequent efforts.

InDesigner

InDesigner (coded in Adobe Authorware) served as an electronic hub during design sessions. Advice consisting of images and audio recordings of the expert designers as well as text translations of the recordings was accessible at all times. InDesigner also contained other instructional scaffolds in the form of prompts and hints (general and specific to each task), and a knowledge base that teams could interrogate to provide more detail on the design briefs that were initially presented. Teams uploaded their responses to the judges' comments in an aggregated database available to all eleven teams at all times. InDesigner logged all use by teams continually.

Some interesting findings

Looking at the use of expert advice

Contradictory evidence appears from two sources of data on the extent to which design teams utilized the expert advice available to them. Usage logs from "InDesigner" suggest that teams listened to one or more recordings of the designer's advice at the commencement of each two-hour design session. However, transcriptions of team conversations from the audio recordings immediately following the playing of the advice suggest that few teams responded to that advice, or discussed it to any length. Nor did they show any reflection of that advice through goals or annotations in their conceptual sketches. It appears that design teams listened to but did not take into account the advice that they were given. Further evidence for this interpretation comes from subsequent commentaries by the expert judging panel that point to the same issues as discussed in the advice. For example, experts commonly suggested looking at prevailing solutions to determine any weaknesses that might need to be addressed in new designs. There was little evidence that most design teams in this study made much effort to determine the limitations of existing product designs as they related to the design briefs. High-performing design teams did occasionally make an effort to profile existing designs but this only occurred in the middle two briefs, not the first brief (rope splicer) or the final one (road-barrier) There were no annotations provided on concept designs reflecting this analysis.

When responding to judges comments on their designs there were clear qualitative differences between the few teams that were (moderately) successful and those that were less successful (the majority of the teams). More successful teams occasionally challenged the comments of the judges on specific issues rather than the general tenor of the criticism. Lower-performing teams tended to respond negatively to criticisms ("who does he think he is?"; "yeah, yeah, yeah [sarcastically]). A common refrain offered by many teams was that "we can't sketch". Even though the expert advisors suggested some simple modeling of ideas, only one low-performing team developed a model for their design for the concourse seat brief. Teams often challenged the design requirements even though they were stated explicitly in the initial brief and, in some cases, completely ignored some requirements in their design e.g., interchangeable seat coverings to accommodate different seat locations in the field, materials for manufacture, stackability for easy transportation. This occurred despite the briefing sessions on each design task that occurred prior to the commencement of design sessions.

Status hierarchies

In collaborative work settings it is common for teams to differentiate themselves into a few core member who contribute actively to conversations, interactions (both within teams, between teams, and with third parties) and receive a great deal of attention, and a majority of peripheral members who participate rarely and receive little attention (Gould, 2002). Dominance of this type reflects status hierarchies formed on the basis of the perceived competence and confidence of some team members by their peers. In the present study, status hierarchies occurred most often in the middle-and low-performing teams and were always dominated by male members. Analysis of audio transcriptions of team conversations suggests that male members were deferred to for their perceived specialised knowledge of materials and manufacturing processes even when this knowledge was clearly inaccurate, inadequate, or plainly wrong. No attempts were made by non-dominant team members of either gender to test claims, even though specific evidence was immediately available through other resources. This pattern of deferral led to interactions and responses to expert judgment being dominated by the hierarchy leaders on a consistent basis.

The presence of dominant team members also helps explain the reduced turn-taking and help-seeking behaviours in teams. Karabenick and Knapp (1991) have shown that college students' help-seeking tendencies were directly related to their perceived likelihood of engaging in instrumental achievement activities, related to self-esteem, and inversely related to students' perceptions that seeking help is threatening. When students do not see themselves as being able to contribute to a design solution, they self-limit their interactions and do not seek help either from other team members or from external sources.

Why didn't teams act on the advice and feedback they received?

Analysis of transcriptions of the audio recordings combined with subsequent analysis of the teamwork samples (conceptual designs) showed that many teams ignored the advice of the expert designers. On the collapsible road barrier many of the experts recommended studying the existing designs in order to understand what the faults were. No team reviewed available designs (based on their submitted work and review of their conversations during design sessions) and critically analysed their performance. In the case of the sequence-seating design at least half of the teams designed seats from first principles, despite having samples of existing designs available in the InDesigner program as well as in lecture theatres around the university. Data logs show that few teams accessed this material (N= 4/11) but of the four that did, none seemed to realise the principles guiding sequence-seating approaches e.g., seating rail supporting individual seat modules that can be configured as required. Several design experts explicitly advised teams on this very issue. The effect of context was not appreciated by many teams e.g. seat at an airport indoors versus a seat exposed to the elements at a railway station. Therefore submitted designs were less flexible in their structure and appearance than they needed to be. No team submitted multiple concept drawings reflecting the sequence seat design in different contexts.

The negative responses of many teams to the asynchronous expert feedback they received raises issues about the extent to which teams acknowledged and used the feedback they received. According to Black and Wiliam (1998), feedback is both directive and facilitative. Commentaries such as "More sausage, less sizzle" (Judge A) in relation to concept designs were in fact a form of advice, not feedback (Wiggins, 2012). It was cryptic code for 'I need to see more detail development in that part of your design to determine if it can really work or not' (this specific form of feedback did appear in some of the other judges commentaries). In this case there was not enough goal-referenced language in the feedback to alert the design teams of the need to provide more detail and annotations in and to their sketches.

Although the expert judges provided advice on how to improve performance on subsequent tasks, this weakness confirms research on the features of feedback suggested by Narciss and Huth (2004) that were missing in this study. The feedback needed to be more tangible and transparent. Had the design expert been in the classroom he/she could have pointed to the issues within the documentation explicitly. Asynchronous commentary with little or no mark-up of the concept drawings hindered the effectiveness of the formative feedback provided. There was no opportunity to interrogate the design expert on the meaning or intent of the feedback, nor on clarifying other issues that might emerge. These communication issues were exacerbated by the very poor sketching skills of most of the design teams.

A further explanation for the ineffectiveness of the formative feedback was that to be useful feedback must be actionable and user-friendly. Common terms and utterances in a design practice where common understandings regarding language conventions develop over time are not necessarily the most appropriate terms to use in the context of technology teacher education students who are not design majors. Timely feedback was possible only in a summative form due to the asynchronous communications used. Although delayed feedback is known to benefit high achievers (Gaynor, 1981), many studies looking at feedback focus on mathematics where correct answers are possible. Design solutions may take many forms. It would have been instructive to consider the design teams to be novices, despite their previous and concurrent design experiences. Seen in this light, immediate feedback would have provided more explicit guidance, structure and support when it was needed which was during the concept design deliberations, rather than after (Moreno, 2004; Graesser, McNamara, & Van Lehn, 2005). If provided in this way, feedback would have become far more concrete and directive (Clariana, 1990).

Transfer of task performance

One of the features of the reported study was the opportunity to improve performance on conceptual design tasks through the transfer of skills that occurred through regular practice with feedback. According to Kulhavy, White, Topp, Chan, and Adams (1985), and Schroth (1995), the delayed feedback available in this study should have facilitated the transfer of design skills. However, there was no discernable transfer of design skills (as judged by the design panel). The findings in this study are consistent with research on the delay retention effect (Dihoff, Brosvic, & Epstein, 2003). A simpler explanation for the lack of transfer between early and later tasks is that the tasks used were too difficult for the students.

Conclusion

This paper reports on an attempt to provide design scaffolding to design teams using a form of cognitive apprenticeship. Analysis of the interactions between students who worked in teams on product design tasks and expert judges/advisors provided evidence on the effectiveness of expert advice and feedback on performance. Design teams did not respond positively to expert judgments about their work and were sensitive, particularly in low and mid-performing teams, to criticisms. A very common response by teams to the lack of detail and annotations in concept design submissions was that they could not sketch. This points to the need to develop basic sketching and drawing skills, use simpler design tasks, and provide more varied practice opportunities with synchronous feedback on performance. Prompting for the use of feedback in subsequent tasks is also indicated.

The ineffectiveness of delayed feedback in improving performance and the lack of opportunity to provide synchronous commentary and advice are seen as impediments to the use of design experts in technology teacher education programs. A further finding relates to the variable efficiency of teams in this study. Imbalanced role taking, gender imbalances in interactions, the appearance of status hierarchies, and social loafing effects point to the need to devote more time to the formation and development of effective teams prior to the introduction of external expert support scaffolds and teaching methods.

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Where do design insights come from and how can they be nurtured in the technology classroom?

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Abstract

Every technology syllabus in Australian schools promotes the development of creative, insightful design outcomes. A common approach to nurturing creativity follows Graham Wallas' four-stage model of insight: preparation, incubation, illumination, and verification. This model was incorporated as part of a two-semester fine arts oriented design course undertaken by students in a technology teacher education program at Sydney University. The following year a formal study of the creative design thinking of technology students took place.

As part of a mentored, authentic design program, eleven design teams reflected on their approaches to design tasks, the difficulties they were facing and how they resolved the dilemmas that were part of the four design problems they faced. Personal journals structured around responses to a series of prompt questions, audio and video recordings of team deliberations, team comments loaded each week into "InDesigner" (an ICT support program), and annotations on concept design drawings provided useful data on the extent to which good ideas and insights arose. Few did and this pattern was typical for almost all students during their remaining candidature.

More recent naturalistic research has revealed a number of paths by which insight can be nurtured and developed in addition to those arising from Wallas' insight approach. The contradiction path encourages us to notice, search for, and apply inconsistencies and anomalies; the connection path provokes curiosity, coincidences and connections by exposing ourselves to novel ideas; and the creative desperation path encourages us to escape an impasse by locating and correcting flawed assumptions and beliefs. Almost all insights emerge from some combination of these paths. These new understandings suggest fruitful methods by which technology students can develop insightful and creative thinking processes.

Keywords

Creativity, insight, Wallas, contradictions, coincidences

Introduction

The promotion and development of creativity in our school children has long been an unquestioned part of the lexicon of technology education. Yet all is not well in achieving this goal. In his famous 2006 TED talk "How schools kill creativity"; Ken Robinson decried the processes by which creativity is suppressed through a focus on English, Mathematics and Science at the expense of the creative and performing arts. (Note that Robinson covertly denies the potential of creativity in those major subjects he "criticised" in that talk). Elsewhere, Kim (2011) reports that creativity thinking scores as measured by the Torrance Tests for Creative Thinking have fallen significantly since 1990, particularly in the measure for creative elaboration. Creative elaboration is related to the capacity to take a particular idea and expand on it in an interesting and novel way. Many other researchers and educators have also made complaints about the focus on standardised achievement tests at the expense of creative outcomes.

In an effort to directly promote creative learning outcomes, education institutions from K-12 and beyond to university and college courses build in creative learning experiences for their students. A note worthy feature of these efforts is the large number of institutions that adopt, explicitly or implicitly, Wallas' four-stage model of creative behaviour as the basis of their programs.

This paper reports attempts in a technology teacher education program to develop creative outcomes when using Wallas' creativity model. A number of explanations are offered to account for the low creativity scores achieved by students. Alternate approaches to nurturing and developing creative outcomes emerging from naturalistic investigations of creativity in a wide range of domains are detailed. The alternative approaches complement rather than replace those based on Wallas' model.

Defining and nurturing creativity in technology education programs

Creative individuals are often described as risk takers, nonconformists, persistent, flexible and able to reformulate ideas in new and novel ways (Staw, 1995). The outcomes of their efforts are usually described in terms of originality/novelty (Rietzschel, Nijstad, & Streobe, 2010; Kaufman & Sternberg, 2010). However, newness or novelty must then be balanced by a degree of appropriateness in order to distinguish creative processes and outcomes from those that are bizarre or strange. Thus creative outcomes are both novel and appropriate. More elaborate conceptualisations of the nature of creativity such as those offered by Wiggins (2012) and Briskman (1980) are not canvassed here.

Conceptualising creativity in school syllabi

Though continually referred to in technology syllabi, the specific conception of creativity envisioned by syllabus developers is never made clear. No attempt is made to define the nature and purpose of creativity except in the broadest possible terms. Creativity is assumed to be innate in all students but not as a fixed immutable entity: rather an aspect of a student's consciousness and personality that can be nurtured in classroom learning context through strategic experiences mediated by appropriate pedagogies. Problems in defining creativity are further complicated by the assumptions teachers make about how to foster and nurture creativity. Different approaches to "teaching" creativity (if it can be taught) or in encouraging creativity in the classroom reflect personal and sometimes school technology community conceptions of creativity itself. This diversity in approaches is reflected in the research undertaken on creativity.

The most cursory inspection of the research on creativity reveals not one unified view, but rather many conceptualisations of creativity. Kozbelt, Beghetto and Runco (2010, p.21) broadly separate theories of creativity into scientifically oriented theories which have the broad goal of mapping the empirical reality of creative phenomena, and metaphorically-oriented theories that attempt to provide alternative representations of creative phenomena. The two orientations are not mutually exclusive. Nor are they endpoints on a continuum.

Preparing students to work creatively – working at cross-purposes

Participants and program

In the year immediately prior to the conduct of this study, every student enrolled in a 4-year undergraduate technology teacher education program (B.Ed) at Sydney University participated in two fine arts oriented design fundamentals units of study (Design Fundamentals 1a/1b). Fine arts qualified staff within the Technology Education Academic Unit (13 staff) of the Faculty of Education conducted these units. Elements of Torrance's (1979) incubation model (TIM) (itself reflecting the four-stage model of insight proposed by Wallas, 1926) were used to structure the seminar and assessment tasks. Of the three basic stages of the TIM (heighten anticipation, deepen expectations, extend the learning), much greater emphasis was given to the first stage which consisted of 1) creating a desire to know, 2) heightening anticipation and expectations, 3) getting attention, 4) arousing curiosity, 5) tickling the imagination, and 5) giving purpose and motivation. The early focus on heightening anticipation is commonly associated with divergent thinking (see for example Treffinger's (1980) creative learning model that focuses on building curiosity, fluency, originality, tolerance for ambiguity and risk taking). Extensive use was made of visual stimuli and prompts, goal free activities and so on. Teachers and seminar leaders who worked on these units assessed tasks. This stage served as a warm up or motivational starter (Murdock & Keller-Mathers, 2008) for the creative work that followed in the program in Yr. 2 where the present study was located (Teaching Technology 2a/2b), culminating in an extended major design project in the final year of the program (Year 4).

A number of other units were running concurrently with the design fundamentals unit. The most relevant for the purposes of this analysis were the curriculum units (Technology Curriculum 1a/1b, and in later years 2a/2b, 3a/3b) that served to provide extensive, varied and prolonged opportunities for students to acquire and master specialized declarative and procedural knowledge relevant to subjects studied in Years 7-12 in New South Wales secondary schools. Almost all tasks within those units, though nominally termed "design tasks", reflected closed experiences that leveraged and reinforced the value of the acquired declarative and procedural knowledge. Learning experiences took place in conventional hard and soft materials workshops and kitchens. There were no adjacent studio spaces for conceptual design work.

Procedure for evaluating creativity

After design teams submitted their conceptual and later physical designs, the external design judges (seven qualified product designers) independently evaluated the work using a modified form of the Australian Design Award criteria. A central feature of this award is the use of a comparison scoring system where judges are asked to rate a product (along each category) against existing/analogous products in the marketplace (a crude form of comparative judgment). Judges assessed work independently. This process therefore reflected a form of Amabile's (1982) consensual assessment approach.

Though the design award scheme included creativity as one of the criteria, it was not given prominence. Staff members from the Technology Education Academic Unit subsequently evaluated conceptual drawings and model product designs. Within the unit, three staff members were textile designers; one was a civil engineer, one a product designer, and four were food technologists, and four were Industrial Arts teachers with at least 10 years school teaching experience. A revised version of the Creative Product Semantic Scale (CPSS) (O'Quin & Besemer, 2009) was used to evaluate the creativity of team designs. This scale uses three major dimensions of product attributes (novelty, resolution, and elaboration and synthesis) with minor measures inside each of the major scales. This scale has been validated in terms of novelty for both naïve and expert judges (O'Quin & Besemer, 1989), though Kaufman, Baer, Cole and Sexton (2008) found that non-expert raters judgments of creativity were inconsistent (having lower inter-rater reliability) compared to expert raters. The elaboration and synthesis dimensions of the scale tend to load on novelty and resolution in different ways depending on the task and other factors (O'Quin & Besemer, 1989).

Methodology

Staff used the modified CPSS to independently rate the creativity of design work. Item presentation was rotated randomly. Judges were instructed to rate the designs relative to one another (one design against another design) rather than against an absolute standard (thus adopting a form of comparative judgment-see Goffin & Olson, 2011, or Pollitt & Crisp, 2004, for an exploration of comparative judgments). Inter-rater reliability was assessed using coefficient alpha and an alpha level of 0.80 was described as good for interpretive purposes.

Data analysis

Across teams, creativity scores were highest for the road barrier (hi=18/20, lo=4/20, median=12/20) and sequence seating tasks (hi=14/20, lo=9/20, median=10/20), intermediate for the rope splicer (hi=11/20, lo=3/20, median=9/20), and low for the watering can (hi=11/20, lo=3/20, median=8/20)). Inter-rater reliability ranged from 0.71 to 0.85 across the four tasks and eleven teams.

As a general population, student teams scored low on novelty (original/surprising/germinal) when compared to resolution (valuable/logical/useful), a measure of appropriateness. In terms of elaboration and synthesis they showed reasonable order but little complexity in their ideas. Their work was understandable and well crafted. This pattern was consistent for all male-only teams, all female-only teams, and for mixed gender teams.

Explaining the results: Design fixation, predictability and perfection

Three interrelated and overlapping explanations for the absence of novel creative outcomes in this study are the occurrence of design fixation, and the predictability and perfection traps. All relate to the activation of prior knowledge and the unwillingness of students to operate away from their cognitive, social and psychomotor “comfort zones”.

Fixation refers to something that blocks successful completion of various types of cognitive operations, including creative idea generation (Chrysikou & Weisberg, 2005 cited in Smith & Linsey, 2011, p.85.). Janssen and Smith (991) showed that presenting an example of an existing solution to a designer often leads them to copy features and principles into new designs. This can also occur even though the hints might be inappropriate, a form of negative transfer. In this study, students (acting as part of a team) displayed a form of fixation termed mental set. Student teams followed a constant frame of thought processes to guide their actions. For example, when questioned, people hold a fixed idea for the concept of a chair that consists of four legs, a seat bottom and seat back. These thought processes are developed and reinforced through extensive practice in hard materials workshops. Whilst efficient, these automated processes can become a barrier to alternate creative thinking processes since they largely operate unconsciously. Constant concurrent exposure to standardised design processes in parallel units of study (reflecting the very specific, mandated processes regarding design defined in New South Wales technology syllabi) reinforced the development of mental set. Student teams were implicitly encouraged to believe that there was one way to design products.

The predictability trap lies in arranging projects to run as smoothly as possible. Student teams in this study were acutely aware of the need to fulfill specific, extensive and sequenced reporting requirements for the major design project in the final year of the program in association with their finished product. It was far easier to achieve a high score in assessments by having all of the formal reporting requirements in place, rather than devoting substantial time and effort to pursue vague, incomplete and risky ideas that were more difficult to document and justify. Student teams became bound by their own prior knowledge and experience and pursued projects that reflect their perceived skills, focusing their efforts instead on extensive documentation of their work and completing a well manufactured and finished product. This approach represented a least line of resistance. Following this path reduced extraneous cognitive load (Sweller, 1988) and maximized effort expenditure within a fixed time interval. Teams played it safe and avoided mistakes by exercising existing well-practiced skill sets. Their achievement orientation (Dweck, 2000) was a performance-oriented one (rather than a learning oriented one). Student teams wanted to appear “smart” or successful as judged by themselves and by their peers. Little extra could be learned since their projects “looked back” rather than to the future.

If the predictability trap led teams to have their projects run as smoothly as possible (ostensibly by completing the tasks and filling in the requisite reporting requirements), then the perfection trap complemented this by encouraging them to eliminate errors and minimize taking risks. Errors slow progress, disrupt the coordination of complex tasks, lead to waste (time and materials for instance), reduce the likelihood that a project can be completed successfully, and lower the perceived reputation of a student (ostensibly because their work is not graded as highly as those that show more “complete” addressing of design goals. Reducing errors reduces unpredictability and uncertainty (two keys to “success” in creative endeavours). Constant practice in specific skills in associated units of study (undertaken individually as distinct from the team approach used in this study) helped students refine and eventually automate them. In these circumstances, the goal was to perfect performance by reducing errors, thus improving efficiency and effectiveness at the same time.

Being biased against creativity: an alternative interpretation of the results

An intriguing alternative explanation might shed light on the disappointing results for student team projects in terms of their creativity. Mueller, Melwani, and Goncalo (2011) argue that people can hold an explicit bias against creativity that is not overt, but which is activated when people experience a motivation to reduce uncertainty. Since by definition, creative ideas are novel; novelty can then trigger feelings of uncertainty that make most people uncomfortable. Research by Rietzschel, Nijstad and Stroebe (2010) report that novelty (the most important part of creative outcomes according to many researchers) and practicality are often viewed as inversely related by many people. An effectiveness-originality tradeoff emerges. This leads people to dismiss creative ideas in favour of ideas that are practical since they are generally valued (Sanchez-Burks, 2005) and more easily evaluated against one or more specific verifiable, observable and testable criteria. Furthermore, the implicit bias held by people against creativity interferes with their ability to recognize creative ideas.

Teams (and students) in this study experienced concurrent reinforcement of the value and utility of their practical skills through their hard materials design work. They were required to conform to specific NSW syllabus documentation requirements; and were restricted in the amount of time they had to complete their design work. The standard program skills work reinforced pragmatic learnings and one explicit goal of this type of work was to learn to reduce errors in production. Students regularly chose the effectiveness (pragmatic) side of the equation when approaching their work.

Moving beyond Wallas' insight approach – alternate paths to the same goal

The present study identified difficulties in fostering creativity in tertiary students when working in design teams on authentic tasks. Possible explanations for this included the design of school syllabi that influenced course content and potential inadequacies of basing creativity components of courses solely on Wallas' four-stage model of insight. More recent research in how people go about being creative offers an intriguing alternative.

When exploring 120 cases of insight represented in narrative form, Klein (2013), found that some creative insights were sudden (the "aha" moment), but some were gradual. Some insights were accidental (thus conflicting with Wallas' argument for specific preparation). Few cases in Klein's study showed incubation and in some it was impossible due to time and other constraints.

One of the important findings Klein made was that insights emerge due to the presence or appearance of triggers ("anchors" in Klein's terms) that led to changes in beliefs. The triggers were the presence of contradictions (inconsistencies, conflicts, confusions), connections, coincidences, and curiosities (where people spot implications), and creative desperation (where people need to escape an impasse). They ranged from weak to strong in their impact. All depended to some degree on exercising of perceptual-cognitive skills (see Klein & Hoffman, 1992, for an explanation).

Inconsistencies in the form of contradictions, confusions and conflicts can act as springboards to (creative) insights (Klein, 2013) by provoking curiosity (a key component of creativity). Curiosity is itself an expectancy violation. The connection path thrives on having many ideas occurring simultaneously, thus increasing the likelihood that one or unusual connections can be made. The connection path encourages students to continuously seek out knowledge and experience in different settings.

In the creative desperation path, students encounter impasse situations in which they may be trapped by flawed assumptions e.g., allowable moves in the nine-dot puzzle. Many tests of creativity load on the creative desperation path. Listing all assumptions when designing and planning is a technique used by many corporations and industries and is undertaken in order to reduce errors. By discarding the flawed assumption(s) we can gain new insights. However, the creative desperation path also provides opportunities to deliberately use leverage points in order to gain new insights. Here we are looking for constraints and affordances that are available and which can be used to shed new light on problems.

Each of the paths described by Klein (2013) uses a different trigger and each can act with or without the elements of Wallas' insight model. Each approach helps us change our beliefs and thus change possibilities in creative thinking and acting.

Conclusion

The limitations of the effectiveness of creativity development methods (based on Wallas' four-stage model) in a technology teacher education program were explained in terms of restricted school syllabi, design fixation and the predictability and perception traps. One further explanation for the low creativity scores was the potential bias people hold for practicality over novelty. Complementary approaches to Wallas' model drawn from naturalistic research such as spotting contradictions and coincidences, and being curious were shown to explain creative insights more completely than the Wallas model on its own. These complementary approaches provide additional complementary vehicles by which learners can develop creative thinking skills.

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Coding scheme comparisons: methods used in examining student cognitive processes while engaged in engineering design tasks

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Abstract

Implementation of design-based learning (DBL) pedagogical approaches has been wide-spread across science, technology, engineering, and mathematics (STEM) education (Crismond & Adams, 2012; Doppelt, Mehalik, Schunn, Silk, & Krysinksi, 2008; Fortus, Dershimer, Krajcik, Marx, & Mamlok-Naaman, 2004; Grubbs, 2013; Jacobson & Lehrer, 2000; Wicklein, 2006). At the same time however, examination of students' cognitive processes used during such experiences has not been nearly as abundant. As a result, minimal consensus has been established for an agreed upon coding scheme to describe students cognitive processes. In an effort to reach some degree of agreement regarding such a coding scheme, this paper presents an analysis of five coding schemes purporting to describe K-12 students' cognitive activity during engineering design tasks. The purpose was to determine the: (a) focus and intent of each scheme, (b) similarities and differences, and (c) from a cognitive science standpoint those concepts not being addressed.

Keywords

Design cognition, coding schemes, cognitive processes, K-12 education

Introduction

As interest in design cognition has steadily grown throughout the past 40 years, researchers have primarily examined the cognitive processes of practicing professionals such as architects, mechanical engineers, and software designers as they complete a design task (Cross, 2001). The main purpose of this line of research is to inform professional designers on how best to prepare future designers (Adams, Turns, & Atman, 2003). Only recently have researchers turned their attention to examining the design cognition of students at the K-12 educational level. The goal for this type of educational research, in addition to improved teaching of design skills, is to enhance the cognitive abilities of K-12 students (Roberts, 1994).

Of the existing studies examining design cognition, at both expert and novice levels, most have been conducted through three research methods: case studies, protocol analysis, and performance tests (Cross, 2001). Of these approaches, verbal protocol analysis has become the most frequently employed to describe and examine cognitive processes. Using a think-aloud design, researchers capture participants thought processes as they attempt to solve an engineering design task. A transcript is then produced documenting their verbalized cognitive processes. Analysis occurs through application of a coding scheme either created prior to the study or derived from an emerging framework. For the former, researchers have employed a variety of coding schemes to describe students design cognition.

Given the steady increase of explorations into connections between K-12 *design cognition*, (also termed *design thinking*), and development of student cognitive competencies, it becomes increasingly important to understand and choose the most appropriate coding schemes available, as each has its own intent and characteristics. To that end, this article examines recent K-12 design cognition studies from the perspective of the coding schemes used with the purpose of determining the: (a) focus and intent of each scheme, (b) similarities and differences, and (c) from a cognitive science perspective those concepts not being addressed.

Coding schemes

Focus and intent

A review of relevant literature revealed five coding schemes used in the majority of cognitive research designed to examine the cognitive processes of K-12 students while engaged in an engineering design task. Table 1 provides a summary of coding scheme elements identified through an examination of those studies. A significant difference between these coding schemes is found in the focus and intent of what is expected to be captured.

General engineering design process

Two of the coding schemes (Welch & Lim, 2000; Wilson, Smith, & Householder, 2013) adopt what is referred to in this study as a general engineering design process (GEDP) model to document the time students spent throughout each of the steps. Though both coding schemes were identified by their authors as being grounded in research related to engineering design, both were also crafted with the intent of being used by teachers as a scaffolding tool for students. Thus, each coding scheme captures broad processes students may work through. This simplification is tantamount to general heuristics one might use during problem solving, with minimal attention to specific engineering design principles. As a result, both coding schemes were classified in this study as being minimally-grounded in the design cognitive science literature.

Table 1. ***Overview of coding schemes***

Research study	Coding foci	Coding approaches	Number of codes
Welch & Lim (2000)	General Engineering Design Process (GEDP) *Instructional Tool*	Concurrent	24 *(5)*
Wilson et al. (2013)	General Engineering Design Process (GEDP) *Instructional Tool*	Concurrent	5
Mentzer (2012)	Practitioner Engineering Design Process (PEDP) *Engineering Textbook*	Concurrent	9
Kelley (2008)	Practitioner Engineering Design Process (PEDP) *Engineers' Notebooks*	Concurrent	17
Wells et al. (2014)	Cognitive Science Foundation *Task & Domain Independent*	Concurrent	6 *(8)*

Note. Parentheses indicate broad categories that subsume the codes used during analysis.

Practitioner engineering design process

Although it shares similarity with the two previously discussed models, Mentzer (2012) applies a coding scheme often represented in undergraduate introductory engineering textbooks. This model was largely based on a 1995 model developed through a content analysis of seven introductory engineering design textbooks (Mosborg, Adams, Kim, Atman, Turns, & Cardella, 2005). In contrast to broad, GEDP models, Mentzer applies a coding scheme with explicit attention to core engineering design processes such as modeling and feasibility analysis. Similarly, Kelley (2008), attends to specific, unique processes engineers engage in by using a 1973 coding scheme derived from notebooks of distinguished engineers that identified particular activities they worked through (Halfin, 1973). In comparison to other models that were created from verbal protocol analysis, the Halfin coding scheme was grounded in a content analysis approach, identifying specific processes engineers documented. Consequently, the intent of both the Mentzer and Kelley coding schemes is to describe students design thinking in terms of specific practices engineers engage in and has been coined practitioner engineering design process (PEDP) model by the researchers of this study.

Task and domain independent

Conversely, the Wells, Lammi, Grubbs, Gero, Paretti, & Williams (2014) study examined students' cognitive processes using the pre-established Function-Behavior-Structure (FBS) coding scheme, which is well-established in the cognitive science literature. Compared to other coding schemes the FBS ontological framework, as developed by Gero and associates (Gero, 2004), presents a significant difference with respect to intent. Specifically, the focus of the FBS coding scheme is to be task and domain independent and center more directly on designers' reasoning processes. Therefore, in this research, the FBS ontological framework was classified as a task and domain independent focus grounded in cognitive science.

Though all coding schemes previously described attempt to capture the cognitive processes of K-12 students during ill-defined design challenges, each employs a coding scheme that is uniquely different from inception in representing those mental activities. However, if the purpose of design cognition research is to examine students cognitive processes it is critical that researchers choose the most applicable coding scheme. Moreover, of significance for the research presented in this paper is that with respect to published research assessing student engineering cognition, minimal discussion describing the rationale for choosing any given scheme is provided in the research methods. This presents a major challenge for others who possess minimal understanding of what each coding scheme actually examines to conduct similar research.

Codes employed

Number and nature of codes

Comparing the actual codes that were used further aides in distinguishing between differences in coding schemes and establishing consensus. Overall, analysis of previous studies indicates the mean number of codes used is 12, ranging from as few as 5 to as many as 24 codes. Though existing literature does not identify a recommended number of codes, suggestions have been made on the challenge of too few codes being able to fully capture an individuals' cognitive process and too many codes being difficult for coders and too complex (Purcell, Gero, Edwards, & McNeill, 1996). In addition to the number of codes, Table 2 illustrates there are differences in the nature of codes attempting to illustrate students cognitive activity. Whereas one coding scheme applies codes to describe students reasoning around the three domains of function, structure, and behavior (Wells et al., 2014), other coding schemes (Welch & Lim, 2000; Wilson et al., 2013) use codes illustrating more of a linear model of designing (e.g. such as identify a need or a problem, research a need or problem, and model a possible solution). Such coding suggests universal problem solving steps, which directly challenges current beliefs that design thinking is a distinct form of problem solving. Additional categories used to describe students design cognition, identified as cognitive processes, include communication (Mentzer, 2012; Kelley, 2008; Wilson et al., 2013) and skill sets such as computing, measuring, and prototyping (Kelley, 2008; Welch & Lim, 2000). To that end, as Table 2 demonstrates, the codes employed capture considerably different processes students might bring to bear during engineering design. If seeking to describe specific reasoning processes, independent of task and domain, only the Gero (2004) coding scheme used by Wells et al. (2014), captures such processes.

Table 2. Codes Used to Describe Cognitive Processes

Wells et al. (2014)	Welch & Lim (2000)	Wilson et al. (2013)	Kelley (2008)	Mentzer (2012)
Requirement	Understanding the problem	Identify a need or problem	Analyzing	Problem Definition
Function	Generating possible solutions	Research a need or problem	Communicating	Gather Information
Expected Behavior	Modeling a possible solution	Develop possible solutions	Computing	Generating Ideas
Behavior from Structure	Building a prototype	Select the Best Possible Solution	Creating	Modeling
Structure	Evaluation	Communicate Solution	Defining Problems	Feasibility Analysis
Description			Designing	Evaluation
			Experimenting	Decision
Mapped Processes			Interpreting Data	Communication
Formulation			Managing	Other
Analysis			Measuring	
Synthesis			Modeling	
Evaluation			Models/Prototypes	
Documentation			Observing	
Reformulation I			Predicting	
Reformulation II			Questioning & Hypothesis	
Reformulation III			Testing	
			Visualizing	

Granularity

The level and degree of specificity of a coding scheme can also be examined to determine how adequate it is at empirically describing students' cognition during engineering design. Only one coding scheme (Welch & Lim, 2000) breaks down broad codes into more specific categories to further describe students' mental activity. However, the existing categories of that scheme covers modeling and construction, while not as much on the higher order cognitive processes such as analyze and synthesize. In comparison, two coding schemes have been developed that specifically address (a) levels of higher-order thinking and (b) the problem identification stage (Purcell, Gero, Edwards, & McNeill, 1996), both often found to be a challenge and/or barrier to novice designers.

Concerns

Consequently, as the purpose of this research study was to build consensus for future research centered on K-12 students' higher-level cognition during ill-defined engineering design tasks, analysis and comparison of existing coding schemes raised multiple concerns. First, though each coding scheme attempts to describe students' cognitive processes, minimal discussion focuses on operationally defining a cognitive process for the purpose of their research. Operational definitions are critical for accurate and consistent coding among coders. In addition, not provided is literature on and/or examples of what cognitive mechanisms are captured by each process. Such discussion should dictate how a coding scheme is derived and how it will be implemented for each study. Doing so will better equip researchers and educators with transferring research and findings to practice.

Second, since the type of task affects the cognitive processes demanded (Menary, 2007), the design challenge presented to students, such as design only, or design-to-make, ultimately results in differences in specific processes identified. As Table 3 illustrates, the design challenge presented to students varied across research studies. Kelley (2008) and Welch and Lim (2000) use cognitive processes that extend beyond reasoning skills and include building, modeling, measuring. Yet, when a verbal protocol analysis is employed for analyzing a design task without a construction component, the coding scheme will prove inadequate. Conversely, Gero's (2004) FBS model was intentionally developed to be domain and task independent, and therefore describes students' cognitive activity during engineering design. Furthermore, the FBS model specifically addresses higher order thinking skills (e.g. analysis, synthesis, and evaluation) which constitute the very competencies educators are most interested in assessing.

Table 3. Overview of study

Authors	Number of Participants	Design Time	Challenge Type	Research Design
Mentzer (2012)	17 (2-4)	2 hours	Design: 2 Briefs*	Descriptive & Comparative
Kelley (2008)	7	30 min.	Design: Different Context	Comparative
Wells et al. (2014)	40 (2)	45 Min.	Design: Prescribed	Comparative
Wilson et al. (2013)	17	3-4.5 hours	Design: Emergent	Descriptive Multiple Case Study
Welch & Lim (2000)	18 (2)	1- 2 hours	Design & Make: Prescribed	Comparative

Note. Parenthesis in participant's column indicates team size. The asterisk* indicates two different design challenges were employed during the study to compare differences between design tasks.

Conclusions

Improved understanding of the mechanisms that promote higher-order thinking skills can assist in developing instructional strategies that aim to improve a student's overall performance and positively impact their achievement and motivation toward learning (Brookhart, 2010). In light of this, design cognition is increasingly perceived as a viable approach for promoting student higher order thinking (Razzouk & Shute, 2012). Therefore, if the primary outcome for employing engineering design pedagogical approaches at the K-12 level is to develop students' higher-order cognition, needed still is research establishing suitable coding schemes for assessing that outcome. And although one such coding scheme (Purcell, Gero, Edward, & McNeil, 1996) has been identified as appropriate for examining students underlying cognitive processes during engineering design, a stronger alignment within the cognitive science literature must also be established. A suitable coding scheme for assessing impact on higher-order thinking coupled with broad support from cognitive science will provide the common platform for future investigations of engineering design cognition at the K-12 level.

Recommendations

As revealed through this examination of the foci and styles of coding currently used to describe students' cognitive processes, the first recommendation is to operationally define cognitive processes and provide some degree of consistency among future researchers of design cognition. Accomplishing this is quite challenging given there is minimal agreement among those in the cognitive science community for an acceptable definition of cognitive processes (Menary, 2007). And though some might suggest that a cognitive process can be described at the task level, the cognitive processes used for tasks such as brushing ones teeth or conversing with a friend might not qualify as the type of higher order thinking that occurs during an engineering design task. Likewise, whereas observing, measuring, managing, or computing might indicate a cognitive process, such processes might not qualify as a form of higher-level cognition required for ill-defined tasks such as engineering design. These considerations challenge existing coding schemes that describe students' cognitive processes in terms of modeling, building, or communicating, as being aligned with cognitive science views.

The second recommendation for achieving alignment with cognitive science would be conducting design cognition research that focuses specifically on the effect attention, memory; metacognition, self-regulation, transfer, and long-term retention have on students' cognitive processes. This is congruent with recent concerns addressing the cognitive limitations associated with decision making during design thinking. For example, Spendlove (2013) suggested such cognitive flaws as anchoring, confirmation bias, affect heuristic, and focusing illusion can affect a student's ability to make appropriate decisions during design thinking tasks. Addressing these cognitive flaws would necessitate the adaptation of current coding schemes, or the development of new coding schemes, in order to account for such cognitive flaws during engineering design tasks and more accurately describe a student's cognitive activity. Moreover, although research has been conducted at the expert level, minimal research has examined the effect such factors have on a student's ability to process information during engineering design tasks, any of which can inhibit their ability to integrate information or construct new knowledge. For example, Bilda and Gero (2007) examined the impact of working memory limitations on the design process during the conceptualization stage of design. Results from their research revealed that when higher cognitive demands were placed upon participants there was an overall negative effect on their cognitive activity performance during an engineering design task. Though such research has been influential in describing the cognitive processes of experts during design, there currently exists minimal research investigating such cognitive processes with students at the K-12 level, none of which has been documented in existing coding schemes. The cumulative evidence presented through published research clearly demonstrates there is still a need to establish a coding scheme that has greater sensitivity for distilling out cognitive processes than does the current coarse schemes such as the FBS ontological framework.

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Affinity for technology – A potential instrument to measure PATT (pupils' attitude towards technology)?

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Abstract

In Swiss secondary schools, technology education has only a marginal position, and many students, especially girls, lack knowledge and interest. To remedy this deficiency, we developed a teaching model called "Explicit, Reflective Technology Education" (EXRETU), and put it into practice within the framework of an intervention study with 14 participating classes in North-western Switzerland. One aim of this study was to investigate the affinity for technology of lower secondary school students in a research design comprising an experimental group and a control group. Based on existing research, we identified four personality trait variables as facets of the construct "Affinity for Technology" (AFT): 1. attitude towards technology; 2. interest in technical and technological contents, activities, and contexts; 3. self-efficacy in solving technical tasks; 4. vocational choice and gender roles. These variables were operationalized in an online survey with 480 students attending one of the three academic tracks (levels) of lower secondary level. By means of quantitative analyses we identified differences between (sub) scales and (sub) groups, thus showing interdependencies between the variables of AFT and effects of the intervention. As for the intervention, the students generally perceived it positively (> 80% likes). Even though AFT on average decreased slightly between grade 7 and grade 9, we could establish an increase under certain circumstances. These comprise teaching conditions that fulfill basic psychological needs like autonomy, competence, and social involvement to an appropriate degree. We shall discuss these findings critically, point out the strengths and weaknesses of the research instruments, and draw some conclusions on different levels: educational policy, school subject(s) and educational research.

Keywords

Interest, self-efficacy, gender roles, technology education

Introduction

This paper presents research findings of an intervention study with a teaching unit implementing the model "Explicit, Reflective Technology Education" (EXRETU), a research project supported by the Swiss National Foundation (SNF). Because of limits on length, the intervention itself cannot be explained in detail. Instead, we decided to focus on the theoretical construct "Affinity for Technology" (AFT) in lower secondary school students. A short outline of the EXRETU model in English is provided by Heitzmann, Safi & Guedel (2014) and Safi, Guedel & Heitzmann (2013), whereas a more detailed description (in German) is available in Guedel (2014).

Objectives and research questions

The objectives of the EXRETU project concerned two different levels: school development, and research. The former involved the development of the EXRETU model into a standardized intervention and in-service training for school teachers in order to prepare them for the intervention. In the research part, affective and cognitive variables such as students' AFT, conceptions of technology, and technical/technological competencies were investigated. Against this background our paper deals with the following research questions:

Q1: What AFT do young people manifest, how do the variables differ between subgroups of the sample, and how do the variables correlate?

Q2: How do students perceive the intervention with technology education?

Q3: How does technology education affect AFT?

Study design and methods

The implementation of the EXRETU model in schools was accompanied by a classical intervention study design comprising an experimental group and control group, in order to gather quantitative and qualitative research data (cf. Fig. 1). AFT was measured quantitatively with online surveys before and after the intervention (S1, S2 and S3), semi-quantitatively with open answers in working journals during and after the intervention, and qualitatively in interviews with teachers and selected students.

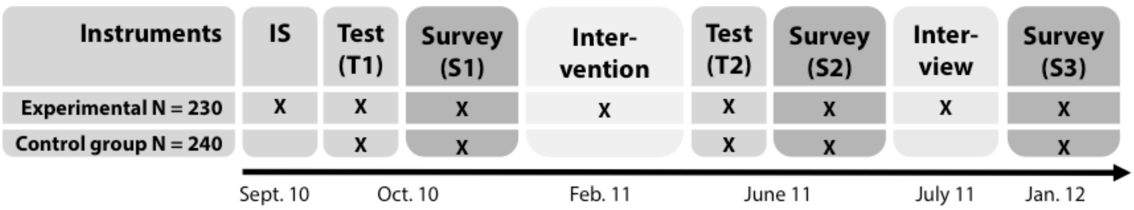

Fig. 1. Intervention study design with experimental group and control group. IS: In-service training for teachers; S1, S2, S3: pre-, post- and follow-up surveys; T1, T2: competency tests.

Altogether 31 teachers or teacher teams volunteered to take part in the research project, with 14 of them being assigned to the experimental group and 17 to the control group. This amounted to a total pre-test sample size of 483 students of grade 7 or grade 8 (aged 12 to 14) from all three academic tracks in North-western Switzerland. On the whole, the sample was evenly distributed between sex and the three tracks. The working journal sample only included the experimental group. Eight students were selected by predefined criteria (track, subject of the intervention, sex, AFT before intervention) for guided interviews after the intervention. Data analyses proceeded as follows:

Written survey, using quantitative methods (Bortz, 2006; Buehner, 2006):

– reducing data to reliable scales by means of principal component analysis;

– exploring differences between subgroups and subscales: t-Test, analysis of variance, effect size (Cohen's *d*);

– testing correlations and effects between variables: Spearman's correlation (rho), structural equation models;

– change over time: analysis of variance with repeated measures, analysis of covariance.

Open answers: categorization of open answers from the students' working journals (e.g. "situational interest").

Guided interviews: inductive and deductive development of categories according to the principles of qualitative content analysis (Mayring, 2010).

Theoretical background and operationalization of the construct "affinity for technology" (AFT)

Within the EXRETU study, the term "affinity for technology" (AFT) denotes a set of four personality trait variables which characterize different aspects of a person's relationship to technology (cf. Fig. 2):

- general acceptance of technology;
- individual interest;
- self-efficacy in solving technical tasks;
- career aspirations.

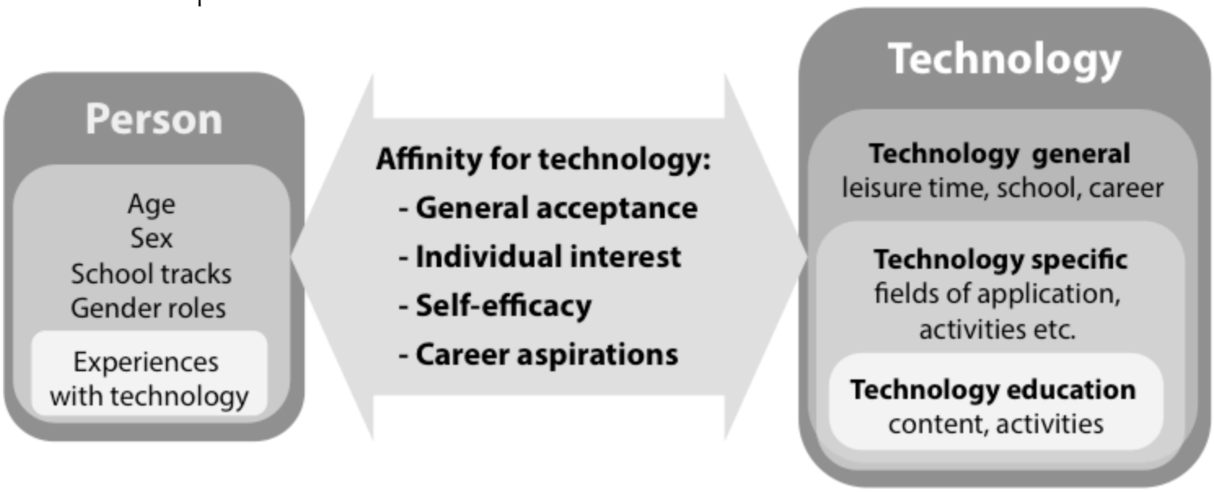

Fig. 2. Model of a person's relationship to technology, defined by four personality trait variables (Guedel, 2014).

Obviously, there are further factors characterizing the relationship between a person and technology, but in educational research and our project these four variables are considered the most important ones. In the following, a short description of each variable is given together with some examples of its operationalization in the questionnaire (example items translated from German). A complete documentation of all the scales (in German) is provided in Guedel (2014).

General acceptance of technology or attitude towards technology (OECD, 2006): We distinguish between "attitude" and "interest", thus presuming that attitude does not so much concern the personal relevance of an object to a person, but rather its relevance in general and for society. The scale asking about the relevance of technology for society was adopted from the Pisa 2006 questionnaire and specifically adapted to technology (OECD, 2006).

Example items:

Technological progress usually improves the living conditions of human beings.

Technology is useful for society.

Individual interest

According to the widely accepted person-object theory, interest is defined as a person's relationship to an object (Renninger & Hidi, 2011; Krapp & Prenzel, 2011). Interest has emotional (enjoyment), value-related (personal usefulness) and cognitive ("I want to know more") components, which were included in the following scales.

General interest in technology in different contexts: According to Todt (2010, 1995), interest can vary between different contexts (e.g. leisure time, school, work), because these contexts are differently connoted.

Example items:

In my leisure time, I like dealing with technology (enjoyment).

At school I want to learn more about technology (cognitive aspect).

Anticipating my future job, I don't see any use in dealing with technology (personal value).

Specific interest in different fields of application (Meyers, 2002): Several studies showed that interest varies remarkably between different contents or fields of application (Börlin, Beerenwinkel &

Labudde, 2014; OECD, 2007; Sjøberg & Schreiner, 2010). Against this background we analyzed interest in learning more about and working in different fields of technology.

Specific interest in design process activities: Within the context of our intervention study we paid special attention to the students' interest in activities concerning the design process each of them had to run through. Thus, we developed an item pool comprising 23 items along the lines of the German "Allgemeiner Interessen-Struktur-Test" (Bergmann & Eder, 2005).

Example items:

I like …/I would like to, if I had the chance to …

working/work with machines and other technical tools.

making/make sketches of new products.

reconstructing/reconstruct and fix things, like my bike or a watch.

reading/read newspaper articles covering technological issues.

developing/develop ideas for new products.

Specific interest in technical activities in future employment. According to international studies (OECD, 2007; Sjøberg & Schreiner, 2010), the appeal of working in the field of technology is not strong, especially in western countries. In analyzing the question concerning the students' interest in conducting specific technology-related activities in their future job, we explored differences and correlations between doing these activities without a given context and in a given context (i.e. the occupational area of technology).

Example items:

- In my future job, I would like to develop new products.

- In my future job, I would like to learn more about technical and technological issues.

- In my future job, I would like to work with and operate machines.

Self-efficacy in solving technical tasks: Bandura (1997) defines self-efficacy as an individual's belief in their own ability to complete certain tasks and reach goals. Bandura defined four sources of self-efficacy – "Mastering complex situations", "Observing models", "Social encouragement" and "Physiological effects" –, which we considered in our study. In the context of technology education, situational self-efficacy (Schwarzer & Jerusalem, 2002) in solving technical tasks is of special interest. Hence, we identified 19 different tasks, and formulated items according to the scale of general self-efficacy proposed by Schwarzer and Jerusalem (2002).

Example items:

- I'm confident that I can fix a dripping tap myself (scale: using and fixing).

- If I make an effort, I can explain technical issues without difficulty (scale: understanding and explaining).

- Even if I am under time pressure, I can draw very precise sketches and plans (scale: planning and designing).

- If my handicraft teacher shows us how to do something, I'm convinced that I will succeed in doing the task myself (scale: craft subject).

Gender role in vocational choice: One reason assumed to account for the remarkable gender differences in the field of technology is a still very widespread traditional gender role orientation, which states that technology is something for men. However, whether gender role orientation is really correlated with AFT has (to the best of our knowledge) not been empirically investigated yet. Thus we included an empirically substantiated and reliable scale to measure gender role orientation in vocational choice (Herzog, Neuenschwander & Wannack, 2006).

Example items:

- I can imagine working in a job that is atypical of my sex.

- In choosing my future job, my interests and strengths are more important than whether it is commonly regarded as a job for men or women.

Results

The presentation of the results follows the three research questions.

Research question 1

Our findings show that the general attitude towards technology of most of the questioned students in grade 7 and grade 8 is more positive (mean = 3.2; Likert-scale from 1 to 4) than their interest in dealing with technology in specific contexts, topics and activities (mean = 2.6–2.7). Interest in conducting technology-related activities in the future job is even lower (mean = 2.1). Hence, in average interest in technology drops with an increasing specificity of the context.

Regarding interest in design process activities, the highest score can be found in creative activities (category "inventing, developing and building"; mean = 2.8), whereas interest in cognitive activities (category "understanding and evaluating"; mean = 2.3) is significantly lower (Cohen's $d = 0.7$). Moreover, there are significant differences between girls and boys in most categories, with boys being more interested than girls, especially in the category "using and repairing" ($d = 0.7$). Solely the categories "planning and designing" and "designing an eco-friendly product" did not reveal gender differences (cf. Tab. 1).

Girls' perceived self-efficacy in most technical activities is lower than boys', particularly regarding the category "using and fixing" ($d = 1.3$). In this area, girls do not feel confident. Turning to the category "planning and designing", however, girls manifest the same degree of self-efficacy as boys. At the same time, these are the activities that interest girls the most (cf. Tab. 1). Accordingly, the correlations between interest and self-efficacy in design processes are high ($r = 0.6$).

Tab. 1. Gender differences in interest and perceived self-efficacy in technical tasks

Scales and subscales of AFT	α	Girls M (SD)	Boys M (SD)	t-test (T-value)	Effect size (Cohen's d)
General acceptance and interest					
General acceptance	0.82	3.04 (0.54)	3.26 (0.57)	4.37*	0.4
Leisure time	0.78	2.61 (0.68)	3.13 (0.62)	**8.68***	**0.8**
School	0.75	2.41 (0.66)	2.78 (0.75)	5.70*	0.5
Future job (general)		2.29 (0.87)	3.02 (0.88)	**9.04***	**0.8**
Future job (specific activities)	0.89	1.87 (0.57)	2.62 (0.69)	**13.07****	**1.2**
Specific interest in design process activities					
Understanding, explaining & evaluating	0.89	2.04 (0.56)	2.48 (0.66)	**7.79***	**0.7**
Inventing, developing & building	0.80	2.51 (0.74)	3.04 (0.73)	**7.87***	**0.7**
Planning & designing	0.75	2.52 (0.66)	2.62 (0.75)	0.29	n.s.
Using & fixing	0.80	2.18 (0.65)	2.97 (0.69)	**12.93***	**1.2**
Designing eco-friendly product	0.71	2.56 (0.72)	2.58 (0.73)	0.29	n.s.
Perceived self-efficacy in technical tasks					
Using, fixing & problem solving	0.88	2.09 (0.66)	3.01 (0.72)	14.57**	**1.3**
Understanding & explaining	0.82	2.49 (0.50)	2.94 (0.55)	9.17**	**0.8**
Planning & designing	0.80	2.44 (0.82)	2.60 (0.80)	2.21	n.s.
Craft subject	0.78	2.55 (0.82)	2.89 (0.79)	4.63**	0.4

Notes:

*Cronbach's alpha (α) of subscales; mean (M) of Likert-scale from 1 to 4, and standard deviation (SD) for girls and boys separately; results of t-test for independent samples (girls and boys); effect size (Cohen's d): 0.2 = small, 0.5 = medium, 0.8 = large; **p < 0.01; *p < 0.05, n.s. = not significant. Large effects (d > 0.7) are in bold.*

According to our data, girls with an open gender role orientation show a significantly higher AFT than girls with a more traditional gender role (cf. Fig. 3). By contrast, the boys' AFT does not significantly correlate with gender role, although there is a tendency towards a negative correlation (cf. Fig. 3).

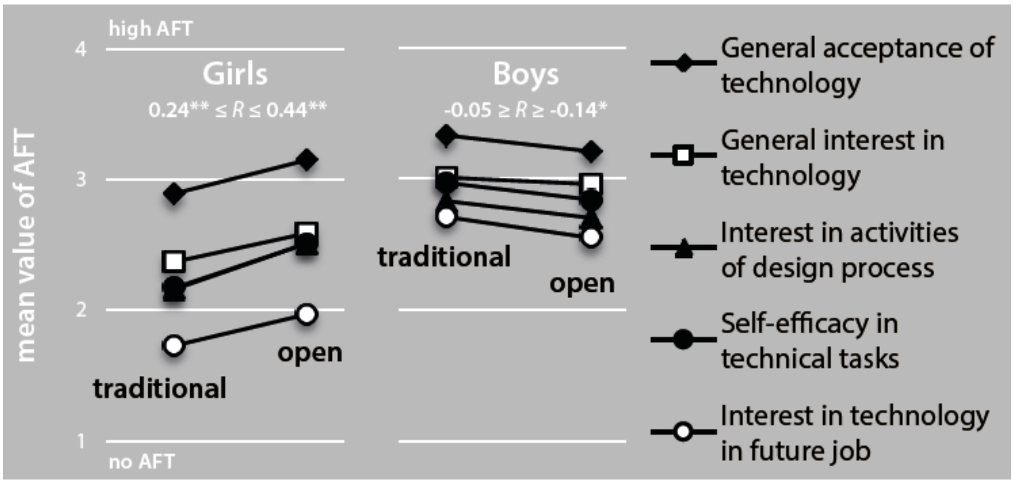

Fig. 3. Effect of gender role orientation on AFT variables of girls and boys (median split of gender role orientation: traditional / open; *R* = correlation coefficient (Spearmans rho); **p < 0.01; *p < 0.05).

Research question 2

Turning to the effects of the intervention with EXRETU, we received very positive student responses to the teaching model: more than 75% of the students liked the technology class. There was no significant difference in positive answers between boys and girls, and no difference between different tracks either (cf. Fig. 4).

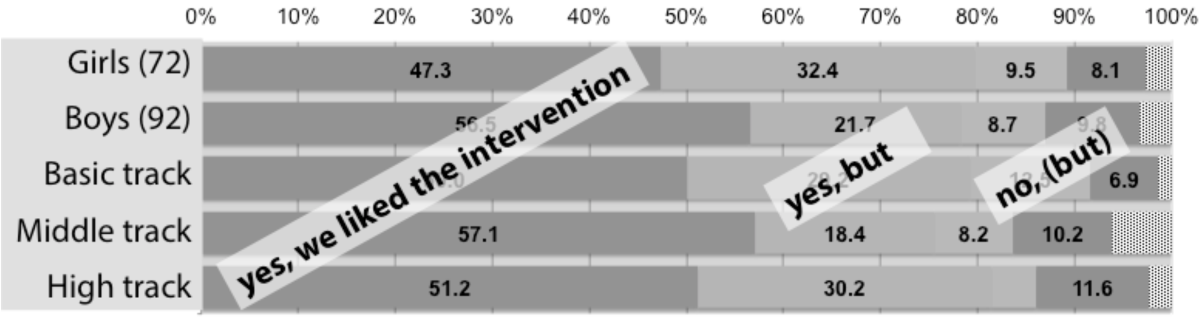

Fig. 4. Percentage of categorized answers to the question "Did you like the intervention with technology education?"

The answers and more detailed reflections extracted from the student interviews indicate that practical work and open project work in teams provided them with opportunities to make new experiences, which was chiefly positively perceived. More negatively mentioned aspects were the keeping of the working journals, the surveys, and in some cases time pressure and problems with team members. Altogether, however, the positive statements were predominant (70%).

Research question 3

Overall, AFT slightly decreased between grade 7 and grade 9, in the experimental group as well as in the control group. In subgroups of the experimental group, however, we found positive effects: in some variables girls showed a more positive development from pre-test to post-test than boys. Moreover, the girls and boys stating low AFT before the intervention exhibited more positive developments as well as one class working on a special issue in a special setting.

Besides, we identified two impacting factors on the effect of the intervention: situational interest (Q2), and fulfillment of the psychological basic needs (Deci & Ryan, 1993) (cf. Tab. 3): the students experiencing competence, autonomy and social involvement during the intervention with technology education manifested an increase in their AFT between pre-test and post-test.

Summary and discussion

Recapitulating the presented results, we can conclude that there is no such thing as "THE" affinity for technology, but that it varies with specific contexts, contents and activities. Hence, important information gets lost, if questions are solely directed to general interest or self-efficacy in technology. In our study, we found that general interest is higher than specific interests. This is plausible, because the participants had not had technical experiences at school before, but only occasionally in their leisure time. This interpretation is supported by the fact that most students do not have fine-grained concepts of technology, and they mostly come up with concrete artifacts like their smartphones and computers, when they think of technology (Heitzmann, 2014).

The differences established between subgroups document the stereotypical gender gap for most technology-related contexts, contents and activities. However, there are some important exceptions, especially with respect to the implementation technology education: girls liked the intervention as much as boys did. Girls even manifested more positive changes between pre-test and post-test. This might be explained by the intervention's special focus on cooperative learning and creativity. It is known that girls like cooperative learning more than boys (Gehrig et al., 2010). Thus, by combining practical, theoretical, creative and social aspects in technology education, there is a good chance that both boys and girls can be addressed and interested.

Not only did girls profit more from the intervention than boys, but also boys and girls whose psychological basic needs were fulfilled during technology education. This finding corresponds with the self-determination theory of Deci and Ryan (1993), which states that in learning processes repeated experience of three psychological basic needs – autonomy, competence and relatedness – is a precondition for effective learning and long-term interest development.

Conclusions

We summarize the general conclusions of the whole study at three pertinent levels:

Research in technology education. For the purposes of our study we developed useful and valid instruments to measure the four personal trait variables of the "affinity for technology". The eminent strength of these instruments lies in their profundity and their theoretical foundation. The disadvantage is their extent, which is practicable for single use, but not in pre-, post- and follow-up designs. Furthermore, one of the great challenges in technology education is to find attractive ways to activate metacognitive processes.

Technology education. Combining practical, theoretical, creative, and social aspects of technology makes the subject attractive to (virtually) everyone. By including product design as one part of technology education, these different aspects can be perfectly combined, thus offering students a unique and special learning experience. Yet it should not be forgotten that building cognitive bridges between practical work (manual skills) and theoretical contexts (knowledge) poses a great challenge, which makes professional assistance indispensable.

Educational policy and schools. There is a great need for technology-related training in Swiss teacher education. Evaluating our experiences from the preparatory in-service courses with teachers, we can state that it is not only the students who need more self-confidence, but also the teachers. Most of them are not prepared for technology education, so that there is also a necessity to offer examples, knowledge and the opportunity to gain experience in this field. Also with respect to "Lehrplan 21", the new Swiss curriculum, special efforts will be vital. Against this background we consider the teaching model EXRETU as a first step to a supplementation of teacher education.

In conclusion, the findings as well as our informal observations during the interventions affirmed our presumptions and convinced us that combining natural sciences with technical design subjects provides a promising way to motivate both girls and boys for technology education – particularly in Switzerland, where technology education does not rank as a separate subject.

Acknowledgements

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Work plans in technology
A study of technology education practice in Sweden

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Abstract

In Sweden an evolution of different initiatives had been taken in order to increase the interest for science and technology studies among young people. This study focuses work plans developed within one particular initiative (Boost of Technology, BoT). The work plans are used as a tool to capture teachers' values, views and perceptions regarding subject content and work methods in technology education. The research question put forward reads: *What technological skills and abilities are highlighted in the work plans developed during the training in the BoT initiative?* Work plans from 19 participating schools have been collected and analyzed according to two schemes, developed by the authors. The schemes covers two focus areas, namely, (1) how the work plans correlates with the national steering documents, i.e. the instruction sheet given from the project management, and (2) to what extend the work plans correlate with Michams' (1994) four "types" of technology/technological knowledge. Findings show that many (most) work plans contains quotes from the curricula without specification regarding how the aspects in question is dealt with (choice of activities and/or aims and learning goals). In the cases where actual suggestions regarding themes and activities do occur the knowledge objectives - the focus and quality of the expected outcome, i.e. what the students should/must conquer - are rarely (almost never) described. Findings reveal few traces of what, according to Mitcham, could be interpreted as "technical content knowledge". Technical volition is an aspect almost invariably anticipated in the work plans. Most work plans also lack progression in the presented themes/learning activities. It is concluded that the teachers in the study, despite having attended a teacher support program, know little about technical knowledge, and therefore are in need of further subject content education.

Keywords

Technology education K-12, work plans, teachers, boost of technology

Introduction

Sweden is a country with a high ambition to have and maintain a strong technology sector in the national economy. Despite this, less young people are choosing a career in the technical area; both depending on low interest among young people but also due to the current demographic situation, e.g. the number of young people able to apply for engineering studies. These facts are not unique for Sweden but relevant for most western countries. In Sweden this situation has led to an evolution of different initiatives taken in order to increase the interest for science and technology studies among young people (Teknikdelegationen 2009, Rooke, 2013). It should however be noted that the outcome of these initiatives have rarely been evaluated regarding aspects like impact and effect (Svärdh, 2013). The importance of appropriate technology education also in the early years of schooling (primary and lower secondary school), in order to increase interest in a career in this area, is pointed out in several studies (Skolinspektionen 2013, Teknikdelegationen 2010; Teknikföretagen, 2013; Skogh 2001). In all teacher support initiatives teachers are key actors. A common denominator in all improvement/development initiatives is that the aspect of teachers' competence is, either directly or indirectly, included. In this study teachers' work with technology education within the initiative Boost of Technology is in focus. We are in particular studying the work plans developed by schools and teacher teams. The work plans are in this study used as a tool to capture teachers' values and views and perceptions regarding subject content and work methods in technology education.

Context of the study

The informants in our study are participants in a regional teacher support initiative – the Boost of Technology (BoT). This project started in 2011 when the House of Science in Stockholm (www.tekniklyftet.se), and partners received funding from the European Social Fund. The long-term ambition of the project is to contribute to a broad renewal of technology education in Swedish compulsory schools and centered on teachers of the subject and their work situations. This is mainly done by strengthening teachers' skills and by trying to raise the status of the subject through a whole school perspective, by including not only teachers who teach technology but also other teachers, head masters within the schools, and representatives from the local school authorities. The teachers' competence is in this project seen as the key factor in increasing students' interest in the subject and in mobilizing more young people into engineering and science studies and future careers in these areas.

The main target group for the project is lower secondary school technology teachers. Twenty-six schools in the region, all interested in becoming certified technology schools, were selected. Each participating school committed itself to work toward a set of project goals. These goals were assessed in 2013, and 19 out of the 26 schools were approved and were awarded a diploma as "*Certified Technology School*".

Participating schools were within the Stockholm area. Although the main target initially was secondary schools (school year 7-9), some of the schools included pre-school to year nine. In order to get the diploma the school, among other things, should submit a local work plan for the subject of technology. The work plan should, according to the instruction, be developed in an interdisciplinary manner, i.e. teachers from different subjects should participate in the process. This mandatory requirement was made in order to raise the awareness and status of the technology subject in the participating schools. Both teachers and school management had to agree upon the work plan.

Prior to the work of developing the work plans, each school got instructions and advises from the BoT project management about what to include in the work plans. These instructions were based on both the overall curriculum and the syllabus for the subject technology. During the project period, the schools were provided with support and feedback. The work plans were red by peers during organized workshops and did undergo a referee procedure, where experts from the universities (KTH and Stockholm University) provided feedback to the teachers before the final product was submitted. Thus, lots of opportunities were given for schools to deepen the knowledge and broaden the content in the areas requested in the instructions for the work plans.

Aim & research question

The aim of this study is to explore one of the outcomes in the BoT initiative, namely the work plans developed by participating teachers during the project. Two focus areas are in particular highlighted; first (1) the relationship between the national steering documents and the work plans is scrutinized. Secondly (2), in order to get a deeper understanding about what type of knowledge the teachers have had in mind, the work plans are analyzed according to Mitchams model of technological knowledge (Mitcham, 1994). The research question put forward reads:

What technological skills and abilities are highlighted in the work plans developed during the training in the BoT initiative?

Background

According to the Association of Swedish Engineering Industry [Teknikföretagen] and the National Centre for technology education (CETIS) there is a strong correlation between the preconditions that are given for teaching and how good teaching is. In a joint report (Teknikföretagen, 2013), it is concluded that there is a “success formula” for appropriate technology education. The suggested formula is based on results from a questionnaire to teachers (n=1000) and head masters (n= 300). One of these criteria highlights the focus of this paper - the importance of technology teachers planning their teaching:

> Each school should have a specific work plan for the subject of technology.
>
> (*Ibid*. p. 14, translated from Swedish)

The quality of work-plans obviously depends on different factors and circumstances. The importance of teachers having a solid subject content knowledge as well as pedagogical skills is a well-known fact pointed out by e.g. Schulman (1986) when he introduced the idea of pedagogical content knowledge (PCK). There is extensive research about teachers’ planning of education (e.g. Marzano, 2007; Miles, K. H., & Frank, S., 2008; Kassissieh, J., & Barton, R., 2009). With focus in technology education in particular Benson (2013) state that a clear understanding of the nature of the technology subject, is an important perquisite when planning technology activities:

> Unless the key elements of D&T are included in its implementation, important skills such as critical and evaluative thinking will not be developed. (p.57)

Engström (2013) points to the different traditions in technology teaching. Different approaches regarding choices of subject content, themes and work will evidently influence what is and could be taught. Although the curriculum and policy documents, lays the foundation for the teaching, each teacher, depending on interest and prior knowledge, experiences and skill will, to a great extend, influence and in different ways demarcate perspectives made visible to students. According to Klasander (2010) there are certain reoccurring areas that teachers commonly emphases in their technology teaching: (1) design and make, (2) industry, (3) sustainable development, (4) manage everyday life, (5) “citizen” and (6) the history of technology. Depending on the views and knowledge of individual teachers teaching will vary, and possibly move from one area to another (Engström, 2013).

The concept of technology and technological knowledge

Technical knowledge is a central component in the understanding of the concept of technology. Over the years a number of philosophers (de Vries, 2003; Ropohl, 1997 and Vincenti, 1990) have presented suggestions regarding the interpretation of the concept. In this paper we have chosen to use the systematization of the understanding of technology suggested by Mitcham (1994). Mitcham (1994) identifies four "types" of technology: (1) technology in the sense of technical knowledge, (2) technology in the sense of man's need to develop technology in order to solve problems and/or to meet needs, (3) technology in the sense of design and construction, and (4) technology in the form of the objects/artifacts that have been developed with the help of technology. It should be noted that we, in this paper, have taken the liberty of interpreting Mitchams model in a slightly modified and simplified manner. The intention here is not to discuss the model from a philosophical perspective, rather to test its usefulness in a practical pedagogical context - our analysis of teachers' work plans.

Fig. 1. An interpretation of Mitchams’ understanding of the concept of technology. The interaction between the individual and an object may concern one or more of the different types of technology in the model. (Adjusted/simplified figure from Mitcham, 1994, s. 160 model).

Technical knowledge and technological intent/act of will should, according to Mitcham, be seen as parallel, equally important "core aspects" of the concept of technology. The longer to the right we get in the overview model, the further away from the "core" of what counts as "technology" we are. It may be noted that the existence of a technological aspect does not presuppose the existence of another aspect.

Wanting to solve a technical problem, as we all know is not the same as being able to solve it ... Likewise, technical activity is not necessarily an expression of technological knowledge.

Mitchams' model paves the way for a systematic analysis of the meeting and interaction of the individual (in this context, made possible in the work plans) within technology education and objects. For example, if students are instructed to make models of robots or bridges this activity (depending on the quality of teacher education) has potential to enhance the development of technical knowledge among the students. This activity (could) obviously include a higher or lesser degree of technical activity. Technology in the sense of technical objects and technological intent is however in this case *not* included. When, on the other hand, students in kindergarten are playing with Lego this according, Mitchams' classification, count as technology in the sense of technical objects (the Lego artifact "itself") and as a technical activity (activity with technical artifact) but not as technology in the sense technical knowledge or technical intent (volition). From a technology/engineering educational perspective, Mitchams 'model' (as we have interpreted it) is not unproblematic. Since the categories are not clearly defined there is considerable room for different interpretation. When a student is playing with Lego (or building a model of a bridge), the technical intent (the desire to solve the technical problem) may be as prominent to the playing child as to the experienced engineer facing a complex design task. Similarly, the question of what counts as "technical knowledge" must be discussed in relation to the context (technological knowledge in the school's technology education and technical knowledge in higher engineering education are quite different things). However as a starting point for a discussion about technology education practice (objectives, content and design), Mitchums' model could be a useful tool.

Method

Work plans from 19 participating schools were collected. The work plans were then thoroughly red through and analyzed according to two schemes, developed by the authors. The schemes covered the two focus areas, namely, (1) how the work plans correlates with the national steering documents, i.e. the instruction sheet given from the project management, and (2) to what extend the work plans correlate with Michams' four types of view on technology and technological knowledge.

In order to scrutinize the first focus area, the analyzing scheme was developed according to the instructions given by the project management, see figure 2. Seven different aspects were selected in the scheme, which together cover a wide range of the content of the work plans. The different aspects were graded (1-5, from poor to excellent) by the authors according to the following criteria:

Grading	**Aspects**
Grade 1	aspect is not mentioned in the document
Grade 2	aspect is mentioned, but no description of the aspect is found in the document
Grade 3	the aspect is mentioned with a brief description, there are no answers to the questions of what and how it will be taught
Grade 4	the aspect is included in the document, and is partly described regarding what or how it will be taught
Grade 5	the aspect is described with full answers to the questions of what and how it will be taught

a.) Objectives of teaching and how they are linked to the curriculum
b.) Evaluation and assessment
c.) Distribution of selected teaching elements between grades
d.) Collaboration between the subject technology and other school subjects
e.) The four perspectives given in the national curriculum (the schools values): the historical, the international, the ethical and the sustainable development perspective
f.) Gender
g.) Entrepreneurship

Fig. 2. Areas in the work planes selected for analyze.

Analyze

The 19 schools were evaluated according to the set criteria and grades were given from 1 to 5. As some schools received half-points it was decided to use a scale of one to ten in the analyzing process.

This made it possible for us to distinguish the different schools (see fig. 3) Every school was given an overall assessment of the work plan, which is the total amount of points in the test. The highest score a school can get is 35 points, i.e. 5 point on all 7 aspects.

The work plans were also analyzed according to Mitchams view on technological knowledge. Five examples where chosen from the top 3- schools (ranked in the first analyze). The schools have been anonymised and are in this study numbered 1 to 19.

Findings

Findings are presented under the heading of the respective focus areas.

(1) How the work plans correlates with the national steering documents (year 7-9)

The average score for the participating schools were 23,7 points. The highest score reached is 32,5 points and the lowest score is 9 points. Nine schools reach over 25 points, which can be seen as a very good result.

In the first column of the table (fig.3), work plans were judged due to how well the teaching and teaching goals were connected to the curricula, aspect a. Here we received an average score of 3,9 and only three schools scored below 3. This is seen as a good score and it shows that virtually all schools are able to use the policy documents when they are developing their work plans.

School	a.)	b.)	c.)	d.)	e.)	f.)	g.)	School grade
1	3,5	1	3	3,5	1	3	3,5	**18,5**
2	4	3,5	5	5	3	3	1	**24,5**
3	3,5	2,5	5	3	3	2,5	2,5	**22**
4	4,5	4	5	3,5	2,5	5	1	**25,5**
5	2	3	4,5	4,5	3	2	4	**23**
6	4	4	4,5	5	5	5	5	**32,5**
7	5	4,5	4,5	2	3	1	2	**22**
8	5	3,5	5	1,5	4,5	5	5	**29,5**
9	3	1	5	4	2	1,5	4	**20,5**
10	4	4	5	4	4,5	4,5	2,5	**28,5**
11	4,5	3	5	5	3,5	1,5	2,5	**25**
12	4,5	2,5	5	5	1	4	3,5	**25,5**
13	4	3,5	3,5	3	3	4	3	**24**
14	5	4	5	1	2	1	1,5	**19,5**
15	1,5	1	2	1	1	1	1,5	**9**
16	4	4	4	3,5	5	5	5	**30,5**
17	4,5	4	5	4	3	2	3,5	**26**
18	4	2,5	2	3,5	2	1,5	5	**20,5**
19	4,5	2	5	4,5	3	3	2	**24**
	75	57,5	83	66,5	55	55,5	58	
mean	**3,95**	**3,03**	**4,37**	**3,50**	**2,89**	**2,92**	**3,05**	

Figure 3. Data on the evaluated work plans for the 19 participating schools.

The next aspect, b, shows how the work plans describe the assessment procedure and what content should be assessed. The average score is 3,0. Only three schools mentioned how and what should be assessed, but most schools included some kind of assessment criteria, most often directly copied from the sample material written by the Swedish agency of education (Skolverket, 2012).

The forth column shows that many schools have managed to include education of other subjects in projects/learning activities aimed at technology education. The average score is 3,5.

When evaluating the fifth aspects, which reveal our grading of to what extend the work plans include the four perspectives (the school values), a big variation could be seen. Even though many schools scored 1 in this aspect, the average was 2,89.

The last two aspects, e and f, gender issues and entrepreneurship, are important school values that should permeate all teaching in all subjects (Skolverket, 2011). The average score of around 3 for both aspects can therefor be seen as low. Only six schools (not the same schools for both aspects) out of 19 described these aspects in a clear and relevant way.

(2) To what extend the work plans correlate with Michams' four types of view on technology and technological knowledge (year 7-9).

Regarding the second focus area of our study – the correlation between the work plans and the four "types" of technology suggested by Mitcham (1994) - findings reveal an apparent absence of traces regarding technical volition in the work plans. Technical content knowledge is accounted for in three (3) of the five (5) examples examined. Technical activities are (not surprisingly) accounted for in all work plans. A reoccurring theme in all work plans, is the lack of progression in the presented themes/learning activities.

	Techn. knowledge	Techn. volition	Techn. activities	Techn. Object/ artifact	Comment
Human rights	-	-	Filming/ photo graphing	Film/movie	Tehnical knowledge and techn. Volition is anticipated. No progression
Internationa l projekt	Lecturer/ Coach	-	Construction/ design work clearly oriented toward solving a specific problem	Robot	Technical volition is anticipated (or – competitive element contributes to expression of will)
Transportati on	-	-	Build electricity driven small car	The small car	Technical knowledge and techn. Volition is anticipated. No progression
Technical systems	Plant visit, industry lecturer Present a technical system	-	Build treatment plant	Treatment plant	Difficult to see progression in technical knowledge, expect the plant visit, no problems to be solved
Technical solutions for future communic. and information	History lession on mobile telephone evolution	Possible	Invent a new solution	The "new" solution	Vague progression of technical knowledge

Figure 4. Overview - findings regarding work plans correlating to Mitchams' types of technology.

Discussion

According to our findings virtually all schools/ teacher teams are referring to the policy documents when developing their work plans. This is obviously positive. The question of if the work plans are *correlating* with the curricula is however quite another thing. Our preliminary findings point to a rather large spread among the schools. Many (most) work plans contains quotes from the curricula without any specification regarding how the aspects in question is dealt with (choice of activities and/or aims and learning goals). In the cases where actual suggestions regarding themes and activities do occur the knowledge objectives - the focus and quality of the expected outcome, i.e. what the students should/must conquer - are rarely (almost never) described. It may also be noted that only six (6) of the 24 schools have described how they work with gender aspects in a clear way. Although communication and discussion about the work plans were an important part of the training findings accordingly show that schools have not taken lessons from each other or from the feedback provided by the external expert consulted. Findings show that the participating schools managed to distribute education elements between different grades. This might be seen as an easy task, but according to collected data, many of the participating schools did not have technology education on the school-scheme in each grade previous to the start of the project.

The correlation between the work plans and the four "types" of technology suggested by Mitcham (1994) is the second focus area of our study. The model is a somewhat blunt tool, but the analysis nevertheless gives indications regarding the subject content of the work plans. Our findings reveal few traces of what could be interpreted as "technical content knowledge" i.e. indication of subject content instructions/ information presented to the students (relevant background information, theories etc.). Technical volition is an aspect almost invariably anticipated in the work plans. It appears as if the teachers presuppose that technical volition occur automatically among students. Technical activities are (not surprisingly) accounted for in all work plans and addresses similar themes/subject areas as mentioned by Edström (2013). A reoccurring theme in all work plans, is the lack of progression in the presented themes/learning activities. In line with Benson (2013), our findings indicate that the teachers in study need additional technology education. Despite the project the teachers know little about technical knowledge. Further studies include new swoops in our rich data set to (like Teknikföretagen, 2013) try to identify success factors. By studying schools with high ratings, it may be possible for us to see additional relationships that we have not yet caught.

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Importance of key engineering and technology concepts and skills for all high school students Comparing perceptions of university engineering educators and high school technology teachers

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Abstract

Objectives: This study compares perceptions of academic engineering educators (AEEs) who prepare future engineers at the university level; and high school classroom technology teachers (CTTs) who provide engineering and technology education (ETE) at the secondary school level.
Theoretical background: the study relates to subjects such as the need for ETE for all students (Barak and Hacker, 2011), U.S. Standards for Technological Literacy (International Technology Education Association, 2000), and prior research on concepts and context in ETE (Rossouw, Hacker, & de Vries, 2010).
Research questions were: 1) Where does the strongest consensus exist among the expert panelists relative to the importance of specific ETE concepts and skills that all high school students should attain? 2) Which ETE concepts and skills are perceived to be most important as part of fundamental education for high school students? 3) Where are there significant differences between AEEs' and CTTs' perceptions of the importance of ETE concepts and skills? 4) What concepts and skills that the study elicits are not presently addressed by the U.S. National Standards for Technological Literacy (STL)?
Methodology: The intent of the study was to solicit and converge expert opinion within the two study groups in order to obtain consensus. The research was carried out using a three-round Delphi survey (RAND, 2011) where feedback from prior rounds enabled panelists to modify and update their positions to achieve consensus. The participants were 18 academic engineering educators and 16 classroom technology teachers – a total of 34 experts.
Examples from results: Strong consensus between AEEs and CTTs was found on 14 of 38 survey items. Among the items that the combined group found to be most important for high school students to attain were to: 1) identify and discuss environmental, health, and safety issues; 2) use representational modeling such as a sketch, drawing, or a simulation to convey the essence of a design; 3) use verbal and/or visual means to explain why a particular engineering design decision was made; and 4) show evidence of considering human factors (ergonomics, safety, matching designs to human and environmental needs) when proposing design solutions.

Keywords

Academic engineering educators, classroom technology teachers

Introduction

Due to the essential roles engineering and technology play in addressing societal and environmental challenges, support for the establishment of PreK-12 engineering and technology education (ETE) programs in the United States has been rapidly growing (NAE, 2009). The idea has been promulgated by many science, technology, engineering and mathematics (STEM) educators and disciplinary leaders, professional associations, and governmental agencies (Katehi, Pearson, & Feder, 2009). As Custer, Daugherty, and Meyer (2010) postulated, there are three factors underlying the growth of PreK-12 ETE: 1) facilitating technological literacy, 2) providing a math and science learning context, and 3) enhancing career pathways.

There is growing recognition that school-based ETE experiences can be pedagogically valuable for all students—not only in providing an effective way to contextualize and reinforce STEM skills, but in mobilizing engineering thinking as a way for young people to approach problems of all kinds (Brophy & Evangelou, 2007; Forlenza, 2010). However, there is no established consensus regarding what constitutes an appropriate K-12 ETE curriculum, primarily because there has been no substantive effort to identify and describe the body of engineering content that such a curriculum might contain (Sanders, Sherman & Watson, 2012).

The objective of this study was to compare the perceptions of two constituencies whose missions focus on preparing students to succeed in our technological world through engineering and technology education. The two groups include academic engineering educators (AEEs) who prepare future engineers at the university level; and high school classroom technology teachers (CTTs) who teach engineering and technology courses at the secondary school level.

Theoretical background

A thorough review of the literature was conducted relative to the need for ETE for all students (Barak &Hacker, 2011); U.S. Standards for Technological Literacy (International Technology Education Association, 2000); prior research on Concepts and Contexts in Engineering and Technology Education (CCETE) (Rossouw, Hacker, & de Vries, 2010); the current state of school-based ETE; and perceptions of engineering design, which according to many scholars is the core process through which engineering endeavors are accomplished (Bloch, 1986; Custer, Daugherty & Meyer, 2009; Rossouw, Hacker, & de Vries 2010; Liao, 2011). Literature related to Delphi survey research methodology was reviewed to establish a rationale for its use to establish consensus about key ETE ideas and skills.

Through the literature review, the most salient ideas that emerged from the ETE literature were synthesized and clustered within a set of unifying themes that emerged through the CCETE study and other major research projects. Clustering concepts and skills within a unifying framework provides learners with a more holistic understanding of engineering and technology and addresses recommendations made by the NSF (G. Salinger, personal communication, March 22, 2001), the National Academy of Engineering (NAE) (NAE, 2010), and the National Research Council (NRC) (NRC, 2011).

The literature review established a basis for identifying concepts and skills that became the starting point (the initial item set) for the survey instrument used in this study. Delphi research methodology was employed because it uses informed judgment of experts to arrive at consensus (RAND, 2011).

This *Comparison of Perceptions* study furthers the work accomplished by the CCETE study (Rossouw, Hacker & de Vries, 2010) to produce a consensus about the underlying ETE concepts and skills within those five broad areas of conceptual understanding. The present research identified concepts and skills that expert AEEs and CTTs (as an entire group) deemed to be of high importance and of lower importance for high school students in the United States to attain as part of their fundamental education. The study then determined where significant differences existed in the perceptions of the two subgroups relative to the importance of these concepts and skills.

Furthermore, this study identified ETE concepts or skills that might be considered important enough for inclusion in the next iteration of the U.S. Standards for Technological Literacy.

Research questions

Four research questions were identified:

RQ1. Where does the strongest consensus exist among the whole group of expert panelists?

RQ2. Which ETE concepts and skills does the expert panel perceive to be most important for HS students to learn?

RQ3. Where are there significant differences between academic engineering educators' and classroom technology teachers' perceptions of the importance of ETE concepts and skills?

RQ4. What concepts and skills are not presently addressed by the national standards for technological literacy that academic engineering educators and classroom technology teachers agree are highly important for students to learn?

Methodology

This study used *Delphi survey research* to solicit and converge expert opinions to obtain consensus (Salancik, Wenger & Helfer, 1971). A convergence of opinion has been observed in the majority of cases in which the Delphi approach has been used (Helmer, 1967). This study employed a three-round modified Delphi survey using the technique designed by Dalkey & Helmer (1963) and revised by Delbecq, Van deVen, & Gustafson (1975).

Several recent important research projects related to this study employed the Delphi survey methodology to identify ETE concepts and skills (Childress & Rhodes, 2007; Dearing & Daugherty, 2004; Harris & Rogers, 2008; Rossouw, Hacker, & de Vries, 2010; Scott, Washer & Wright (2006); and a study conducted by well-respected science researchers established a set of basic and broad concepts related to science education using this methodology (Osborne, Collins, Ratcliffe, Millar, & Dutchl, 2003). Researchers (Delbecq et al, 1975; Ludwig, 1997; Dalkey, Rourke, Lewis & Snyder (1972) suggest that ten to fifteen subjects could be sufficient if the background of the Delphi subjects is homogeneous.

This research was carried out using a three-round Delphi survey (RAND, 2011) where feedback from prior rounds enabled panelists to modify and update their positions to achieve consensus. The participants were 18 academic engineering educators and 16 classroom technology teachers – a total of 34 experts. Three Delphi administrations have been found to be sufficient to arrive at consensus (Brooks, 1979). A literature review found that after three iterations, not enough new information was gained to warrant the cost of more administrations (Altschuld, 1993).

Seven stages characterized the Delphi procedure, in accordance with the method suggested by Fowles (1978).

1. Define the research questions
2. Assemble panel of experts
3. Design and validate an initial set of survey items
4. Conduct the three round survey
5. Analyze survey results
6. Draw tentative conclusions
7. Present tentative conclusions to the validation panel and reach summary conclusions

During the conduct of the three-round survey, Delphi panelists were invited to reconsider their item ratings if these were at variance with prior-round group median ratings. Thus an attempt was made to achieve expert consensus. After the first round when it was evident that scores on all items were quite high, on subsequent rounds panelists were asked to give high scores sparingly. After the third Round, concepts were ordered according to their scores and a final ranking of concepts was determined.

Survey instrument and data analysis methodology

The survey Instrument included 38 survey items comprising concepts and skills in five overarching domains of engineering and technology that are repeatedly referenced in the literature:

1. Design (12 survey items)
2. Modeling (6 survey items)
3. Systems (6 survey items)
4. Resources (7 survey items)
5. Human Values (7 survey items)

The survey was conducted online using Qualtrics survey software and data was exported to SPSS for analysis. In this study, Likert scale data was treated as ordinal data and was reported using descriptive statistics – (medians, frequencies, percentiles, interquartile range (IQR) statistics, and z-scores. A nonparametric test (the Mann-Whitney U) was used to determine statistically significant differences between the two study groups and p-values were reported at the $\alpha = 0.05$ level.

Relative to Research Question 1 (RQ1) – (Where does the strongest consensus exist among the expert panelists relative to the importance of specific ETE concepts and skills that all high school students in the U.S. should attain as part of their fundamental education?), analysis determined the strength of consensus on each item by subgroup and by the whole group. According to Rojewski and Meers (1991), the Delphi technique is used to achieve consensus among participants, and that "consensus is determined using the interquartile range of each concept statement. Interquartile range (see figure 6) refers to the middle 50% of responses for each statement (i.e., distance between first and third quartiles)." Low IQRs are a measure of strong group consensus on a particular item. As suggested by Rayens and Hahn (2000), the IQR may be an insufficient criterion for determination of agreement. An additional measure that contributed to establishing consensus in this study was frequency distribution and the criterion of some percentage of panelists responding to any given response category is used to determine consensus (Loughlin & Moore, 1979, p. 103; Seagle & Iverson, 2002, p. 1; Putnam, Speigel, & Bruininks, 1995; as cited by von der Gracht, 2008).

In this study, factors determining consensus included the whole-group IQR and frequency of responses at the high end of the scale (respondents choosing scale points 6-7) and at the low end of the scale (respondents choosing scale points 1-4). These "consensus factors" were validated by the validation panel and are displayed in table 1.

Table 1. Consensus Factors

Item Importance Level	Determinants of Consensus
Consensus that an Item is of Higher Importance	If IQR ≤ 1.61 and frequency of high scores (6-7) ≥ 80%
Consensus that an Item is of Lower Importance	If IQR ≤ 1.61 and frequency of low scores (1-4) ≥ 25%

Relative to Research Question 2 (RQ2) – (Which ETE concepts and skills does the expert panel perceive to be most important for high school students to attain as part of their fundamental education?), the study examined the median ratings for each item rated by the panelists in the third Round of the Delphi administration. The whole-group median ratings for each survey item and median ratings for each subgroup (AEEs and CTTs) were determined using IBM SPSS V21.0 for Windows software. Median statistics were used because the median is less affected by outlier responses than the mean, and provides a finer level of numerical discrimination than the mode. Once median statistics were obtained for the whole group's rating of each survey item, the medians were ranked using the data ranking function of Microsoft Excel. This ranking indicated which of the survey items the subgroups and the entire panel perceived to be most important.

The validation panel reviewed the final research results and a cutoff point was established. The cutoff point determined which items rose to the level of being considered highly important. In the case of this study, because median ratings for all items were quite high (ranging from a high median rating of 6.71 to a low median rating of 4.60 on a 7-point scale), the validation panel set the item cutoff point at median ratings of ≤ 6.0. Those items that rose above the agreed-upon cutoff level were then deemed to be of "high importance" for HS students to understand. No items were deemed to be unimportant by the validation panel.

Relative to Research Question 3 (RQ3) – (Are there significant differences between academic engineering educators' and classroom technology teachers' perceptions of the importance of ETE concepts and skills?), the Mann-Whitney U statistical test was used to analyze whether the median ratings obtained from the two groups were significantly different. This test is nonparametric and develops statistics based on ordinal data as opposed to interval data. Nonparametric methods are particularly suited to data that are not distributed normally (Pidwirny, 2001). Nonparametric tests compare medians rather than means and, as a result, if the data have one or two outliers, their influence is negated (Hayes, 1997).

Relative to Research Question 4 (RQ4) – (What concepts and skills that the study elicits, do academic engineering educators and classroom technology teachers agree are highly important for high school students to attain as part of their fundamental education and are not presently addressed by *STL*?), the study identified concepts and skills that the study has shown to be highly important for high school students to attain as part of their fundamental education, and did a gap analysis with the existing STL.

The study compared survey items rated "important" by the Delphi panel to existing benchmarks in the high school level Standards for Technological Literacy. If items were similar, rewording based on survey item wording is suggested. If there were gaps, survey items were suggested as additions to the next iteration of STL. During the validation panel meeting to review research results, the validation panel confirmed the researcher's gap analysis and suggested that revisions to STL be addressed in its next iteration based on survey results.

Findings

Based upon an analysis of final (Round 3) data, conclusions related to each research question were drawn.

Related to RQ1, there was strong consensus between the two groups on 14 of 38 survey items. The strongest consensus that items were **highly important** related to students being able to:

1. Identify and discuss environmental, health, and safety issues involved in implementing an engineering project; and
2. Use representational modeling (e.g., a sketch, drawing, or a simulation) to convey the essence of a design.

The strongest consensus that items were of **lower importance** related to:

1. Provide an example and an explanation of how design solutions can integrate universal design principles to help meet the needs and wants of people of all ages and abilities; and
2. Describe, through an example, how the reliability of a system and the risks/consequences associated with its use have or have not been adequately considered prior to its implementation.

Related to RQ2, the ETE concept/skills perceived by the combined group to be most important for high school students to attain were to:

1. Identify and discuss environmental, health, and safety issues involved in implementing an engineering project;
2. Use representational modeling (e.g., a sketch, drawing, or a simulation) to convey the essence of a design;
3. Explain why a particular engineering design decision was made, using verbal and/or visual means (e.g., writing, drawing, making 3D models, using computer simulations); and
4. Show evidence of considering human factors (ergonomics, safety, matching designs to human and environmental needs) when proposing design solutions.

Related to RQ3, significant differences between academic engineering educators' and classroom technology teachers' perceptions were evidenced on four items:

1. Solve engineering design problems by identifying and applying appropriate science concepts;
2. Provide examples of how psychological factors (e.g., bias, overconfidence, human error) can impact the engineering design process;
3. Explain the difference between an open-loop control system and a closed-loop control system and give an example of each; and
4. Develop and conduct empirical tests and analyze system and analyze test data to determine how well actual system results compare with measurable performance criteria.

All of these except the third were rated higher by AEEs than by CTTs.

Related to RQ4, recommendations are made that the next iteration of the STL add, substitute, or reword standards based on 16 survey items that panelists agreed are highly important for HS students in the United States to attain as part of their fundamental education, but are not presently addressed by STL.

An important point worth mentioning is that even though three Delphi rounds were conducted with the objective of reaching consensus between the two groups of experts, there were four items for which a significant difference was found between the two groups at the end of the process. This finding reflects the differences in the educational backgrounds of the two groups. Academic engineering educators are professional engineers who have extensive mathematical and scientific knowledge; classroom technology teachers, on the other hand, study little mathematics and science during their training and are most comfortable teaching about technological tools, materials and processes.

Technology Education in the United States has its roots in crafts teaching and many of today's more experienced technology teachers were educated as Industrial Arts teachers. Therefore, revising technology education curricula with an emphasis on integrating aspects of mathematics and science also implies re-conceptualizing teachers' professional and pedagogical preparation.

Recommendations and implications for further research

Recommendation 1. Using the instrumentation developed and validated in this study, further comparisons of perceptions might be conducted with other subgroups such as science educators, industry-based engineering professionals, international engineering and technology educators, school board members, school administrators, and secondary school students.

Recommendation 2. In selecting panelists for future studies, targeted efforts should be made to recruit younger panelists to determine if their perceptions about the importance of knowledge and skills related to contemporary technologies differ significantly from their more experienced, presumably older, colleagues.

Recommendation 3. In any future related study related to disciplines where females and other minorities are underrepresented, targeted efforts should be made to recruit members of these groups to gain deeper insight into their perspectives and to enable gender-equitable approaches to selecting ETE content and pedagogical approaches.

Summary

The outcomes of the present research add to the literature by providing a comparison of perceptions of two groups of educators (AEEs and CTTs) that both have, as their core mission, educating students about the human-made world.

It is hoped that as a result of this study's findings, curriculum decision makers will plan their ETE instructional priorities to reflect the concepts and skills expert AEE and CTT panelists have indicated to be, in their consensus view, to be most important for high school students to learn as part of their fundamental education.

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The black box and beyond: introducing a conceptual model as a learning tool for developing knowledge about technological systems

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Abstract

In the last decade research about technological systems in technology education has attracted increased attention. This research has pinpointed pedagogical challenges in teaching about systems, particularly how pupils are given the opportunity to learn about complex systems in a conscious progression; the components and connections in between, system boundaries, and the relation to society in general and other systems in particular. The aim of this paper is to construct a conceptual model as a learning tool for developing knowledge about technological systems. Since we base this model on previous research about technological systems, this study is a *qualitative research synthesis*, where we employ comparative and hermeneutic methods. Our model contains focal points for teachers and pupils to attend to in technological systems education: 1. System structure, 2. System function with single or multiple inputs, and 3.The relationship between components without and with feedback loops. Important concepts for education about technological systems are system boundary, function, flow, feedback loop, black box, consequence, and historical evolution. Finally we introduce the concept of systems horizon as the limit for what can fruitfully be analyzed as a technological system.

Keywords

Technological system, conceptual model, technology education, concept

Introduction

Learning about technological systems has become an important item in technology curricula and standards across the globe, for example, in Sweden, the USA, and New Zealand (*Läroplan för grundskolan, förskoleklassen och fritidshemmet 2011*, 2011; *Standards for Technological Literacy: Content for the Study of Technology*, 2000; "Technology in the New Zealand Curriculum," 2007). There has also been an increased attention to this in technology education research in the past ten years. Örtnäs (2007) studied how secondary school pupils perceive technological systems in their everyday lives. Her conclusion is that with a little scaffolding they can understand how the cell phone system, the deposit can system and the washing machine work, at least the structure of the systems and how they relate to sub-systems and humans. However, the older pupils show a greater knowledge of single components than the younger ones. Svensson (2011), who studied 10 and 15 year-old pupils' experience of technological systems, concludes that they understand the structure quite well but not to the same extent how components interact and how humans fit in the systems. Hallström and Klasander (2013) show that technology teacher students find it difficult to grasp more complex systems like urban traffic, while familiar and/or well-defined systems such as an elevator are easier to understand.

Klasander (2010) concludes that systems thinking among teachers is often poor and is hampered either by a focus on scientific, reductionist aspects of systems or on single artefacts. Svensson and Klasander (2012) studied how two groups of technology teachers plan teaching about technological systems in lower secondary school. The study shows that the teachers require a better understanding of which systems may be relevant. More knowledge about the similarities and differences between various technological systems could be helpful to be able to select systems. A better understanding of the system's components and different layers could also contribute to a more developed understanding. Koski and de Vries (2013) designed an intervention where primary pupils and teachers did a pre-test, the teachers then taught lessons and lastly the pupils did a post-test, all related to how they perceived various aspects of technological systems and how the teaching could be improved. The concept of input, for example, was clearer to the pupils than output. Setting boundaries to systems was also a challenging task. When the teacher included some systems thinking in technology teaching, alternative approaches to discussing the problems were introduced to the class. Although systems thinking was rather limited among the pupils, they were at least able to reach beyond basic descriptions.

Even though the previous research on technological systems in technology education is rather limited, one can draw a few conclusions of relevance for this study. First of all, pupils seem to gain a deeper understanding of systems as they grow older, especially regarding the included components. Secondly, pupils also seem to understand systems better when they are scaffolded, either by an interviewer or by teaching interventions. Thirdly, teachers seem to be confused as to what systems to teach and would therefore want more knowledge of various differences and similarities between technological systems.

The ability to choose and define, compare between, and generalize about systems thus seems to be lacking both among pupils and teachers, and consequently becomes a major challenge when teaching about technological systems. Current system teaching in technology education does not take advantage of system theories and models. At the same time the available system models are not developed for teaching and learning about technological systems. The aim of this paper is to construct a conceptual model as a learning tool for developing knowledge about technological systems. In engineering practice, a model of a technological system could be used to describe, investigate, construct, or steer a system, but system knowledge intended to make pupils in the school technologically literate needs to be pedagogically adapted. We therefore suggest a model that will make pupils understand certain basic characteristics of technological systems, in order for them to be able to describe and investigate them.

Theoretical background

A technological system constitutes a whole that is more than the sum of all its individual parts; it consists of components and connections between them, but serves a function not immediately reducible to each individual component. Previous research about technological systems has pinpointed a few basic characteristics that apply to all systems: they are social constructions defined by a number of components and connections and flow of information or matter between them as well as a system boundary (e.g. Hughes, 1987; Ingelstam, 2002). Such a crude description could serve as a starting point for education about technological systems, although the systems could be of many different kinds; electric circuits, control systems with feedback loops, socio-technical systems, systems of innovation, etc. Consequently, a model of some kind would be helpful in order to make comparisons between and generalize about systems. In technology and engineering, a model can be said to be a simplified representation of an object, system or process, intended to make it comprehensible and manageable. Technological models are of many different types: physical objects, computer simulations, drawings, diagrams, flow charts, and more (cf. Wells, Hestenes, & Swackhamer, 1995).

In the same way, a pedagogical model is a simplified representation of something but for educational purposes. The kind of model we want to develop in this paper is a conceptual model, which can include both the sort of model used by professional technologists and more pedagogical models. Conceptual models have four main purposes: a) to boost the understanding of a domain or system, b) to help communication between developers and users, c) to serve as a foundation for design, and d) to document the design of the system (Burton-Jones & Meso, 2006). We will primarily focus on the first purpose or function: a conceptual model for *understanding* systems, to be used in technology education.

Methodology

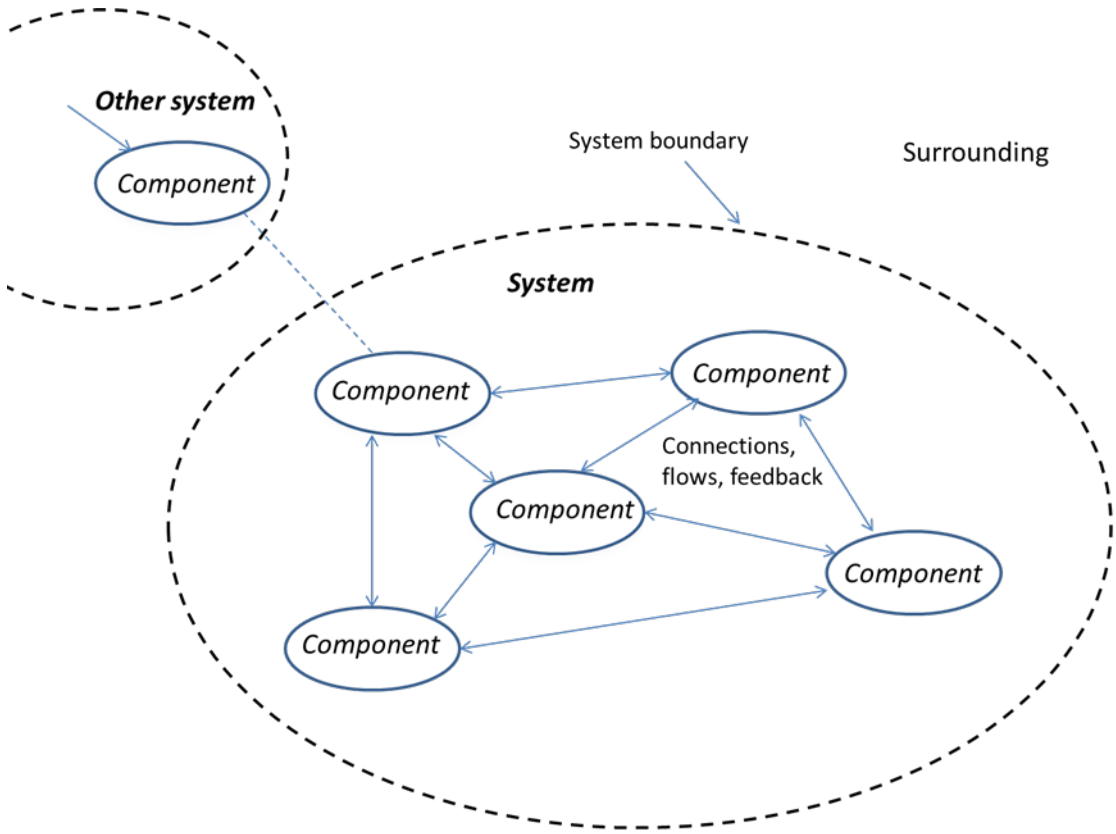
In this paper we put together a pedagogical conceptual system model from previous research about technological systems. It is thus a *qualitative research synthesis*, similar to, but less structured and systematic than, the meta-ethnography of Campbell, Pound, Pope, Britten, Pill, Morgan and Donovan (2003). As regards the selection of research we selected a number of "classics" about technological systems in the field of sociology, history, and philosophy of technology. The method of analysis involves, first of all, various modes of hermeneutics and interpretation of previous system theories (Ödman, 2007). Secondly, we employ a comparative method where we juxtapose theories and relate them to the field of technology education (Burke, 1992), in order to construct our own system model.

Results

Given the fact that there is not much research on the modelling of technological systems in educational settings, we have seen the need to construct a system model from scratch, so to speak, based on previous research about technological systems as described above.

The first image of our model focuses on the overall structure and brings to the fore a few basic characteristics of technological systems (Figure 1). The first point we want to make is that technological systems are in essence social constructions and therefore have to be defined (Hughes, 1987). The system boundary is therefore an arbitrary border that has to be marked out for every system, which is the primary challenge for the technology teacher. Secondly, the surrounding is everything which is outside of the direct control of the system, although the system can interact with the surrounding and other systems (Klasander, 2010). Thirdly, within the system there are a number of components with connections between them; these connections can be physical like wires, pipes, and cables, but may also be "abstract" in the way that flight paths connect components (airports) in the airplane system. Fourthly, these connections pass on flows of matter (including people), energy, or information (Hallström, 2009; Kaijser, 1994, 2004). This is also a major pedagogical challenge since the flow of information could be both a substance transported in/by the system *and* a means of controlling the system, like the dialogue vs. the caller information in cell phone systems.

Figure 1. Modelling the structure of a technological system



From this model of the structure of a system we move outward to look at the purpose of the system, in which case pupils' awareness should be directed toward the system's main output. The image of the model in Figure 2 we use to describe how the output is used in different technologically related contexts as an explanation of technical activities such as manufacturing processes, design processes etc. This use of the model is an advantage and a strength when one wants to clarify the nature of technology as process oriented, or when modelling, for example, electronic systems (Martin, 1990).

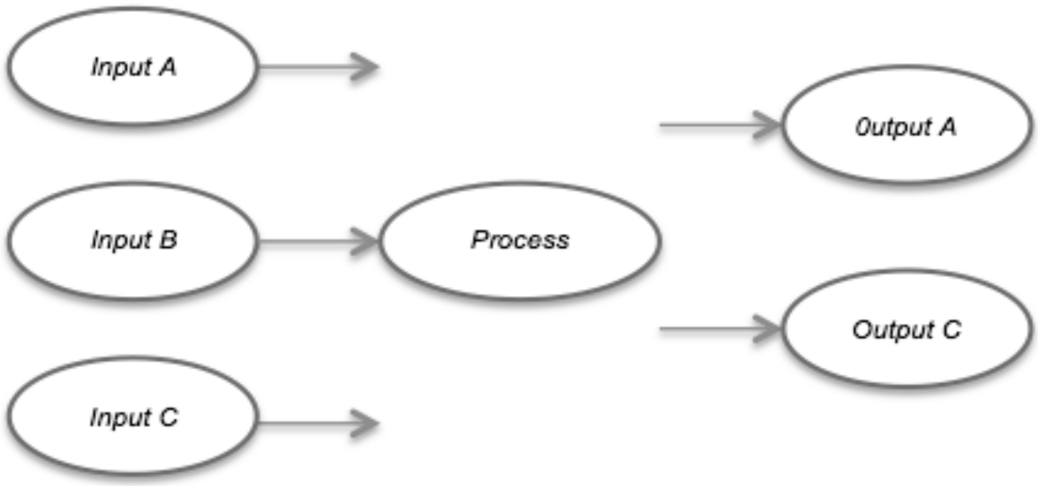
When teaching about technological systems this view of the model makes it possible to focus on what the main resource that flows in the system is, in order to make the input and output visual and to look at differences between input and output without placing too much importance on the processes that cause possible changes. It is crucial for understanding that there is a flow related to the intention of the system (Svensson, 2011). To understand why in cities we build water supply systems pupils need to be aware of the fact that the flow of water from different sources is the actual purpose of building it. The image of the model in Figure 2 is based on the black box metaphor, that is, there is input and output and in between some transfer characteristics without information about the internal workings. This could be helpful in education when we want to know how the system behaves and develops, whilst avoiding pupils getting caught up in details about a specific process (Boulding, 1956; Latour, 1999).

This model is thus linear, which can both be seen as a problem and an opportunity in educational contexts. A linear model simplifies and hides the network character of the system but it also makes it easier to understand at the level of function with pupils in the lower grades of compulsory school.

Figure 2. Modelling the function of a technological system with input and output

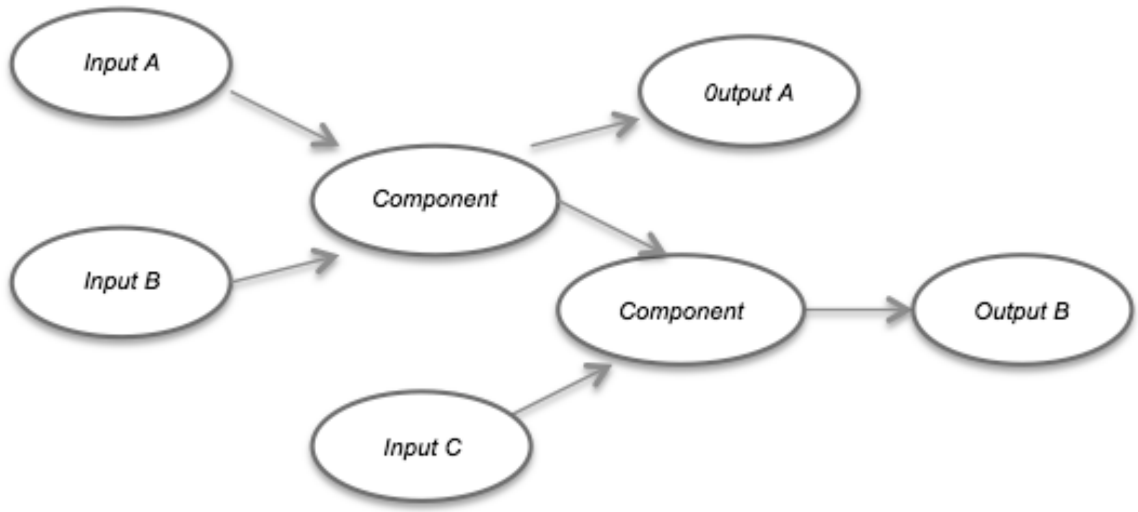
To clarify that a system requires more than one input, the main resource, and that the processes in the system result in varying outputs, we have to complement the model of function and move closer in to the system, as in Figure 3. With this part of the model pupils have the possibility to identify all three resources – matter, information and energy - that may be needed for the functioning. If we look at a water supply system, the resource that is linked to the purpose of the system is water - matter - but to make the system work energy as well as information are required. When including input from more than the main resource the connection to subsystems becomes visible. The employing of the model in teaching thus depends on the purpose with using the model and the level of pupils' knowledge. When we do this zooming-in, described in the image of the model in Figure 3, it means that we are opening up one or more black boxes to create opportunities to develop further knowledge about the internal working of a system.

Figure 3. Modelling differentiated input and output



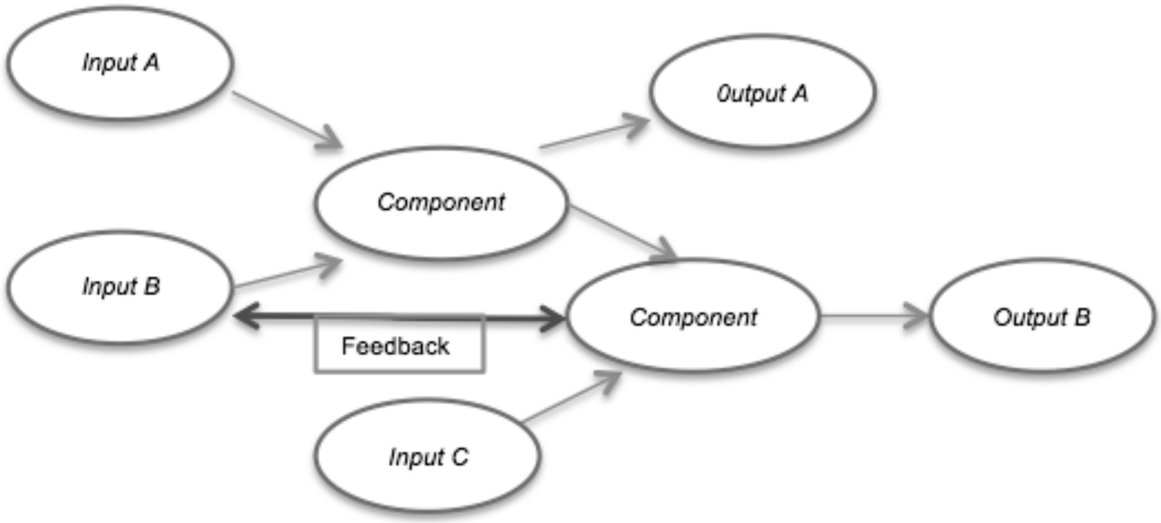
The next image of the system model aims to look even closer into the process and find out about what component is involved in the process and identify the function - transforming, storing, controlling and regulating - of the different components. Visualization of the components, Figure 4, means opening more of what was a black box in the image of model in Figure 2 and by that putting a focus on important technical principles and functions that are part of the knowledge field technology. Pupils have the possibility to look closer into what is happening with the resources in different components and how it affects the flow. What happens, for example, with the water in a water treatment plant, is there any transformation and/or storage, is the flow controlled in a special way? The image of the model in Figure 4 also makes different resources needed in the system and in specific components visible. A pedagogical challenge could be to balance the level of detail of what is happening in the components and to select relevant components. Another challenge could be not to lose the systemic nature in favour of the individual components' functions.

Figure 4. Modelling visualized components



A development of the image of the model in Figure 4 is to include some feedback loops (see Figure 5). These loops make the connection between components more clear and the functions in components that control and regulate the flow get increased significance. One of the pedagogical possibilities with this image of the model is to discuss the consequences of various interruptions in these feedback loops for the system as a whole but also for individuals, for the environment and for society. In a water supply system an interruption in the feedback of regulating the level of mercury in water could have disastrous consequences, for instance.

Figure 5. Modelling feedback



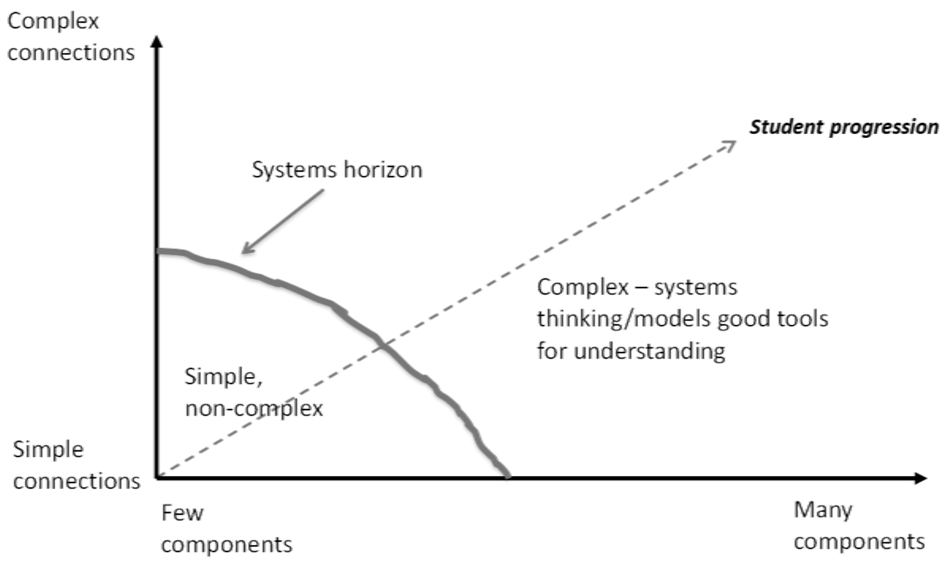
Concluding discussion

The model presented in this paper zoom in on characteristics that according to system research are central to an elaborate understanding of technological systems. However, in an educational context there also needs to be an idea of what competencies pupils of different ages need to develop in order to be able to successfully acquire an understanding of technological systems. In short, just as in other subjects, pupils need to practice to learn systems thinking in general and certain aspects of technological systems in particular. Consequently, we developed aspects or focal points for teachers and pupils to attend to in technological systems education, which can also be seen in the above ways of modelling: 1.

System structure, 2. System function with single or multiple inputs, and 3.The relationship between components without and with feedback loops.

When teaching about a particular technological system the teacher, first of all, needs to focus on the *system boundary*, which, in turn, is determined by the *function* of the system. Secondly, there is a *flow* of information, matter or energy in the system, making it able to fulfil this function. Thirdly, the flow of information can be of two kinds, as something connecting the components and thereby contributing to the function as well as for controlling the system through a *feedback loop*. Fourthly, the system can therefore also be regarded as a *black box*, that is, it can be understood on a system level with input, output, feedback, etc. without having to look at every single, internal component. Fifthly, the system has an output that may have unintended *consequences* in terms of environmental pollution, work-related injuries, etc., but also unforeseen beneficial effects. Lastly, which is not easily visualized in a model, it is crucial to look at the historical evolution of the system; the actors and driving forces in and outside of the system that contributed to and still contributes to its evolution (cf. Hallström & Gyberg, 2011).

Figure 6. A diagram of pupils' progression beyond the *systems horizon* between non-complex artefact and complex system



In conclusion, in order for teaching and learning about systems to be effective it is crucial to be able to differentiate between technological systems and other technologies that are best understood as not being systems, something which our model does not take into account. We therefore want to further explore the term *systems horizon* for the border between a "simple" or non-complex apparatus or artefact on the one hand, and what can fruitfully be analyzed as a technological system on the other. This border or horizon is important for the progression of pupils' knowledge about technological artefacts and systems, and should ideally go from lower left to upper right in the above figure (see Figure 6). However, this is something that needs to be further explored and developed in a future research study.

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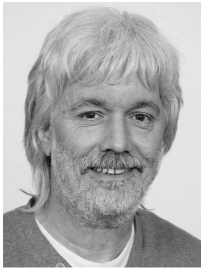
Industrial technology and engineering sciences in France
The disciplinarization process and its impact on technology education



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Abstract

This paper describes the historical process of development of engineering sciences as a school discipline and as an academic subject. It aims to understand the evolution of contents and their structuration, mainly, of the industrial technology for men, and of the home economics for women, from the *Liberation* to today. It contributes to analyse the history of technology education in the basic school and its positioning in the curriculum.

This historical and didactic research focuses on the prescribed curriculum, analysing official texts about contents (practical tasks, functional analysis, graphic tools, modelling…), the training and the certification of teachers, equipment and administrative organization. It identifies the concordances between the emergence of engineering sciences within the university, their development within the tertiary and secondary schools and the development of technology education within the basic education. This contextualized sociological and political history reveals the movement of the deprofessionalization and the despecialization of the current courses, the opportunities to take into account of the sustainable development, the relegation of producing, the priorities for scientific approaches, the integration of mechanics, electronics, automatics, energetics and numerical tools.

Keywords

Curriculum, disciplinarization, engineering sciences, technical teaching, technology education

Introduction

This paper describes the disciplinarization-process of a component of French technical teaching, i.e., the historical process of the development of engineering sciences such as a school discipline and such as an academic subject. It aims to understand the evolution of contents and their structuration, mainly, of the industrial technology for men, and of home economics for women, from the *Liberation* to today. It contributes to analyse the history of technology education in the basic school and its positioning in the curriculum (de Vries, 2011). It also enlightens the specificity of the French school organization characterized by its three ways to get high school diploma.

This historical and didactic research focuses on the prescribed curriculum from the analysis of official texts concerning its purposes, its contents (practical tasks, functional analysis, graphics tools, modelling…), its administrative organization and the training and certification of teachers. Taking into account the sociological and political context this history reveals the disciplinarization process (Goodson, 1981) divided in six main periods.

The restructuration after the *Liberation,* creation of new technical school and diploma

Following the Second World War, such as the others countries, France, has to be rebuilt. Technical education is specially requested in order to develop the workforce and to help the families deeply affected by war by providing food, health and housing. Several administrative and pedagogical reforms affect the technical education in order to include it in the school system. Their middle and high vocational schools are restructured in order to train the workmen, the technicians and the future engineers or teachers. The three respective diplomas are the "vocational ability certificate" (instituted in 1920), the "industrial training certificate" (instituted in 1893) and the "technical high school diploma" (*Baccalauréat technique* : just created in 1946). Pupils respectively are being coached for the exam in specific technical schools: "apprentice center" (vocational middle school created in 1944), "local vocational school" (vocational middle school created in 1893) and the most prestigious "national vocational school" (national vocational high school created in 1903).

For all of these degrees, the boys learn three technical school-subjects: technology of mechanical manufacturing, manual work on machine-tools and technical drawing. The technical teaching for young boys is organized around the elements of the "machines paradigm" (Hamon, 2015), while the young girls are trained for the "vocational ability certificate" of home economics. They learn cutting clothes and sewing, and applied sciences for housework (Lebeaume, 2014). The syllabus are divided in two parts: (i) practical teaching is implemented by workshop teachers who are senior workmen recruited by the management of the technical education or directly employed by the school establishments; and (ii) theoretical teaching with teachers who are recruited by competitive national examinations, trained and certified for teaching.

In 1952, a new "vocational technician diploma" is create in order to increase vocational qualifications and to resorb the penury of technicians (*cf.* matrix 1). In the same period arts and crafts are implemented within general junior high school. The aims of these new "educative manual works" mainly are to reveal the interests and aptitudes of the teenagers for manual jobs and to discover their perseverance and their sense of teams work. Pupils produce useful and fun artefacts: wood and iron for boys, sewing, dress making and cooking for girls. Their teachers have a specific certification: manual work for the men or home economics for the women.

<table>
<tr><td>Organization</td><td colspan="4">Technical teaching</td><td>General teaching</td></tr>
<tr><td>School</td><td>Apprentice centers</td><td>Local vocational schools</td><td colspan="2">National vocational schools</td><td>High school</td></tr>
<tr><td>Future engineers or teachers</td><td></td><td></td><td></td><td>Technical high school diploma</td><td rowspan="3">General way</td></tr>
<tr><td>Future technicians</td><td></td><td colspan="2">Industrial training certificate
Vocational technician diploma</td><td></td></tr>
<tr><td>Future workmen</td><td>Vocational ability certificate</td><td></td><td></td><td></td></tr>
<tr><td rowspan="2">School</td><td></td><td></td><td></td><td></td><td>Junior high school</td></tr>
<tr><td colspan="5">Primary school</td></tr>
</table>

Matrix 1. In 1952, after the restructuration of technical teaching (in bold, the changes)

But this specific hierarchic and compartmentalized organization of technical teaching, patiently built by their defenders, does not resist to the requirements of the democratization of the education.

The 60’s, the adaptation to the modernity and an unified educational system

In the early 1960’s, compulsory school age becomes 16. Two facts influence the evolution of the educational system: (i) the democratization of education and its mass dissemination; (ii) a shortage of skilled technicians.

Therefore, technical education is again involved and its degrees are restructured. The first one of the “apprentice centers” becomes “technical middle school”. At the second one, the “local vocational schools” and the “national vocational schools” are merged into new “technical high schools” progressively integrated in the unified school system.

Technical teachers are better trained in specialized areas. New teachers are trained in different domains (mechanics, industrial electricity, biochemistry…). The administrative status of these theoretical technical teachers (drawing, technology of mechanical manufacturing…) is aligned with that of the teachers of general-high schools (1959). For the practical technical teachers, two years of pedagogical training are implemented with an official certificate of teaching (1965). From 1961, in the same way, the teachers (mainly females) of arts and crafts and home economics have the same certificates. In 1962, due to new requirements in the areas of health and nutrition, home economics becomes more scientific mainly in the disciplines of physiology and biochemistry. The high-level competitive examination for the recruitment of teachers, “*Agrégation*” in French, is created to select the teachers’ trainers and the inspectors. In 1968, the same movement concerns the mechanics.

Finally, under the influence of Lucien Géminard (*Arts et Métiers* engineer and general inspector of technical teaching), each of the three most scientific “industrial training certificate” (mechanics, electro-mechanics, electronics) is converted into a “technician high school diploma” (first examination in 1969). Its programs include the technical analysis and the functional schema of artefacts. These new contents reveal a more scientific approach of technical teaching, in comparison with the machines paradigm-based classical industrial school-subject. In the upper high school and university, the technical teaching is born with the creation of the “superior technician diploma” in 1962 and a “technological university diploma” in 1966.

At the same time of this important evolution, the different general junior high schools are harmonized without affecting the "apprentice centers". Their label changes to "technical teaching middle school", but their aims - the vocational training - do not change. In 1966, a new workman-training diploma the “vocational study diploma” is established, more generalist than the “vocational ability certificate” (*cf.* matrix 2).

<table>
<tr><td>Organization</td><td colspan="3">Technical teaching</td><td>General teaching</td></tr>
<tr><td>School</td><td>Technical teaching middle schools</td><td colspan="2">Technical high schools</td><td>High school</td></tr>
<tr><td>Future engineers or teachers</td><td></td><td></td><td>Technical high school diploma</td><td rowspan="3">General way</td></tr>
<tr><td>Future technicians</td><td></td><td>Vocational technician diploma
Technician high school diploma</td><td></td></tr>
<tr><td>Future workmen</td><td>Vocational ability certificate
Vocational study diploma</td><td></td><td></td></tr>
<tr><td rowspan="2">School</td><td></td><td></td><td></td><td>Junior high school</td></tr>
<tr><td colspan="4">Primary school</td></tr>
</table>

Matrix 2. In 1969, after the democratization (in bold, the change)

These changes show the great evolution from the separation of the vocational and the technological teachings, confirmed by two successive reforms.

The reform of the 70's, the separation between the vocational and the technological studies

Two important reforms affect the school system in the 70's and achieve its unification. The first one (law: 1971) is the introduction of technological teaching. This change officially distinguishes the vocational schools and the technological schools. The second reform is known by the name of its initiator, the minister René Haby. In 1975, he creates a unique junior high school which postpones the beginning of the vocational and the technological studies after 15 years' old. One year later, a decree renamed the "technical teaching middle school" in "vocational teaching high school" (*cf.* matrix 3). After this great change, three different high schools exist: vocational, technical and general studies. So distinguished from vocational training, technological teaching keeps on its evolution. In 1975, three new "*Agrégations"* of mechanical engineering, electrical engineering and civil engineering are instituted. Two years later, some technological "*classes préparatoires aux grandes écoles*" are opened. In these high school classrooms, a new paradigm is implemented for the analysis of automatized systems. The artefacts are considered as a "black box" with energy, matter and information inputs and outputs. In the same time, home economics has been declining for the benefit of the nutritional sciences and the medical and social sciences.

<table>
<tr><td>Organization</td><td>Vocational teaching</td><td colspan="2">Technological teaching</td><td>General teaching</td></tr>
<tr><td>School</td><td>Vocational teaching high schools</td><td colspan="2">Technical high schools</td><td>High school</td></tr>
<tr><td>Future engineer or teacher</td><td></td><td></td><td>Technical high school diploma</td><td rowspan="3">General way without technology</td></tr>
<tr><td>Future technician</td><td></td><td>Technician high schools</td><td></td></tr>
<tr><td>Future workman</td><td>Vocational ability certificate
Vocational study diploma</td><td></td><td></td></tr>
<tr><td rowspan="2">School</td><td colspan="4">Junior high school</td></tr>
<tr><td colspan="4">Primary school</td></tr>
</table>

Matrix 3. After the 70's reforms (in bold, the change)

Thus, the school system evolution upsets the technical teaching.

The reform of the 80's, the birth of the technology education

The 80's are a new period for the school system that begins by a political change. The main aim is defined: an increase of percentage of pupils with a high school diploma level (baccalauréat) from 40% to 80% in 2000. This aim induces an important upset in the vocational training and the technological training, their organization, diploma and contents.

In 1985 (a new law is voted), the names of the high school changed again: the "vocational teaching high school" becomes the "vocational high school", and the "technical high school" becomes the "technological high school". On one hand, the specific purposes of this two courses are accentuated with the creation of the vocational high school diploma (baccalauréat professionnel). On the other hand, the "technician high school diploma" becomes a technological high school diploma (baccalauréat technologique), more generalist (cf. matrix 4). In this sense, in 1986, a joint propaedeutic training year was created for this two diploma, named the "automatism-system technology". Then, with the new automatism-system paradigm, this teaching unifies different technological school-subjects (mechanics, electronics, energetics, pneumatics...). In continuation, two years later (1988), the manual work on machine-tools is replaced by information technology. The practical teachers then are joined with theoretical teachers with a new certification in mechanical, electrical or civil engineering. In the same time, the changes affect the junior high school. Two school-subjects appear, the "manual and technical education" and the "technology education" (Lebeaume, 2011a). But in the competition, the new vision of "technology education", without vocational aim, eventually is the winner. A new certification of technology teachers for junior high schools is created (1985). At the same period, in the university, mechanical and electrical engineering courses appear.

Organization	Vocational teaching	Technological teaching		General teaching
School	**Vocational high school**	**Technologic high school**		High school
Future engineer or teacher			Technical high school diploma	General way without technology
Future technician		**Technologic high school diploma**		
Future workman	Vocational ability certificate Vocational study diploma **Vocational high school diploma**			
School	Junior high school			
	Primary school			

Matrix 4. After the 80's reform (in bold, the change)

At all of these degrees, the technological contents change with the systemic analysis and practical work on real technological systems. The new vision of the technology is now clearly oriented to the functional analysis and the conception rather than the production.

The turning point of the 20th century, the triumph of engineering sciences

The turn of the 20th century is a new occasion for some positive evolutions of technological teaching.

In 1992, the renovation of the high school formalises the three ways, vocational, technological and general, whose foundations date from *Liberation*. If the "vocational high school diploma" does not move, the "technological high school diploma" is qualified such as the "sciences and industrial technologies" whereas the "technical high school diploma" obtains the more prestigious designation of "scientific high school diploma" with "industrial technology option". This diploma is now propaedeutic to the new "engineering industrial sciences", a school-subject within the "*classes préparatoires aux grandes écoles*" (1995). In the beginning of the 2000's the "industrial technology option" of the "scientific high school diploma" is renamed to "engineering sciences option" (*cf.* matrix 5). This evolution to an excellence way appears such as a consecration for a school-subject devalued for a long time. At this moment, the engineering sciences develop the system-analysis paradigm and the three dimensions (3D) modeling by computer. In 2008, under the influence of the general inspection, the syllabuses of technology education within junior high schools are redesigned (Lebeaume, 2011b). With the pluritechnical-system paradigm, the new contents prefigure a harmonization between high schools and "*classes préparatoires aux grandes écoles*". In the vocational way, the "vocational study diploma" disappear (2009).

Organization	**Vocational way**	**Technological way**	**General way**	
School	Vocational high school	**General and technologic high school**		
Future engineer or teacher			**Scientific high school diploma (with options)***	General way without technology
Future technician		**Sciences and industrial technologies high school diploma**		
Future workman	Vocational ability certificate Vocational high school diploma			
School	Junior high school			
	Primary school			

Matrix 5. The three ways of educational system (in bold, the change *with industrial technology option in 1992 and engineering sciences option in 2000)

However, this changes do not affect the new “sciences and industrial technologies” whose programs have not veritably revised since 1988. It’s a new challenge for the technological teaching.

The break of 2010

As in 1946, and in 1959 for technical teaching and in 1985 for vocational teaching, technological teaching is involved by the school system to allow to elevate the global school level in France, i.e., to be in conformity with the aims of Lisbon: 50% same age-group with baccalaureate level.

Thus, in 2010, the technological high school diploma (*baccalauréat technologique*) is completely updated. The scientific general teaching replaces the applied-sciences. It is exactly a deprofessionalization and a despecialization of this training. As the engineering high school diploma, the aim is to keep on studying to tertiary school, in particular “*classes préparatoires aux grandes écoles*” and “engineer schools”. The technological contents are structured around matter, energy, information. This important reform allows opportunities to take account of the sustainable development. The different specialities (mechanics, electronics, energetics…) are merged in different options and a common teaching that uses the engineering method with Systems Modelling Language (SysML) imported from informatics. The technician education is currently reported in tertiary school (*cf.* matrix 6). This revolution continues with the teachers’ certification: the specialties of mechanics, electronics, energy… are merged into the undifferentiated engineering with the label “engineer industrial sciences teaching”.

<table>
<tr><td>Organization</td><td>Vocational way</td><td>Technological way</td><td colspan="2">General way</td></tr>
<tr><td>School</td><td>Vocational high school</td><td colspan="3">General and technologic high school</td></tr>
<tr><td>Future engineer or teacher</td><td></td><td>Sciences and technologies of industries and high school diploma</td><td>Scientific high school diploma (engineering sciences option)</td><td rowspan="2">General way without technology</td></tr>
<tr><td>Future workman</td><td>Vocational ability certificate
Vocational high school diploma</td><td></td><td></td></tr>
<tr><td rowspan="2">School</td><td colspan="4">Junior high school</td></tr>
<tr><td colspan="4">Primary school</td></tr>
</table>

Matrix 6. The contemporariness situation (in bold, the change)

Thus, a technology curriculum from the junior high school (and primary school) to the tertiary school, is built with the same teachers and progressive contents. After the secondary school, the technological course or the engineering open the doors for tertiary school.

Conclusion

In 1945, technology is not a school-subject but only one of the three vocational school-subjects with manual work on machine-tools and technical drawing. The engineering sciences do not exist. The disciplinarization process of technology is the product of vocational technical teaching moving towards a general teaching of engineering sciences, i.e. the transition from an utilitarian vocational objectives-driven to an academic subject-based content-driven (Ross, 2000). This lengthy process results in three main linked changes: political, institutional and content teaching in relationships with technical environment.

According to the historical periods and the evolution of society, the assignment for technology education within high school successively are the rebuilding of the country and the increasing of the workforce that needs higher and higher qualifications and consequently longer studies. The political and socio-economics choices are translated in a progressive aligning of the different school ways to the general secondary school model (same recruitment of teachers, extension of the school career, rejection of workshops…). This trend drives the deprofessionalization and the despecialization of technology at school with important effects on the contents. These contents are in a constant progress. Under the influence of innovative teachers and inspectors, industrial technology and its pedagogical method change in different paradigms. Currently, the purposes and the actualization of contents are fundamental in order to justify and to legitimate its existence, such as it has been shown with the disappearing of home economics.

Thus, for 70 years, one part of the vocational technical teaching has been becoming an academic subject. On one hand, one vocational relegation way keeps on existing. The two high school diploma of technology and engineering are more similar. Technology education and engineering currently are one of the better ways to rise to "engineer schools" or university: 80 % of students titular of "engineer sciences high school diploma" keep on studying in "*classes préparatoires aux grandes écoles*".

If evolution keeps on the same trend, with simplification of school system and its aligning on the European model, the technological way could disappear (cf. matrix 7).

<table>
<tr><td>Organization</td><td>Vocational way</td><td colspan="2">General way</td></tr>
<tr><td>School</td><td>Vocational high school</td><td colspan="2">General high school</td></tr>
<tr><td>Future engineer or teacher diploma</td><td></td><td>Scientific high school diploma
(engineering sciences and technology option)</td><td rowspan="2">General way without technology</td></tr>
<tr><td>Workman diploma</td><td>Vocational ability certificate
Vocational high school diploma</td><td></td></tr>
<tr><td rowspan="2">School</td><td colspan="3">Junior high school</td></tr>
<tr><td colspan="3">Primary school</td></tr>
</table>

Matrix 7: The future situation? (in bold, the possible change)

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What do others think is the point of design & technology education?

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Abstract

As a result of a national curriculum review in England (Department for Education [DfE], 2011), a new curriculum for design and technology (D&T) is being taught in secondary schools from September 2014 (Department of Education [DoE], 2013a). This curriculum is compulsory for a decreasing number of schools; two potential consequences are the nature of D&T in secondary schools changing to reflect local perceptions of the subject and maybe D&T being removed from the curriculum completely. The pressure on D&T's curriculum content is likely to come from different stakeholders such as senior school leaders, D&T teachers, and pupils. D&T school departments could respond to this pressure by adapting the curriculum to popularise the subject or produce high exam results with a consequence that much of the subject's value is lost.

This paper reports on a small research project conducted in two secondary schools where stakeholder representatives were interviewed to identify their values of D&T. These different stakeholders were interviewed using the active interview method (Holstein & Gubrium, 1995), coded following Aurebach and Silverstein's method (2003) and their values compared to Hardy's values framework (Hardy, 2013b). Analysis shows most stakeholders believe a key value of D&T is to provide 'practical life skills' (Hardy, p.226), whilst only one recognizes that learning in D&T involves 'identifying problems to be solved'.

The outcomes from the research are being used to support critically reflective conversations within both D&T departments (Zwozdiak-Myers, 2012) framing their evaluation of their local curriculum and making changes to their curriculum.

Keywords

Values, stakeholders, design & technology

Introduction

A new curriculum for design and technology (D&T) has been taught in English secondary schools since September 2014 (DoE, 2013a) but it is compulsory for a decreasing number. Two potential consequences are the nature of D&T in secondary schools changing to reflect local perceptions of the subject, such as to support pupils into local employment by providing vocational education, and maybe D&T being removed from the curriculum completely. Pressure for change will probably come from key stakeholders, such as senior school leaders, D&T teachers, and pupils, who may have conflicting views about the purpose of D&T.

Our research question is: how do three different stakeholders in schools value D&T and what are the similarities and differences in their values? This research explores three stakeholders groups' values of D&T in order to help D&T teachers in schools understand where there maybe conflict and consensus about the purpose of D&T. We will show how two schools have begun to reflect on these values in order to clarify the purpose of D&T in their schools.

Context

Previous studies in technology education about attitudes and values have primarily focused on attitudes towards technology (For example: Ardies, De Maeyer, & Gijbels, 2013; Chikasanda, Williams, Otrel-Cass, & Jones, 2012; Volk, 2007). We have decided to use values following critical analysis of Rokeach's investigations about how values and attitudes interdependency impacts on behavior. He determined that a value is an "enduring belief, ….a standard or criterion for guiding action, for maintaining and developing attitudes towards relevant objects and situations…." (1968, p.160). He argues that because values are enduring they influence attitudes and behavior; therefore by understanding stakeholder's values D&T teachers can take steps to change people's attitudes and behavior towards D&T if necessary.

There are two significant, timely arguments for this research; firstly a new National Curriculum and secondly changes to the state school system.

A new D&T curriculum was published in February 2013 (DoE, 2013b) and then rewritten (DoE, 2013a), with the final version being taught in schools from September 2014 (DoE, 2013a). Analysis of the first version revealed some alarming values of D&T potentially held by the (unknown) author/s, which some influential stakeholders agreed with (Dimbleby, 2013; Royal Horticulture Society, 2013). Although derided by the D&T community (Design and Technology Association, 2013; E4E, 2013; Hardy, 2013a; Prince, 2013) it is useful to remember that there are some stakeholders who believe this is the value of D&T. By exploring what people, other than D&T teachers, think is the point of D&T we hope to help D&T teachers understand how others perceive the subject, which in turn might help them reflect on the consequences of some of the D&T learning activities (Zwozdiak-Myers, 2012) and respond to any pressures they might be under to change the philosophy and direction of D&T.

The second argument is about the type of state schools pupils can now attend: free schools, faith schools, academies and community schools. Each has different structures and regulations but the most significant difference affecting D&T is that academies do not have to follow the National Curriculum, it can be decided at local level and designed to meet the community and business needs. Consequently the views and values of academy senior leaders towards D&T could have a significant impact on who teaches or studies D&T. With 56% of all secondary schools in England (Mansell, 2014) now academies we argue this time-context provides an imperative for the D&T community to determine how a school's stakeholders view D&T.

This research is based in two academy schools; St. John's is a city school with a Christian approach and Upton School, in the same city's suburbs.

Each stakeholder in a school's curriculum has different priorities for a curriculum and can be categorized based on differing attributes (Mitchell, Agle, & Wood, 1997). Williams (2007) illustrates the applicability of Mitchell et al's (1997) theory of stakeholder identification in determining the salience of different stakeholders dependent on their attributes. Taking Mitchell et al's definitions of the three attributes we have customized them for school stakeholders rather than business stakeholders: "(1) the stakeholder's *power* to influence the [curriculum], (2) the *legitimacy* of the stakeholder's relationship with the [curriculum], and (3) the *urgency* of the stakeholder's claim on the [curriculum]" (derived from Mitchell et al., 1997, p.854).

So which stakeholders' values should be explored? Using this theoretical framework and William's examples we have focused on three stakeholder groups ensuring coverage of the attributes:

- Senior leaders have power to influence the curriculum through organization of the curriculum (timetabling), resources (budgets) and awarding status (profile), urgency because of the demand for success in national league tables.
- D&T teachers have legitimacy through their relationship with D&T and power because of their influence in the classroom (Dakers, 2005).
- Pupils have urgency because of their claim (need) on the subject and legitimacy because their education is affected by D&T.

Method

In Upton School three D&T teachers and two senior leaders were interviewed and in St John's two from both groups were interviewed (Table 1). In both schools pupils in year 9 choose whether they will continue studying D&T towards a qualification in years 10 and 11; the eleven pupils interviewed were year 9 (fourteen years old) and included pupils who were both going to continue with D&T and those who were not.

We were conscious that each stakeholder's 'stock of knowledge' (Holstein & Gubrium, 1995, p.30) might be drawn from more than one perspective. Although we initially placed participants in one stakeholder group there was potential for them to belong to more than one group, having more than one narrative about D&T. Consequently all stakeholders completed a pre-interview questionnaire; the teachers and senior leaders gave information about themselves and their personal D&T history (Did they study D&T at school? What was it called?). We compiled this information and used Martin's (2013) five eras of D&T (making, personalising, designing, manufacturing and valuing) to determine in which era the participant studied D&T at secondary school; our participants only represented four eras. By using Martin's theoretical framework we hoped it might help us explain why different stakeholders held different values.

Participant & stakeholder group	Gender	Age	Era
Upton pupil group 1 (5 pupils)	F & M	14	Values
Upton D&T teacher 1	F	52	Making
Upton D&T teacher 2	F	22	Values
Upton D&T teacher 3	F	61	Making
Upton senior leader 1	F	52	Making
Upton senior leader 2	F	30	Manufacturing
St John's pupil group 1 (3 pupils)	F & M	14	Values
St John's pupil group 2 (3 pupils)	F & M	14	Values
St John's D&T teacher 1	F	26	Manufacturing
St John's D&T teacher 2	M	45	Making
St John's senior leader 1	F	35	Personalising
St John's senior leader 2	M	37	Personalising

Table 1. Profile of participants

Two of the three researchers are D&T teachers in the schools, the third an academic at the local university. This had ethical implications for the collection, data analysis and interpretation. The school-based researcher made the initial contact with potential participants and contacted pupils' parents. Interviews were conducted by the university-based researcher, recorded with permission and later transcribed. Teachers and senior leaders were interviewed individually and face to face with only the interviewer present; pupils were interviewed in groups with a schoolteacher present. The school-based teacher from Upton was one of the participants as well.

Holstein and Gubrium (1995) argue that the relationship between the interviewer and interviewee can be active; they interact and create the knowledge collaboratively, which was our approach to the interviews. The interviews were structured slightly differently for each stakeholder group: pupils choose one photo from a selection picturing different D&T activity that was the closest representation for them of D&T, the photos helped them explore what was the point of D&T. The same photos were used with senior leaders but the interviews explored what they thought was the purpose of the D&T activity in the photos. The teachers were asked to talk about the value of the pupils' learning in their most recent D&T lesson. From all of these positions the interviewer was able to explore their opinions about D&T, why it was useful, how it helped them today and in the future, also its unique place in the curriculum.

Data analysis

Firstly we applied Value Codes (Saldaña, 2012) to all the interview transcripts using Rokeach's definition to identify a value:

> "An enduring belief that a specific mode of conduct or end-state of existence is personally or socially preferable to an opposite or converse model of conduct or end-state of existence"
>
> (Rokeach, 1968, p.160)

To test the coded value was a D&T value we checked that it either:

- Explained why the speaker thought pupils should do D&T or
- Gave some benefits of doing D&T or
- Justified the point and purpose of D&T.

Next we established intercoder reliability for three interviews, agreeing the first code values and then individually consolidated the value coding for different stakeholders. The two school-based researchers only consolidated codes from the other school, not their own.

The second phase of coding was elaborative (Auerbach & Silverstein, 2003; Saldaña, 2012) building on previous research by Hardy (2013b) that explored the values espoused in writing by trainee D&T teachers and interviews with academics from the discipline of D&T education. In her research Hardy identified the values using the same definition and checklist above to find themes (Auerbach & Silverstein, 2003) leading to a series of twenty-two different values (see appendix). Hardy does not claim these values to be definitive but only from these two stakeholder groups, so in part we saw this research as an opportunity to develop Hardy's original framework but we also used it for deductive coding purposes (Miles, Huberman, & Saldaña, 2013) to facilitate the comparison between our three stakeholder groups. To compare the coded values we used the computer analysis data software MAXQDA.

Findings

First coding revealed 673 text segments identified as a value, in the second phase of coding forty-five items could not be assigned to one of Hardy's twenty-two value codes. The most commonly assigned value was 'learn practical life skills' with 120 coded segments, the second was 'using raw materials to make a product' (n=62) and 'identifying problems to be solved' was not recognized as a value of D&T by any of the stakeholders.

Senior leaders and D&T teachers at St John's School hold the same values of D&T (21 out of a possible 22), where as the pupils hold a more limited range (12/22). At Upton School there was no obvious correlation between the three groups, but the senior leaders do hold a wider range of values (18) than both the D&T teachers (14) and pupils (14).

Analysis

Our research question was: how do three different stakeholders in schools value D&T and what are the similarities and differences in their values? We explored the similarities and differences between three stakeholder groups' values in two schools: pupils, senior leaders and D&T teachers. We have also done further analysis to see if the stakeholder's age might have a bearing on their values.

Pupils' values

None of the pupils interviewed held any of these values of D&T:

- Meaningful activity of solving real problems with real solutions
- Designing for future needs and opportunities
- Freedom to take risks and experiment
- Identifying problems to be solved

- Helps the understanding of human beings' position and existence in the world
- Whereas at least one pupil in each of the two schools held nine of the values of D&T:
- Empowers society to act to improve the world
- Personal ownership of decisions and actions
- Learning of vocational skills and techniques that open doors to a range of careers
- Alternative to academic subjects
- Activity of designing
- Provides a practical purpose for other school subjects
- Examination and questioning of the made world
- Using raw materials to make a product
- Learn practical life skills

Senior leaders' values

One idea that arose from our research question was that D&T teachers would have the widest view of the subject, followed by pupils and then senior leaders; in fact the reverse is true. We were initially surprised that the senior leaders have one of the widest views of D&T, but further reflection and discussion acknowledged that their wider school role would probably influence their view of each subject's contribution to a pupils' education.

D&T teachers' values

We did not anticipate the narrowness of the values held by the D&T teachers from Upton School. For example none of the Upton teachers held seven of the values, including:

- Learning happens through using brains and hands together
- Empowers society to act to improve the world
- Designing for future needs and opportunities
- Provides a practical purpose for other school subjects

We were not surprised to see that D&T was identified as a subject that led to vocations, correlating to the nineteen separately coded segments when D&T teachers indicated a purpose of D&T was to help the pupils in 'jobs they're going to do in the future'; but we were disheartened that the teachers suggested on forty-four separate occasions that a purpose of D&T was to provide pupils with practical life skills (6.5% of the total number of coded segments – the highest weighted value by the teachers).

Values and the five eras

In our conceptual framework time was linked to values through the implementation of a new curriculum and changes to a school's structure. It also made sense to consider if the time the participants studied D&T made any difference to their values (Martin 2013).

Using Martin's suggestion that there have been five eras of D&T we proposed that stakeholders over the age of forty would have experienced a curriculum that focused on making and we might expect to see this reflected in their values. When we considered the variable of age we could see some differences, but taking into account the number of participants it is difficult to suggest any significant reasons for these.

Discussion

Most disquieting to us was that none of the stakeholders believe that D&T is a subject that involves 'identifying problems to be solved', both the previous (Qualifications and Curriculum Authority, 2007) and current National Curriculum (Department of Education, 2013b) expect children to be able to do this. We think this has implications for the curriculum content in both schools.

Five of the values not recognized by pupils relate to either being free to design or free to consider wider society issues. We wondered if this was due to the nature of D&T activity primarily undertaken in their secondary schools.

The breadth of values held by the four teachers from the making era surprised us, but closer analysis revealed it was the St John's D&T teacher who held the widest range. This teacher was the subject leader, working with a young team of D&T teachers, he is also studying at postgraduate level and it is plausible that these three factors have contributed both to his number of values and the impact he has had on the values of the other teacher in the department and the senior leaders. The other three teachers in the making era group were from Upton, over 50 years old and female, two of them were D&T teachers and between them identified that D&T was about life skills nineteen times.

The values profile of the Upton D&T teacher who was also a researcher (Upton D&T teacher 2) in her first year of teaching and from the values era was consistent with the profile and weighting of the other two Upton D&T teachers. This was a surprise to us, and more personally to the researcher; we think the impact of 'implicit attitudes and theories' (Dow, 2014, p.152) could go some way to explaining this similarity. In her personal reflection on the research process she wrote 'this (first) year felt (like) mainly ticking boxes, exhaustion, all new, pressures for contract to be made permanent and fitting in with school life. Didn't have many opportunities to question why I was doing particular lessons and what the students were actually learning – if any value to them both present and future'. Although this reflection has caused the researcher to feel slightly despondent there is an underlying strength to this department, its' cohesion and the close alignment between the pupils and D&T teachers values of D&T. Consequently we think this area is worth further exploration as the age and experience profile of a department could have implications for the values held by pupils and younger teachers, and for teacher training institutions (Dow, 2014).

Implications for Upton and St John's D&T Departments

At Upton School the school-based researcher is considering whether the school's schemes of work reveal more traditional beliefs and values of D&T and if this could be part of the reason for the limited view of D&T the pupils have. As a new teacher she is also using the findings to develop her own practice and confidence: '(The) research has helped me understand (the) department's philosophy, I think it will impact on my confidence to explore away from department (within reason). (Setting) themes for students to explore as opposed to narrow briefs'

The school-based researcher from St John's School is more established and been in post for over three years, recently taking a curriculum leadership position in the department. This research has helped her clarify her thinking about D&T and been able to communicate that with her department. Consequently new activities are in place, which she hopes will align the teachers' values with those of the pupils.

Conclusion

There were two parts to our research question of this paper, firstly how do three different stakeholders in schools value D&T and secondly what are the similarities and differences in their values?

All stakeholder groups held a range of values, the most significant of which was that D&T provided practical life skills, the second most common was that pupils had the opportunity to make products. Using Hardy's (2013b) values framework to analyse the stakeholder groups' values we saw that whilst there were several core values no one thought D&T provided an opportunity for pupils to identify problems to be solved.

Analysing the values across the stakeholder groups within a school and between groups across the schools we determined that the senior leaders in both schools held the widest view about the value of D&T and the pupils had the narrowest view. Our interpretation was that the senior leaders position gave them the greatest understanding how D&T contributes to a pupil's whole education. In both schools D&T teachers rated highly the subject's practical content. One explanation for this is that the teachers were focusing on the unique practical aspect in order to influence the year 9 pupils to choose to continue with their D&T study the following year.

There were noticeable similarities and differences between the groups within the schools. In Upton School the D&T teachers and pupils' values were more closely aligned to each other than the senior leaders'; the converse was true at St John's. Our view is that this could be influenced by factors such as the teachers' ages and the classroom activities.

This research shows that different groups and different schools have similar and different values of D&T; we cannot say yet if this will have a consequence on the place of D&T in these two schools. That is not to say that the consequence will be negative given our finding that senior leaders have the widest view and the greatest power to retain D&T in a school's curriculum. However if our findings about the values held by D&T teachers are more aligned to those held by the Upton School teachers then the challenges faced by other D&T stakeholders (teacher trainers, university lecturers) could be significant. D&T teachers have the power and legitimacy to influence what happens in the classroom, and it is this that influences the perceptions of those with a more wide-ranging power, such as head teachers and government ministers. In our opinion a key challenge is to address the dominant view that D&T's purpose is to teach practical life skills and bring forward the values relating to D&T's capacity to improve society's quality of life.

This research could have broader implications for other countries that are also considering the place, purpose and value of D&T in the curriculum.

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Appendix

Twenty-two values of D&T from Hardy (2013b)

1. Meaningful activity of solving real problems with real solutions
2. Learning happens through using brains and hands together
3. Empowers society to act to improve the world
4. Personal ownership of decisions and actions
5. Learning of vocational skills and techniques that open doors to a range of careers
6. Using raw materials to make a product
7. Designing for future needs and opportunities
8. Develops the skill of creativity
9. Freedom to take risks and experiment
10. Considers the ethics of technological development
11. Alternative to academic subjects
12. Identifying problems to be solved
13. Activity of designing
14. Helps the understanding of human beings' position and existence in the world
15. Become aware of the economic impact of technological development
16. Develops the skills of autonomy and collaboration
17. It is fun and enjoyable
18. Provides a practical purpose for other school subjects
19. Examination and questioning of the made world
20. Learn from evaluating personal success and failure
21. Contributes to the nation's industrial and economic competitiveness
22. Learn practical life skills

A model for design activity in technological education

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Abstract

This paper discusses the design activities of students in secondary school in France. Computer Aided Design (CAD) tools are now part of the capacity of design professionals. It is therefore apt to reflect on their integration into the technological education. Has the use of graphical tools changed students' performance, and if so in what direction, in phase of seeking solutions through a design activity in a situation of teaching and learning?
The influence of CAD tools on professional design activities has been the subject of much research, but little has focused on student activity. Thus, analysing student work through an experimental device, we ask that students produce more solutions without using CAD tools. Do CAD activities encourage the modeling of a particular solution? Does drawing by hand before CAD activities support the production of various solutions and define them more precisely? Through the analysis of solutions developed by students, including traces of their activity (sketches, digital files), we test our hypotheses. Finally, these studies contribute to the understanding the teaching-learning of design process by proposing a model for design activity in technological education.

Keywords

Technological education, modeling creative design, computer aided design, graphical tools

Context of the study

This paper completes a study published in 2014 (Laisney & Brandt-Pomares, 2014). It analysed design activities of students when faced with situations which require solving design problems. We focused on the role of CAD tools. More specifically, we considered the relationship between sketch realization (hand-drawing) and the use of CAD tools in the activity of students, especially in the early stages of research. Through analysis of drawings made by students as they use or do not use CAD tools, we aim to understand the creative process they employ.

The findings of this study relate to the fact that it is important to consider the introduction of these tools in promoting and facilitating the process of finding solutions. Our results confirm our hypothesis that hand-drawing – as is the case for architects and designers – favours a broader search for solutions. The introduction of a second phase, CAD tools, provides a model of the object that is enriched due to the assistance the tools provide to students. As such, CAD is required in the process of object design.

The scope of this research and its findings is contingent to situations, problems and specific tools. To complete these results, we propose to test new situations and new tools. These studies contribute to the understanding the teaching-learning of design processes by proposing a model for design activity in technological education.

Model for analysing teaching of design activity

Creative design, a model for design activity

The general model of the design activity borrowed from Lebahar (1983) identifies three main stages to describe the process of architectural design. This general model of the cognitive aspects of design assimilates this activity in "resolution of badly defined problems" (Simon, 1991) and is characterized by "creative design". This notion of creativity develops through the mechanisms which it involves: exploration, generation of solutions and evaluation. But especially, this model takes into account an essential aspect of design activity, which concerns drawing in all its forms, including with the use of computing tools. The drawing is at the same time a representational medium and a tool of thought. More precisely, the sketch is considered as an integral part of creative design activities. It is defined as the dominating tool of thought for designers. Drawing is indeed seen by specialists in cognitive psychology (Goël, 1995; Schön, 1983) as a representation of mental activity, fixing the ideas in the first phases of design. But more than that, these drawn visual representations, which take several forms following the design phases, are recombined, modified and adapted. In Lebahar's model, graphic intermediaries appear in each of the stages:

The architectural diagnosis; in this first phase the architect seeks to identify and define the problem to be solved with regard to the constraints. She is then in the phase of exploration and the result will be a first graphic "base of simulation", a mix of notes and first drawings.

Research for the object through graphic simulation; from then on, the designer is going to work on generation of the solutions and their evaluation, in an incremental and iterative process. The drawing is going to be the privileged medium for this approach. It represents, as underlined by Lebahar, "the object in creation and the thought which creates it".

The establishment of the model of construction; in this phase the designer defines precise graphic representations, intended to make clear the solution for the builders. It is the "definitive decision" concerning the whole project (plans, precise drawings with a specified scale, etc.).

Rabardel and Weill-Fassina (1992) work on the implementation of graphics systems allows us to consider the analysis of graphics intermediaries involved in all three stages of Lebahar's model in a triple point functionally, semiotic and cognitive. The graphics are intermediate semiotic objects embedded in complex tasks that are functional to the task at hand. For example the shapes, the size, the subject, the structure or the function are among the aspects of the object useful for the designer action. This action raises various transformations operated on the subject (manufacturing, assembly) as well as mental operations of treatment of the information inherent to the resolution process of design problems. So, the drawing is a tool, an instrument which the subject uses to solve design problems. Design is so considered as a creative process of an object by progressive elaboration of a mental representation and a graphical representation of this object by the subject.

The role of the graphic tools

Lebahar (1996, 2007) studied the place of the tools of CAD – in particular where articulation enters traditional drawing "by hand" and modeling by means of CAD software. "Whitefield showed, by comparing the works of industrial designers drawing by hand, in those produced by designers using a CAD system, that the first ones tended to investigate several possibilities of alternative solutions (strategy in width), while the second, more concentrated on their operations of modeling on computer, more got into detail and developed only a unique solution, during all the process (in-depth strategy)" (Lebahar, 2007, free translation, p. 146). According to Lebahar, "strategy in width" is rather connected to drawing by hand, while the in-depth strategy depends on the implementation of a CAD system.

Other research on the use of CAD software by industrial designers (Asperl, 2005; Bonnardel, 2009; Bonnardel & Zenasni, 2010; Chester, 2007) shows that most CAD software do not really support creativity and are after all only a range of "computing techniques". First of all at the cognitive level, their methods of construction of a digital model tend to impose choices on the user and do not base themselves on the indistinct data of the design initial phases; this is reflected by the fact that the designer is forced at an early stage to handle specific geometric entities. The systems do not know how to manipulate vague, indistinct data characteristic of the problem-solving stage. At the contextual level, meanwhile, the modes of representation and interaction paradigms they offer do not place the user in an optimal context for creation.

We underlined the importance which holds the drawing in the design first phases as the "freedom" which it infers in the generation of the solutions to a problem, essentially thanks to an intuitive relationship with the designer. He goes away nevertheless in quite a different direction for the CAD software.

At this stage, these studies show that while CAD tools are sophisticated, it is still beneficial to incorporate hand-drawings in the design activity, and especially in the teaching of technology.

From the point of view of the teaching-learning processes, Martin (2007) shows the contribution that can be made to schools by computing tools which aid the learning of drawing. The use of a digital tool can help the children while they copy a model, but does not improve their capacity to use their own internal model. At middle school level, Pektas and Erkip (2006) show the necessary level of “familiarization” with CAD tools to favour pupils’ commitment in the design task, as well as the role of the representations. All these works agree on the fact that on one hand, the computing tools must be adapted to the teaching-learning process, and on the other, it is important to take into account the representations in every stage of the process.

To conclude, this study is interested in the development of design activities by pupils within the framework of technology education, which traditionally centers on the use of tools (Brandt-Pomares, 2011). We propose to use a model built by considering a “grey area” in which the use of traditional design or CAD tools will help the process of finding solutions for pupils of middle school. This “grey area” corresponding to this particular time that students spend to use one drawing tool or another, we intend to understand. We think that creativity could be expressed through the variety of solutions developed by pupils.

At the methodological level, we propose to analyze the student activity. The analysis of the activity has been described in many studies (Engeström, 2005; Leontiev, 1972; Vygotski, 1962). It’s a way to look at what the teacher asks the students to work through and it offers insights to students and what pupils *actually* do.

Methodology

Our hypothesis is that use to drawing “by hand” favours the shaping of a bigger variety of solutions, while the use of the CAD tool particularly favours the deepening of a solution. As a result, the order in which the pupils would be advised to use these tools would also have an influence. Preceding CAD activity with an activity without recourse to computing tools should end in the production of valid solutions with regard to the constraints, more numerous, more varied and defined, with more precision at the end of the process. We therefore formalize the following three operational hypotheses: the pupils produce more solutions when not using the CAD tools (H1); the CAD favours the modeling of one solution in particular (H2); drawing by hand prior to the CAD activity favours the production process of solutions, several possibilities and more detail (H3).

Research plan

To test our hypotheses, we proposed a plan in which the pupils are requested to solve a “closed” problem. The teachers ask their pupils to fit out a space in house. The following instruction was given to the pupils: “Your work consists of proposing solutions to fit out a house by respecting the constraints of the specifications”.

It should be noted that teachers, agreed to participate in the experiment, were asked to intervene as little as possible and avoid guiding the actions of pupils. The specifications given to students are as follows in table 1:

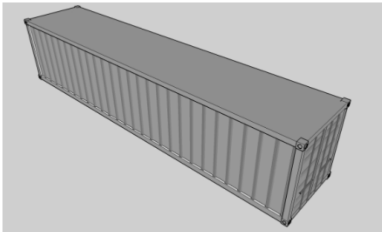
Use a container (12m x 2,5m x 2,6m) 	
Sleep area	Be quiet Two places to sleep
Eat area	Prepare meals Eat meals
Wash area	Clean oneself, WC To be out of sight
Work area	Be quiet An office
Circulation area	Able to move between different areas

Table 1. Specifications

We analysed the productions realized by more than 300 pupils (aged 12) in France confronted with a design task. Table 2 presents the distribution of the tested population.

Middle school	1	2	3	4	5	6
Nb of divisions	1	2	3	2	2	4
Nb of pupils	27	35	59	42	43	100
Sweet Home 3D	Prior experience			No prior experience		

Table 2. Tested pupil population

Similarly, classes are divided into two groups, A and B, which are balanced (no group level) and correspond to those established by the teacher who has responsibility within the institution.

Table 3 presents the three working modalities corresponding to what the pupils had to make during two 50-minute sessions.

Sessions	Group A	Group B
1	Modality 1 “by hand”	Modality 2 “SketchUp”
2	Modality 3 “freedom of choice”	

Table 3. Plan of the experimental device

We want to implement tools already used by teachers, which are recommended on the various sites of academic resources for technological education in France. Sweet Home 3D software, based on features inspired by traditional “intuitive” design, seems to offer a quick route to learning.

During the first session (modality 1), group A has to realize the design task by exclusively using the traditional method of drawing “by hand”. Meanwhile, group B (modality 2) has to realize the same task by exclusively using the Sweet Home 3D software. During the second session (modality 3) both groups (A and B) are again confronted with the same task; that is, they have to pursue their research to find solutions, but this time they have the freedom to choose the graphic representation tools. To verify the impact that the pupils’ familiarization with the software could have, we shall test two populations of pupils: those who “know it”, because they have already used it within the framework of teaching realized by the teacher during the previous sessions, and those who “discover it”.

Data and analysis indicators

The pupils made their graphic productions in the conditions of an ordinarily functioning middle school technology course of technology in the middle school, in class and with their usual teacher. At the end of sessions 1 and 2 and for each of modalities 1, 2 and 3, all the written and digital files produced by the pupils were collected.

We coded the various solutions according to the distribution and the choices to fit out these areas. From the choices made and their combination, we can determine all the solutions to this problem. Indeed, there are five solutions at least for the choice of distribution, four solutions to fit out the sleep area. Altogether, there are only twenty solutions. Illustration 1 proposes an example of a solution.

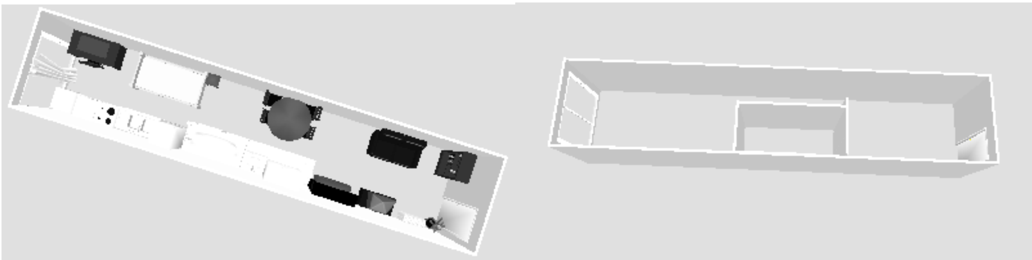


Illustration 1. Solution (to the left) and production (to the right)

Concerning the first hypothesis, the indicators are the numbers of productions and solutions represented by the pupils according to the tool used. Every paper or computer file developed by the pupils will be called a production, whatever its state of elaboration; that is, for example, even if it is a simple sketch or an incomplete digital model. Any production will be considered as an eligible solution; that is, a possible solution to the problem posed. An eligible solution is not necessarily at this stage a finalized solution to the problem. The numbers of productions and solutions so found during the three modalities of the experimental plan will allow the comparison between both groups A and B.

Concerning the second hypothesis, the indicator is the state of elaboration of the models represented by the pupils of both groups A and B, in three modalities. It will take into account the dimensional respect through manipulation of the scale of representation, the presence of decoration elements and material texture and the deepening of a unique solution deducted from the number of solutions developed by pupil.

Finally, concerning the third hypothesis, the indicators are of two kinds: the variety of the solutions developed in three modalities and graphic tools chosen and used in the third (free) modality between the sessions 1 and 2 for groups A and B. The variety of solutions will be measured with regard to the diversity of the proposals.

Results and data analysis

Number of productions and solutions

Each production by a pupil is identified as the result of a work which ends in the realization of graphic. The productions retained as solutions include only the graphic tracks which represent a structural organization of distribution (Illustration 2).

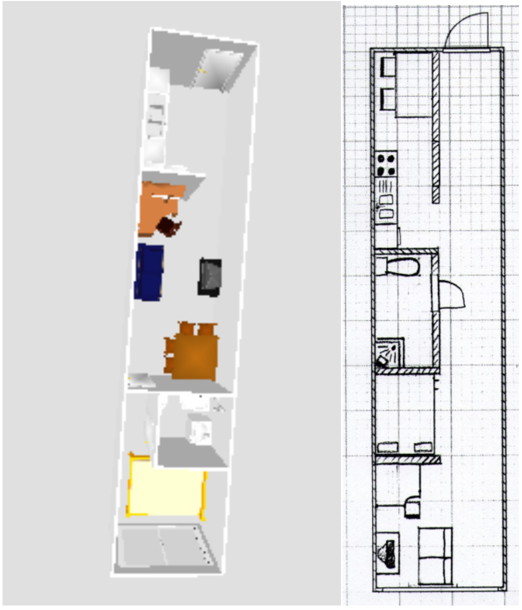


Illustration 2. Solution with Sweet Home 3D (to the left) and by hand (to the right)

We counted the number of "solutions" produced by the pupils. The number of productions and solutions developed by all the pupils at the end of the first session appear in tables 4–6.

Session 1	Nb of pupils	Productions	Solutions
Group A	157	251	214
Group B	149	154	128

Table 4. Number of productions and solutions elaborated

The analysis of the number of productions and solutions confirms our first hypothesis, according to which the pupils produce more solutions without using the CAD tools. Indeed, on one hand table 4 shows that the pupils in group A realize more productions and solutions than the pupils in group B, while on the other, tables 5 and 6 show that this difference is not due to any pupils in particular but to a general tendency which concerns the majority of the pupils. The pupils in group A are capable of developing mainly more than a production (or solution) while the pupils of the group B do not rarely propose it any more of one.

Session 1	1 production	2 productions	+ 2 productions
Group A	70	83	4
Group B	142	6	0
Total	212	89	4

Table 5. Number of productions developed by pupil

Session 1	1 solution	2 solutions	+ 2 solutions
Group A	85	60	3
Group B	122	3	0
Total	207	63	3

Table 6. Number of solutions developed by pupil

Our methodological precaution, with no level group, is confirmed by statistical test. Confirmatory tests show, as seen in table 4, that both groups are equivalent in terms of constitution (Khi2 = 0.028; Ddl = 1; $p<0.05$). More than that, we think it is not the group's composition that influences the number of productions and solutions, but the role played by the graphic intermediaries in the tasks. Nevertheless, we observe in tables 5 and 6 significant differences (Khi2 = 94,888 and Khi2 = 59,671; Ddl = 2; $p<0.05$) which we attribute to the task and the fact that in one case the pupils use the traditional method of drawing "by hand", while in the other they use CAD tools.

Difference between knowledge and discovery of the software

In order to look to the effects of pupils' level of familiarization with the software, we differentiated the population into two groups: those with prior experience of CAD and without. Table 7 give the number of productions and solutions developed by the pupils in group B at the end of the first session.

Session 1		Nb of pupils	Productions	Solutions
Group B	(No prior experience)	94	98	78
	(Prior experience)	55	57	51
Total		149	155	129

Table 7. Number of productions and solutions developed by group B

Proportionally, the number of productions and solutions realized by pupils in group B who discovered the software and those who know it is of the same order.

Main results

For a 'closed' design problem, the exploration phase of the search for a solution grows rich by using drawing "by hand". Indeed, the use of traditional drawing in the early stages of finding solutions allows pupils to rough draw solutions to design problem. The pupils are all capable of producing drawings which allow the expression of their ideas. The results of the experiment tend to show that the use of traditional drawing before CAD tools are used allows the pupils to develop quantitatively more solutions. The Sweet Home 3D software seems to be considered early in the process of finding solutions. We note nevertheless that in this case, the exploration of a range of possiblities is reduced and the pupils aim at only one solution. The general model of the design activity proposed by Lebahar (1983, 2007) is interesting to understand the design activity of architects and designers. However, it is not fully efficient to analyse the design activity of pupils in a context of teaching and learning in the classroom. We therefore propose a new model (Illustration 3) adapted from Lebahar to better understand the design process in the context of technology education in secondary school. This model includes CAD tools and the drawing by hand.

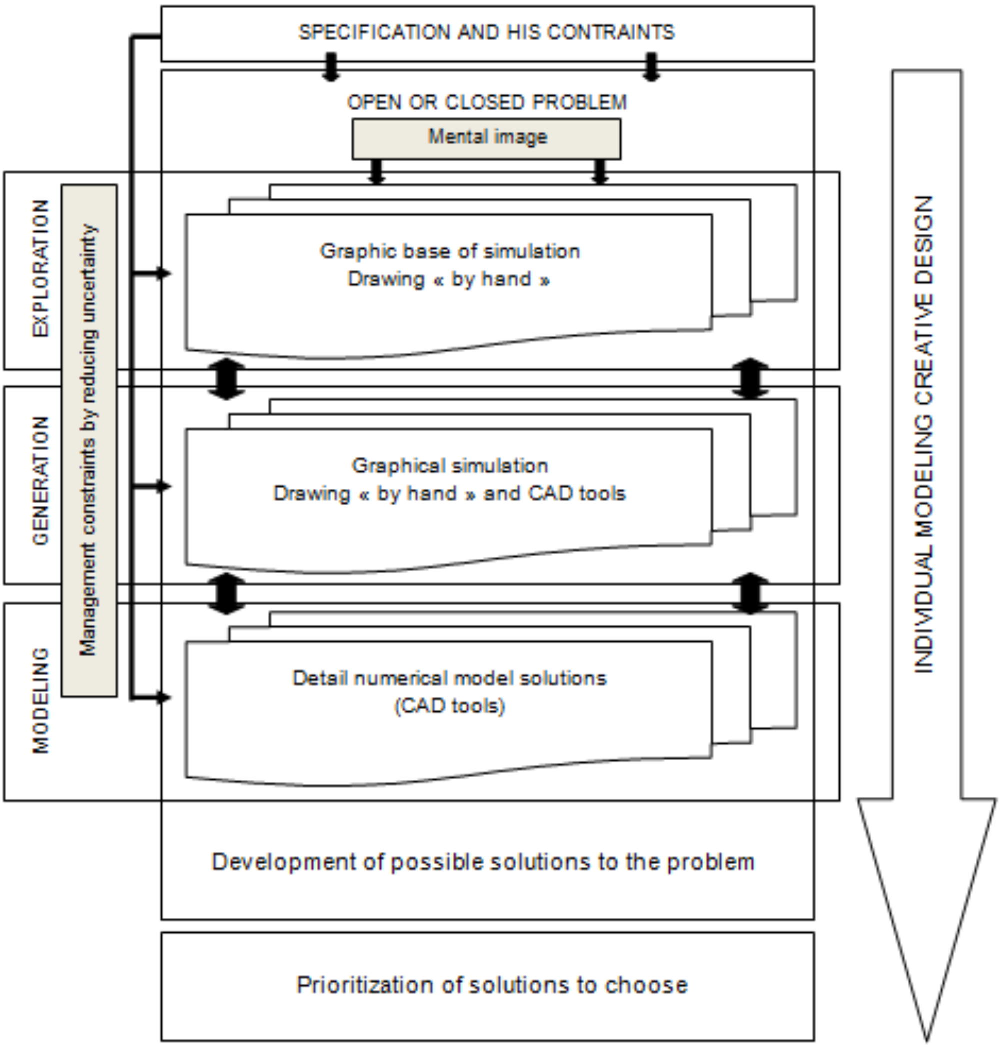


Illustration 3. Individual modeling creative design

Considering all our results (Laisney & Brandt-Pomares, 2014), we propose to complete Lebahar's model by including the role of graphic tools in the design process. This helps to understand better the "gray area" in which it is both the use of traditional drawing "by hand" and CAD tools that can help the process of finding solutions for pupils.

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Mapping young pupil's attitudes and capabilities in design & technology

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Abstract

As the title states this work does two things: defining the qualities of Design and Technology (D&T) 'the subject', and finding ways to identify and map those qualities in primary aged pupils. Drawing on previous research and our own understandings of D&T we created five defining 'descriptors'. These are justified and discussed through the text, but the basic descriptors are as follows:

1. Skills acquisition.
2. The ability to mentally 'time travel'.
3. Having and exercising values.
4. Design intervention or giving answers by doing something.
5. Design Rhetoric as communication and reflection.

We then worked with a group of thirty, 7-8 year old pupils to establish a clearer picture of their D&T **attitudes and capabilities**. In order to do this two activities were created, first a drama based, 'time traveling experience' and second a more formal small group interview, both of which aimed to assess children's **metacognition**. The recordings of both the drama based activity and the interviews were transcribed, critically assessed and mapped against the five descriptors to give a measure of the pupil capability in both quality and scale.

The results have been used to assess each individual's overall D&T 'attitudes' and 'capabilities' and to highlight areas for developing student's learning. These results will be used to inform a new vision for restructuring our school's D&T primary curriculum.

Keywords

Metacognition, design & technology capability

Introduction

This paper reports a small-scale research project aimed at identifying a framework for Design and Technology (D&T) that meets the developmental needs of primary aged children. The research was conducted with 7-8 year olds in an independent school in London.

We have used the term D&T to mean both the subject as taught in schools and also the activities of designing and 'technologising' in the wider context. There is therefore a speculation on our part of what could and should exist in the curriculum.

Recent research into children's understanding of D&T often focuses on secondary aged students or is approached from standpoints 'outside' of teaching. Thus primary D&T curricula often appear as a watered down version of a secondary approach. Our research represents our commitment to developing primary aged students D&T capabilities and concurrently the primary D&T curriculum.

Understanding metacognition and its importance in this research

Establishing the significance of metacognition to this research is essential, both for pupils developing pupils' ability to talk about their designing and making, and for putting teachers in a better position to develop students' learning. Metacognition relies on *"conscious awareness of one's own learning and thinking"* (Hewitt, 2008, p.29).

Dialogue has the capacity to help children to organize their thoughts and is also a starting point for developing those thoughts, which might develop into assimilated knowledge and understanding. However as Donaldson (1978) argues, a child may be competent in speaking in everyday situations, but "*have little reflective awareness of spoken language"* (p.96).

The implications for teachers are that they use not only D&T specific language, but also facilitate opportunities to discuss and reflect upon tasks and activities. This develops children's general vocabulary alongside the specific language of learning that enables them to talk about how they think they learn, what they find challenging in their learning and to ask for help when they need it.

For this reason, we will first examine what metacogntion is and then justify its relevance to this research. Lucas et al. (2002) describe metacognition as follows:

> *"It involves the kind of strategies that effective learners need to develop to become autonomous. To do this it inevitably involves meta-cognition or meta-learning – the development of language to describe thinking and learning processes"* (Lucas et al., 2002, p. 10)

Therefore, one must consider the complexities of language acquisition, age and developmental theories. The former point is acknowledged by Lucas et al.(2002) as they highlight how important it is to *'develop a language for learners and teachers to talk about learning'* (p.10). However this is not as straightforward as it may first appear. Hewitt (2008) explains that

> "*as a problem or activity is approached, the learner brings to bear their knowledge of the task, themselves and others (metacognitive knowledge) and the 'here-and-now' experiences of the success or failure of the solution of the activity (metacognitive experience)*." (Hewlitt, 2008, p. 29).

Young pupils find it more difficult to understand their own thought processes and abilities in tasks for reasons which include immature language development, inability to disassociate from and reflect on the task at hand or even because they have not been given the opportunity or responsibility to do so. However, Illeris (2007), Meyer et al. (2008) and Anderson et al. (2003) all claim that students as young as three can develop metacognitively. One of the key ways of facilitating this in young children is through role-play and play-based independent learning. This seems particularly relevant where D&T is concerned as if children are not encouraged to learn metacognitively, they lose the relevance of what they are learning. The repercussions of this are that children may be able to use isolated skills on demand but are unable to chose and apply them in context (Illeris, 2007, p.29). It would seem that those children who are taught to develop metacognitive skills could be better placed to transfer what they have learnt from the school setting to broader contexts and enable teachers to better understand their pupils' learning (Anderson, 2003; Meyer et al. 2008; Williams, 2003).

Defining what D&T activity is

Drawing on our previous research (Lawler et al., 2012) and literature from within design research and D&T education research (see below), we created five descriptors of D&T activity that we explored and consolidated through the research reported here. The position we explored is that, to be valid, all D&T practice should include all of these descriptors. These descriptors are:

1. Skills acquisition.
2. The ability to mentally 'time travel'.
3. Having and exercising values.
4. Design intervention or giving answers by doing something.
5. Design Rhetoric as communication and reflection.

The following is a summary of the literature and discussions that led to the establishment of these descriptors.

Skills acquisition

An emphasis on acquiring and using skills to produce answers has always been a fundamental part of the inherent understandings of D&T. This is seen as of value 'in' the acquisition of skills but also 'through' what one can do with the skills once acquired. The choreographing of skills acquisition, learning, making and designing is for most the fundamental quality of the area and is in part what makes the subject so exciting for young pupils. Skills acquisition in young children is inherent in their development, from the moment they become conscious of their hands, they are exploring and developing their fine motor skills and so when they come to lessons, it is not only the thrill of using tools, but also many of them find great success and joy in their application. This is no new argument.

From its first origins as an educational activity 150 years ago, D&T has gained credence through skills acquisition. Penfold, (1988) noted that its introduction to English Schools (through Sloyd by Cygnaeus, 1865) was in response to the Industrial Revolution. Sutton (1967) outlines how the practical skills of woodwork, metalwork, needlework and cooking facilitated a requirement for teaching better skills acquisition in the early 20th century.

In more recent years, the spiritual and mental benefits of having and using practical skills has gained approval, despite our technologically more advanced society (Alexander, 2010). Persig's (1974) *Zen and the Art of Motorcycle Maintenance* remains a seminal text, which has been recently trumpeted by Frayling's (2011) *The New Bauhaus* and Crawford's (2009) *A case for working with your hands and why office work is bad for you and why fixing things feels good*. These examples all highlight the importance of skills acquisition, despite the changing needs of society.

The ability to mentally "time travel"

This describes the ability of designers to put themselves into situations, which may involve other places and times, in order to speculate on possibilities for that which does not yet exist. Essentially, although often referenced from what exists in the past and present, what one designs 'now' will always be realised in the 'future.' This notion has been fundamental to design theorists and thinkers. Jones (1972) defines this sort of time-travel as *"performing a very complicated act of faith"* (p.3) and Page (1966) saw it as *"the imaginative jump from present facts to future possibilities"* (p.4). Simon (1992) interpreted Aristotle's use of "*poetics*", (p.57) from the Greek for making, as the productive science of the artificial. Buchanan (1995) asserts that design can be seen as, *"an indeterminate subject waiting to be made specific and concrete"* (p4).

All of these descriptions highlight that an essential part of designing and making is for pupils to initiate and conceptualise future possibilities as well as having the skills to make them. The extent to which younger pupils are able to do this has been signposted in the previous section on 'metacognition' and its importance is reinforced in the English Early Years curriculum as follows:

> *"Such a playful approach to learning builds on children's interests and responds to their ideas for play and also allows scope for structured activities to teach specific skills and knowledge."*
>
> (http://earlyyearsmatters.co.uk/index.php/eyfs/a-unique-child/play-learning/) .

Having and exercising values

The reasons why designers and technologists do things are important. Alongside skills acquisition and the ability to 'time-travel', we would argue the sense of 'purpose' is imperative. Design always attempts to 'improve' things but improvement is a highly culturally determined construct that influences both the purpose and the execution of the outcome. As an extreme example, Michail Kalashnikov, designer and maker of the most produced automatic rifle ever, saw his rifle as a means to 'defend' his homeland. In his view it was a 'force for good'. As Bronowski (1973) states:

> *'Man is distinguished from other animals by his Imaginative gifts. He makes plans inventions and other discoveries by putting different talents together'* (p.20).

Whilst engineers often attempt to reduce emotional judgments, analysis shows that they work within a cultural and values laden framework. It is therefore important that D&T pupils recognise that they are dealing with and coming to value positions in their attempts to make things 'better'. This is reinforced in the current English National Curriculum for D&T, which states that

'Using creativity and imagination, pupils design and make products that solve real and relevant problems within a variety of contexts, considering their own and others' needs, wants and values'

https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/239041/PRIMARY_national_curriculum_-_Design_and_technology.pdf

Dealing with values can be challenging for children. One will often hear them ask in school 'is this right?' or with younger children 'do you like it?'. We recognize the need to encourage children from the youngest age to place value on the product they have made themselves so that they retain ownership over it. It is important that they do not just make things for the teacher rather than valuing their own judgments (Sir Ken Robinson) (http://www.youtube.com/watch?v=zDZFcDGpL4U).

Design intervention or giving answers by doing something

D&T always centres around doing things, making 'stuff' and giving answers. It is never enough just to theorise, it has to be able to offer solutions. Whilst much of the focus on learning can occur 'in' and 'through' designing and making, the dialectic between skills and learning and real outcomes is fundamental to the discipline. Designed outcomes depend on both personal preferences and educational ideologies. From its inception as Sloyd (cited above) D&T has been based around making things and reflecting on them. Buchanan's (1995) discussion of 'Wicked Problems' embodies both the challenge and the joy of this activity, as well as highlighting the transient nature of design solutions.

Design rhetoric as communication and reflection

This is what might be called 'design metacognition' (Lawler, 2003) and is typified by the idea of a level of mental activity that not only focuses on the big pictures or broader concepts of designing but also the small steps of the activity in hand. Sometimes designers call this 'the small voice inside their heads'.

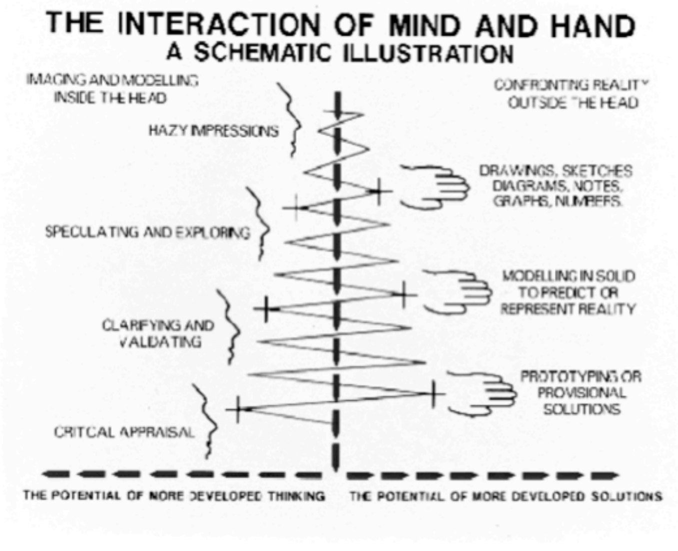

Figure 1. The APU Design and Technology Model (Kimbell et al 1991, p.20)

In their study of D&T capability Kimbell et al. (1991) created a defining model in which they used the activities of action, reflection and appraisal. They summarized this as an interactive activity moving from the vague to the specific, from the simple to the complex via action, (doing stuff,) and reflection, (thinking) the choreography between these areas being via appraisal, (making judgments). Their view of capability was an amalgamation of the qualities of the actions and reflections and the movement between them (see figure 1). The way this was applied or embodied within pupils' learning was, to the APU research team, of fundamental importance and relied on the pupils being what we would describe as metacognitively able. The complexity of the relationship between language, thinking and learning, especially with younger students (Fisher, 2005; Donaldson, 1978; Meyer et al. (2008); Pritchard, (2005) has further been addressed in the previous section on metacognition.

Methodology

The children used in the study were 30 seven year old pupils in year 3 of an English independent (fee paying) school in London. The school ethos is liberal and practically oriented, with less emphasis on grades and exam results than individual and appropriate success for all pupils. All children from age 4 to 14 have workshop-based designated D&T lessons, either weekly or every 2 weeks. All year 3 pupils took part in either prototype or actual activities described. The data derived from the analysis of the activities and interviews with 16 pupils were used in the results. Year 3 was chosen because one of the researchers knew these children well having been form teacher to them the previous year.

The research aimed to identify evidence of the five D&T descriptors within pupils interaction with each other in a devised D&T role-play context and then explore these further through small group interviews. The role-play element was incorporated as a method to elicit children's ideas without placing demands on their hand-writing, which may have inhibited some children's responses.

The intention of the role-play activity was to explore the pupils' abilty to put themselves into an imaginary situation, different in time and place to the present, and to describe it in detail. We used a few props, including a notional time machine (a pop up tent), to contextualise the activity. The pupils were then questioned as they emerged from the 'time machine' about their 'new' situation. The questions explored areas such as, how they lived, what they ate and what materials and technologies they had around them. Each group was encouraged to describe, in role, the same range of questions.

The small group interviews that followed the activity were conducted to explore further and triangulate the findings that came from the role-play exercise. The same small groups of pupils were interviewed with the following 3 questions:

- What do you think of as design and technology?
- Where do you find design and technology in your life?
- If you want to design and make something, what do you do?

Knowing the children well helped in this instance as we could use language appropriate to the children's individual needs (see sections on metacognition) to ellicit the most in-depth responses possible within the context. The text of the role-play activity and the interviews were then analysed for evidence of understandings of the five descriptors, both qualitatively and quantitatively.

Assessment

In assessing the overall quality of the groups' data, we developed a rubric that drew on an aspectof the APU DT assessment (Kimbell et al., 1991). In this work they identified four levels of capability which they characterised as:

- Level 0 : No evidence/ or no capability
- Level 1 : Evidence at 'Black Box' level - typified by being able to say very generally what happens, in a certain situation for example 'I use the key in the car and it starts'
- Level 2 : Evidence at 'Street" Level – typified by a more developed but still general understanding, for example 'I turn the key in the car ignition, that makes the motor turn and then the engine starts.
- Level 3 : Evidence at 'Developed' Level - where a detailed and informed understanding is demonstrated.

In the analysis of the 'levelness' of the evidence of the descriptors, we evolved a more critical analysis of the way the desciptors were defined. The work was independently analysed, the results discussed and the levels agreed. In doing this it was seen as important to ensure that the children were assessed in an approriate way, based on their age and ability. The following were useful in identifying, explaining and quantifying the five descriptors.

Skills :	The specificity of facts and skills gave indications of the levels ofunderstanding
Time Travelling:	The ability to not just fantasise or recount previous learning but to describe in detail and rationalise within their imagined situations.
Values:	The complexity of the value judgements expressed.
Design Intervention:	The ability to describe having, growing and proving of their design ideas as levels of capability (Kimbell et al, 2004).
Design Rhetoric:	Fluency with which they operated in and moved between action and reflection by communication/appraisal. See (figure 1) above

Results and what they tells us as teachers

The quantitaive data derived from the analysis identified the levels of understandngs that were evidenced in both the role play and the interviews. These data were summarised as a series of pentagonal charts (figure 2). The measure of the children's D&T ability is indicated by the area inside the pentagons. We posit that the bigger the area, the better able the group were to engage with D&T. Using this approach, potentially able design and technologists were identified.

This research can also be used diagnostically. For example, by looking at Group C, (figure 2) we might surmise that their almost total inability to 'Time Travel' and empathise has restricted their ability to operate with the other desciptors. Their strength is shown as their knowledge and skills. So their teachers might judge that they would make best progress in 'skills based' activities that support the development of their ability to 'time travel' and empathise. In contrast Group D demonstrate the ability to understand values and propose solutions and could benefit from support in moving between action and reflection in developing those solutions.

As a piece of small scale research the results are only truly reliably applicable to the specific groups in one school. What this tells us about those pupils is particularly valuable to us, their teachers. But beyond what it tells us diagnostically, it has also enabled us to propose the structure of a curriculum framed around the inclusion of the five descriptors, even for very young children. The ability to extend this overall approach to other pupils in other schools at ages, stages and contexts is an exciting possibility, which we hope to explore. The use of this approach as a means to help other teachers to understand and teach D&T and also to give guidance for developing their curricula to better accomodate individual pupils' particular bias of capabilities.

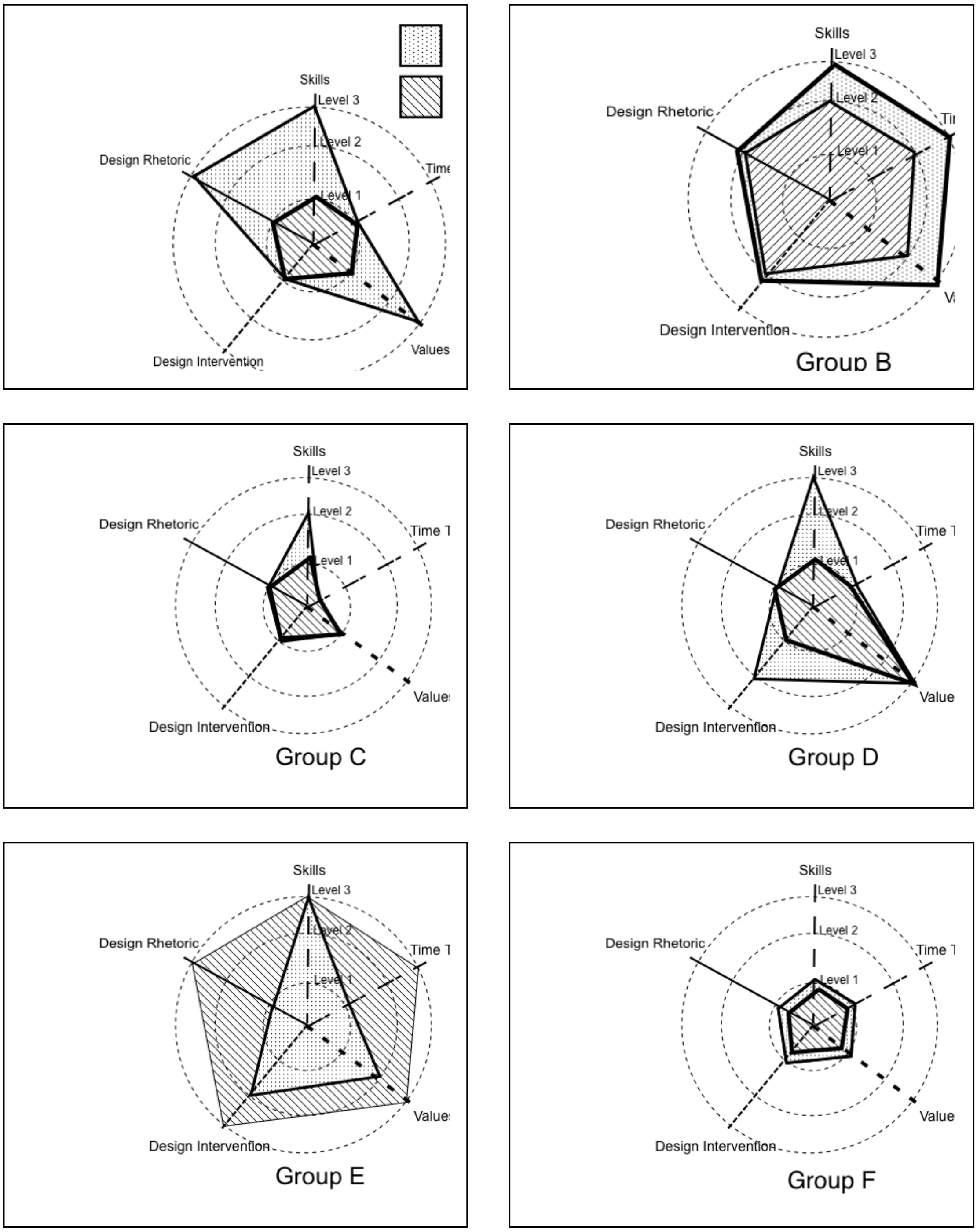

Figure 2. Results charts showing capability values with descriptors for pupil groups

Conclusions

In this research we set out to find ways to describe pupils' understandings of D&T in such a way that we would find useful in teaching the pupils and developing their curriculum. To that extent we feel we have been successful. We recognise that we made assumptions as to descriptors of elements of wholistic D&T activity. Our initial proposals for these has however been strengthened through identifying evidence and assessing these through the children's activity. This has increased our understandings and faith in the descriptors as a basis for a rounded D&T curriculum for young children..

The research was conducted in a quick succession of action-reflection cycles. Critically reflecting on the whole process, a range of questions have emerged

- Can capability be reduced to performance in less of the descriptors? Kimbell et al (1991) effectively used what we have called Design Rhetoric as the single descriptor for capability. Therefore does that make our descriptors over-elaborate?
- Are there other elements that would better indicate capability? Would it be possible to use practical tasks or designing and modelling based 'design challenges' to evidence kinaesthetic and other relevant skills and knowledge?
- Is the focus on the small group specific enough or would it be better to gather data on individual learners?

This is a first iteration of what we hope will be a longer process, we welcome help, advice and offers to participate in this learning journey.

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Technology education in the new curriculum of the Republic of Burundi: changes and constraints

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Abstract

The Republic of Burundi, one of the poorest countries in East Africa has initiated a widespread curriculum reform, with new guidelines for the basic education (named Fundamental School). This reform aims for the emergence of a new responsible and entrepreneurial citizen. Major changes to the curriculum relate to (i) the organization of a field of Science and Technology organized into three worlds: the material world, the living world and the technological world; (ii) the creation of an area of Entrepreneurship; and (iii) the introduction of active methods and a skills-based approach.
The analysis of this institutional innovation is driven from the official documents and from the prescribed contents in the textbooks for 7th and 8th grades (age 12-14). It is completed by exchanges with trainers and teachers. From a didactic point of view, the analyses of proposals through the critical investigation of the coherence between Tasks, References and Purposes reveal the tensions between (i) references, (ii) contents driven curriculum and skills-based approach and (iii) skills, curriculum, disciplines and contents. This analysis serves to identify the challenges due to the constraints of education and to discuss the possibility of a reform, the conditions of its implementation and its limitations.

Keywords

Curriculum, Burundi, didactics, technology education, basic education

Introduction

This paper is built on an expertise about the design of school lessons in sciences and technology education within the context of the implementation of the new curriculum in Burundi supported by UNICEF and the International Center of Educational Studies (Centre international d'études pédagogiques, CIEP de Sèvres, France). This didactics expertise was done (2012 – 2014) with in a first time the analysis of contents and school books for the first grade and in a second time the design, with the trainers and teachers educators, of new lessons for the second and third grades and the proposals for teachers' accelerated training.

This paper focuses on concepts and tools used in order to analyse this curriculum design and curriculum implementation and highlights the specific conditions and constraints of this curricular reform.

Didactics and curricular approach

The numerous studies about curriculum indicate three main levels of analysis (Hasni & Lebeaume, 2010; Martinand, 2003): a political level with the definition of purposes, missions and functions of the curriculum and its structure and organisation; a pedagogical level with the attention to principles of teaching-learning and its resources; a didactics level about the contents. Ross (2000) distinguishes three models of curriculum: contents driven, skills driven and social driven and shows the main oppositions between these forms, such as the whole of sociological researches (Forquin, 1989; Goodson, 2005). Jonnaert & al. (2009) insist on the hierarchical nesting of programs and curriculum, pointing out that the disciplines are only means for the political, social and cultural project of the curriculum. These points concern the first level of the analysis. In order to understand the changes of any curricular reform, it is necessary to examine the public documents about the challenges and the strengths and weaknesses for its implementation. For the didactics level, Lebeaume (2000) proposes a tool that tracks the consistency between Tasks, References and Purposes of school activities, contents and methods.

The renovation of curriculum in Africa countries is linked with the development for the future. Sankara (2013) or Harber (2014) show the main researches about education in Francophone Africa and indicate the issues: gender and education, schooling language, teachers' education, policy and education, information technology, health education, education, employment… The relationships between Technology Education and Development are poorly documented. For example the International Handbook of Technology Education (de Vries & Mottier, 2006) don't present chapter about this topic. The analysis of International Journal of Technology and Design Education for ten years only reveals several papers about South Africa and one about Gabon, but not directly based on the topic of Development. In contrast, Agbangla (2004) focuses on the importance of enlightenment and technological literacy and argues the interest for useful knowledge. Nehmé (2004) emphasizes the issue of integration of these contents in the culture and she prevents the risk of importing foreign models. In the same spirit Schweisfurth (2011) notes that culture is often at odds with the learner-centred education in the global South. In the case of Burundi developed in this paper, the research questions are about facilitators and barriers of the reform of technology education contents.

The main method of this research and expertise is a literature review in order to understand the context and its cultural foundations. It is completed by analysis of teachers-trainers pedagogical proposals and their discourses during interviews.

Educational challenges for Republic of Burundi

The Republic of Burundi is one of the poorest countries in East Africa with the resurgence of scourges such as hunger, AIDS, malaria, etc. Some historical elements enable to understand the current context (figure 1). Burundi was a Belgium colony (such as its neighbours Rwanda and Congo-Kinshasa) and has been an independent country since 1962. From this date to 1993, Burundi has been growing economically and the living conditions of its population have been improving. But the social and political crisis of 1993, the worst in its history, drove the country within a civil war. This conflict had disastrous effects on society and economics, during about ten years. The national reconciliation is recent with the Arusha Accords in 2003. For 2005 school became free.

Area: 27 834 km2
Total population: 8 500 000
Density: 300/ km2
Repartition: 0-14 years old: 46%; 14-64: 51,6%; > 65: 2,5%
Average age: 16,9 years old
Demographic growing: 3,1%/year
Share of the population located in beneath of threshold of poverty (2002): 68%
Proportion of the adult population literate (>15 years old): 42%
Economics mainly rural: agriculture and breeding 93,6%, industry 2,3% and services 4,1%
[http://www.axl.cefan.ulaval.ca/afrique/burundi.htm]

Figure 1. Elements about the Republic of Burundi

Demographic and educational challenges

Burundi faces demographic challenges linked with a rapid growth. The government has set itself the ultimate goal of "contributing to the reduction of poverty and improvement of the quality of life through the control of population growth in the country". The evolution of the number of pupils also is an educational challenge (Table 1).

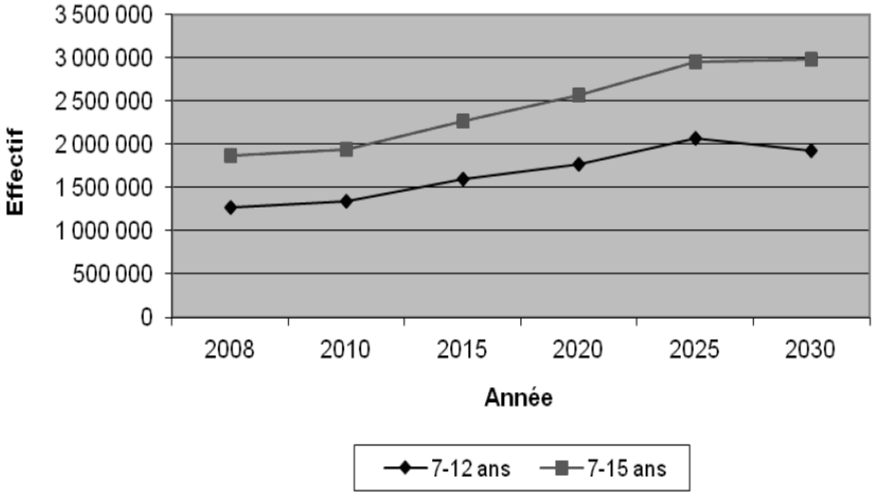


Table 1. Evolution of children 7-12 years old and 7-15 years old. (ISTEEBU, 2013)

With the introduction of basic education, the age category at primary school will be 7-15 year-olds instead of 7-12 year-olds. But the two curves indicate the same trend until 2025. This increase of the number of pupils for both the primary and secondary levels, implies a greater number of teachers to recruit and classrooms to build.

The new organisation of schooling

The educational policy implies both a structural change and a pedagogical change. The first one concerns the organisation of schooling and the creation of basic education named Fundamental School (Table 2). In the African situation (Africa Union, Vision 2015) and international recommendations (UNESCO), the education strategy of the Burundian state is formalized in terms of sectors of development of education and training (PSDEF, 2009) and three major long-term goals have been set: equal opportunities for all youth aged 7 to 12 years old complete a quality primary education; mechanisms for improving and strengthening the general and technical secondary education; development of vocational training and higher education. They aim to adapt contents to the needs of the economy and society.

Until 2012-2013			From 2012-2013	
Kindergarten			For pupils (4-6 years old)	
Primary	1st grade	1st and 2nd years	Fundamental School	1st and 2nd years
	2nd grade	3rd and 4th years		3rd and 4th years
	3rd grade	5th and 6th years		5th and 6th years
	Entrance examination to secondary			7t, 8th and 9th years
Secondary (junior school)	General Final National	4 years test		
Secondary (high school)	General	3 years	Secondary (high school)	General: 3 years
	Pedagogical	2 or 4 years		Pedagogical: 4 years
	Technological and vocational	2, 3 or 4 years		Technological: 3 or 4 years
				Vocational: 4 years (2 x 2 years)
				Jobs education: 1 or 2 years
Tertiary		2, 3, 4, 5 or 7 years		2, 3, 4, 5 or 7 years

Table 2. Organisation of schooling

Within the new curriculum the three grades of primary education are added a fourth bearing including the 7th, 8th and 9th years. The aim is to enable pupils to complete primary school with sufficient capacity to pursue teaching jobs, to reduce the "bottleneck" effect of the final examination of primary education and to increase promotion rates to year 7.

The new curriculum

The implementation of the "Strategic Framework for Growth and Poverty Combat 2nd generation" (République du Burundi, 2012) is consistent with the curricular orientation. The CSLP II is part of a national process of shared prosperity based, firstly, on the transition from a subsistence economy to modern production systems; secondly, on a development policy dominated by the humanitarian emergency and, finally, on a strategy of growth and sustainable development.

The new curriculum encourages the greatest possible number of children schooling in the nine years of the "basic education". It is necessary to prepare an individual with entrepreneur skills and useful in the community. It is a big change compared to the existing policy. This mutation implies in fact a revision of goals, programs, organizational methods and evaluation. The curriculum is, ultimately, to train responsible and autonomous Burundian. "The state is no longer the dairy cow of yesteryear. It is up to each individual now formed to build his future. (...)". (Ministère de l'enseignement de base et secondaire, de l'enseignement des métiers, de la formation professionnelle et de l'alphabétisation, 2012).

Contents and curricular organisation

The basic education thus implies the reduction of existing programs, grouping currently taught subjects in learning areas to reduce failures and allow learners to discover relations between schools disciplines, the interdependence of phenomena and hence to confront the difficulties of efficiently life. Thus, the curriculum of basic education is structured around six main areas namely: languages; mathematics; science and technology; the humanities; the field of entrepreneurship; arts. Peace education is a cross curricular area.

For each area, the output profile describes the final product at the end of learning related to the field by clarifying the learner's skills at the end of each grade, the themes and their logical sequence. For Science and Technology, it is enunciated that it is an interdisciplinary field, at the junction of science and technology that needs to be better understood, an overhaul in a dynamic and coherent whole. This field of Science and Technology brings together Biology, Chemistry, Physics, Technology and ICT. The field of "Science and Technology" includes three themes:

– The material world;

– The living world and its environment;

– The technological world and the environment as a crosscutting theme in three other subjects. All these issues are addressed in an integrated manner, with a view to enhance inter between science and technology.

The skills required were developed by each learning cycle. The themes from one cycle to the other end up gradually and the contents will be to develop a coherent whole that shows the output profile at the end of cycle 4 of basic education. This area provides an opportunity for students to:

– Discover the natural and technological environment by observation;

– Understand and interpret physical, chemical, biological and technological phenomena;

– Apply the laws and principles laid down by science and technology in order to positively affect their environment and ensure the well-being of the community. The assembly of all these elements draws the outlines of the output profile of the pupils.

These orientations define two levels of purposes:

- **output profile**: development and formation of the individual deeply rooted in its culture and in its environment; men and women aware of their political and civic responsibilities and ready to play their roles as catalysts for the economic and social development of the community;
- special purposes for science and technology education:
    - A scientific fulfilled man, animated by a creative spirit, imaginative to promote his self-development and that of the community.
    - A man awakened to the realities of the natural and technological environment; able to positively affect his environment to improve his living conditions.
    - A man capable of adopting attitudes that maximize the efficient use of natural resources;
    - A man capable of behaviours to ensure his physical, social and psychological well-being.

These orientations also define the following references:

- the living environment;
- the domestic socio-technical practices

Lessons, textbooks and contents

Pedagogical proposals in textbooks must achieve these ambitions and ensure the coherence according to figure 2.

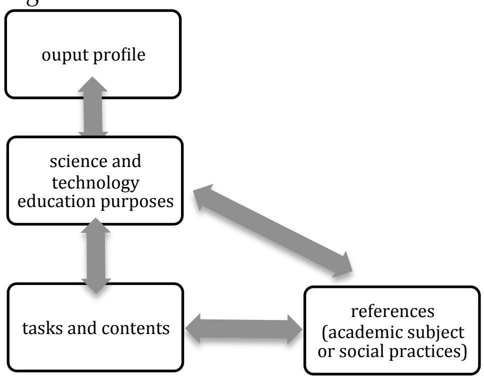
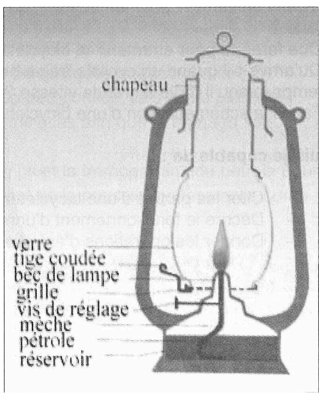


Figure 2. Coherence of tasks, references and purposes

In the first textbook (7th), each lesson of the part of technology education is structured in four parts: (i) I observe and think; (ii) I hold the key (the summary of lesson); (iii) I use what I learned (restitution of knowledge); (iv) Am I able to? (assessment). For example, the lesson about oil lamp describes the pieces (tank, oil, glass, hat…) and questions about how it works; indicates several information but these elements don't focus on explanations of phenomena and functional analysis of the artefact. The structure is mainly centred on vocabulary and information about using the lamp and the assessment focuses on memorisation.



The final part indicates:
Am I able to :

- Recall the pieces of the oil lamp?
- Explain how do the oil lamp work?
- Give the utility of the oil lamp?

The lessons then are designed such as objects lessons with a low level in the scale of cognitive operations. They are also more driven as applied sciences than technology education. Although consistency between tasks, references and purposes of education is not false, the contents may be more relevant to students' education.

The new textbooks (8th) try to improve this teaching-learning conception. It distinguishes the restitution of knowledge and its mobilisation in a new situation. However the work with Burundian teachers' trainers reveals that the model of teaching-learning is founded on teaching by objectives with a gap between this approach and the skills-based approach.

Concerning the teachers' education enabling them to teach the new curriculum, the trainers have to analyse one lesson with four questions. The aim of these four questions seeks to discuss the relationships between technology education purposes and the output profile (figure 2). They have to: (i) identify the teaching objective; (ii) identify the curricular ambition; (iii) propose a situation for assessment of the competency; (iv) propose one or several assessment situation(s) of the objectives. The analysis of their proposals indicates that these questions constitute a useful tool for the implementation of the reform but with differences according to school subjects.

In order to help teachers with the implementation of new pedagogical practices in Togo, Degboe (in press) suggests a comparative approach. He finds the same characteristics of teaching practices with opposite conceptions: one including frontal teaching and transmissive pedagogy, and the second one an inductive approach linked to the domestic use of knowledge. With this perspective, he proposes the concept of "meaningful activities" (« activités orientantes ») that focuses on the relationships between knowledge and social practices. He offers to write the lesson within the traditional pedagogy as well as within a more meaningful perspective.

Lesson: contents	
Traditional pedagogy: teacher based education	New pedagogy: pupils based education
Stages in the progress of the session the teacher writes on the blackboard the title of the lesson; he gives the notion and explains it with an example, pupils complete different exercises in order to apply the knowledge; …	Stages in the progress of the session the teacher writes on the blackboard the title of the lesson; he proposes an active situation in order for pupils to understand its meaning; pupils analyse it and discover the problem and its solving; …

This way is interesting because it allows discussions between teachers about their practices and their conceptions about learner-centred education and about technology education.

The implementation of the reform and its main issues

The new curriculum meets several difficulties due to the change of contents, pedagogical means and the material constraints (classrooms, class size, available textbooks…). However, the most important difficulty and barrier for technology education is the lack of teachers' skills within this area and the ignorance of its specific contents. It is also their cultural conception of teaching-learning founded on a learner-centred approach. The main issues linger in the reconciliation of the key challenges of the curriculum for the development of Burundi and the planning of resources for its implementation. The facilitators are the teachers' education in order to aware and to understand the principles of learner-centred approach and the principles of technology literacy.

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Master degree as a promoter of craft, design & technology education in basic education

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Abstract

This paper presents shortly the tradition of craft, design and technology (CDT) education in basic education and in teacher education in Finland. It highlights the gender-based tradition as the most important barrier for the development of CDT subject. After that the paper introduces the present CDT subject in the Finnish basic education and CDTE in teacher education in the University of Turku, Rauma Unit.

In Finland a teacher is an autonomic expert who is expected to have a competence to develop his/her work. To get a permanent teacher position, a master level examination is compulsory for craft teachers as well as for all the other teachers. However the gender-based tradition of teaching and organizing an infrastructure is very strong in CDT subject, e.g. learning environments, study groups. The new combination of courses, research and practical development work in advanced studies, in academic major discipline craft, design and technology education since Autumn 2014, is seen as a potential solution for developing CDT subject teacher students' competence to develop the subject, teaching and learning models at school. The research topics in master's theses are future-oriented and promising according to the implementation of the new basic education curriculum in 2016. The future research will focus on the research-based practical competence of young teachers to get the feed-back if the advanced studies in a new master of education program will help them to cut out the gender-based tradition in CDT subject content, teaching and learning.

Keywords

Craft design & technology education, gender-based, master degree, teacher education, basic education, multi-materiality

Craft, design & technology education in Finland

In Finland Uno Cygnaeus started craft and technology education in basic education in 1866 as the first in the world (Kantola, 1997). A concept craft/sloyd is used in the Nordic countries as a concept for a school subject that has crafting, designing and technology with a focus in making innovative three dimensional solutions for open problems in material world. According to a National Core Curriculum for Basic Education (FNBE, 2004) the content of craft subject is in Finland above all based on materials, techniques, tools, machines, and devices, in other words technology in wide material areas. The basic idea is that the subject is a common subject with a varied content of design and technology in textile and technical work material spaces. The concept of common crafts is used to point to a combination of textile and technical work, instead of traditionally choosing one and dropping the other. The name *craft/crafts* is used in Finland for the school subject similar to e.g. Design and technology education or Technology education. In this paper I use a concept Craft, design and technology (CDT) education as an English translation for the subject in the Finnish basic education to express the nature of it and to make connections internationally with other subjects similar to the Finnish one.

The CDT subject is a part of arts and crafts studies (table 1). The CDT as the common subject for all pupils is taught in the Finnish basic education, grades 1-9 (ages 7-16). It is the compulsory subject in primary school from 1st to 6th grade (ages 7 to 12) and in secondary school in the seventh grade (age 13). On the 8th and the 9th grade it is optional. CDT education targets and objectives are defined nationally in the National Core Curriculum for Basic Education (FNBE, 2004). The National Core Curriculum is a normative regulation and a basis for the municipalities and the schools as they plan and make a local curriculum. All pupils study CDT eleven weekly lesson hours in basic education. One weekly lesson hour means 38 study hours, each 45 minutes.

Table 1. Weekly lesson hours. Craft, design and technology as a part of arts and crafts studies (MEC, 2012).

Subject	Grades 1-2	Grades 3-6	Grades 7-9	summary
Craft, design and technology education	4	5	2	11
Music	2	4	2	8
Visual arts	2	5	2	9
Sports	4	9	7	20
Home economics	-	-	3	3
Optional studies	6		5	11

Arts and crafts have optional lesson hours which pupils can choose. The schools can decide independently, on what basis and how they share the optional lesson hours between the subjects. Usually there are two lesson hours CDT per week during the first six grades and three lesson hours in 7th grade, after which there are three elective weekly lesson hours in 8th and 9th grade.

The CDT education is regarded as a diverse and versatile subject on the basis of curriculum objectives since 2004. The basic elements of the CDT subject in the Finnish basic education are material and processing techniques, as well as crafts, design, and technology (FNBE, 2004.) However the content of CDT education is divided to textile work and to technical work. During the first four grades pupils study both textile work and technical work. After that pupils can choose what to study and what to omit.

In Finland the education system is quite stabile throughout the country. Teachers are seen as experts of education and the substance of the subject they teach. There is no need for a national inspection system. And very few national evaluations and tests are held. There are very few private schools. To get a permanent teacher position, a master level examination is compulsory for every CDT subject teacher as well as for all the other teachers (Lindfors, 2010a).

The challenges to develop CDT education

A way of teaching and learning CDT subject has been based on the traditional gender segregation. The CDT subject in basic education has been divided into different content areas for boys and girls from the beginning. This has been possible on the basis of the curricula since 1866 (figure 1).

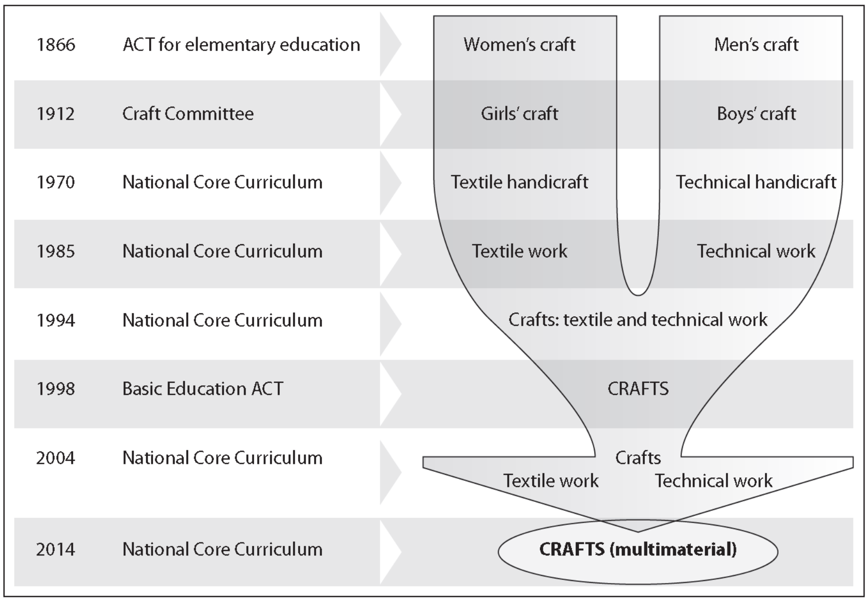

Figure 1. The historical development of craft from gender-based craft to equality oriented multi-material school subject.

The history of CDT education, the realization of teaching and learning is a gender-based dichotomy. Despite an alteration in the curriculum since 1970 (figure 1) from gender-based division to material based division that is, in the textile and technical work content areas, the subject kept its dichotomy nature. Mostly male teachers teach most of the technical work contents and female teachers textile work contents. The division between the contents and teaching methods maintains and supports gender segregated CDT education (Kokko, 2012; Lepistö, Rönkkö, & Tuikkanen, 2013; Lindfors, 2012). If the pupils are allowed to choose the content of CDT education, nearly all boys choose technical work and nearly all girls textile work (Lindfors, 2012). A latest and a very new National Core Curriculum for Basic Education, approved in the end of 2014 (NCCBE 2014), will make it finally impossible to follow the gender-based tradition from 2016. However the present infrastructure for CDT subject at school e.g. the separate learning environments for textile work and technical work, the way to organize study groups and lesson hours and finally teacher's competence to teach multi-materiality are all barriers for the development of CDT.

Along with the CDT subject the CDT teacher education has followed the dichotomy tradition as well (see figure 1; Kantola, 1997 ; Marjanen, 2012). These societally bound phenomena, invite us to consider what kind of teaching models would support a holistic learning process in relation to future-oriented solutions in diverse material environments instead of gender based choices (Lindfors, 2007). The question for today is how to educate and train CDT teachers who could promote the renovation of CDT subject and the realization of the new basic education curriculum without the traditional gender based dichotomy in the content of the subject and without the dichotomy of the choices made by pupils as they select the other content and omit another.

The challenges require development and regeneration of the CDT subject at school and the studies in teacher education. As one possible solution to gender-segregated CDT, Turku University, Rauma unit has promoted multi-materiality in teacher education since 2005. The latest curriculum for teacher education is from 2014. The multi-materiality is a combination of holistic design and making processes on a wide material area, soft and hard materials: plastics, fibres, yarns, fabrics, metals, wood, electronics etc. In the multi-material CDT pupil/student designs creative and innovative solutions by choosing and performing various materials meaningfully in order to make a usable and functional solution as an answer to some need (Lindfors 2010b). During the process she/he learns the concepts, materials, techniques and technology by hand. Every pupil/student does not have to learn all the materials and technology available. Instead she/he has to get meaningful learning experiences to get to learn and to develop the material world we live in. (Lepistö & Lindfors, 2015.)

There are no more textile work and technical work teachers. Instead there are CDT teachers with multi-material and technology competence. The problem arises as these young teachers go to school. Do they have the courage to promote multi-materiality or do they accept the traditional way of teaching?

The CDT teacher – master of education

In Finland all teacher education from kindergarten and pre-school to high school has been in universities since 1973. Today the becoming teachers accomplish bachelor and master examinations in various teacher programs: kindergarten and pre-school teacher program, class/primary teacher program and secondary school/subject teacher program. Bachelor studies are 180 ECTS credits and master studies are 120 ECTS credits. Master of education with pedagogical studies is obligatory for every teacher to get a permanent teacher position (Lindfors, 2010a).

Craft, design and technology education (CDTE) is an academic discipline in Turku University, Rauma unit. It is a major discipline (139 ECTS credits; table 2, 3) for CDT subject teacher students. The major discipline means that CDT education has autonomic and specialised research areas and professors in the faculty of education. The teacher students in CDT teacher program have various opportunities to construct their examination to focus their competence or to acquire double competence.

Teacher degree: Bachelor and Master studies 300 ECTS credits Obligatory studies		CDT subject teacher, grades (5-6) 7-9 (-12)	CDT subject teacher grades 1-9 and class teacher grades 1-6	CDT subject teacher and special education, grades (5-6) 7-9(-12)	Class teacher, grades 1-6 and CDT teacher, grades 1-9	Class teacher, grades 1-6 and CDT teacher, grades 1-6
Major discipline (Master's thesis)		CDTE discipline 139 ECTS	CDTE discipline 139 ECTS	CDTE discipline 139 ECTS	Education 200 ECTS (including 60 ECTS pedagogical studies)	Education 200 ECTS (including 60 ECTS pedagogical studies)
Minor disciplines	Pedagogical studies 60 ECTS	X	X	X		
	A school discipline 60 ECTS	X	-	-	-	25 ECTS
	Multidisciplinary studies 60 ECTS	-	X	-	X	X
	Special education 60 ECTS	-		X		–
	CDTE discipline 60 ECTS	-	-	-	X	25 ECTS
	Optional studies 31 ECTS	X	X	X	X	X
Communication and orientation studies 31 ECTS		X	X	X	X	

Table 2. The degrees required in teaching craft, design and technology (CDT) subject in basic education (grades 1-9, ages 7-15) and in high school (grades 10-12 ages 16-18) in Finland.

Teacher students have several opportunities to focus their studies beside the major discipline. The table 2 presents various combinations of examinations after which it is possible to act as a CDT teacher in the education system. A student can plan his/her studies in order to consider the future teacher position. CDT subject teacher students can choose minor discipline to acquire double competence, e.g. the competence to teach another subject (e.g. math, sports, physics) or the competence to elementary teaching or special education competence. Class teacher students can also acquire the competence to teach CDT in elementary school (grades 1-6) or in secondary school (grades 7-9) by choosing it as a minor discipline. Some of the CDTE studies are compulsory for every primary teacher student at the Finnish universities.

The master studies (advanced studies) in CDTE

The advanced studies in CDTE (70 ECTS credits) are the main content in the master level in CDT subject teacher education. The aim is that the master student develops a critical attitude and development orientation to his/her future work as a teacher. This is supported by research studies and with the participation to the Research and development projects (table 3). Master students have to join to some research projects to write their master thesis. This opens new possibilities to develop the CDT subject in basic education.

Craft, design and technology education as a m**ajor discipline (70 ECTS CREDITS)** → **On the way to investigave teachership:** Critical attitude, development orientation		
Studies in Research Methodology	12 ECTS	Research project
Master's thesis	34 ECTS	
Social and Global Perspectives in Sloyd Education	8 ECTS	Society orientation
KSS6. Participation in Research and Development Projects in Craft, Design and Technology Education Safety Culture and Safety Education in Experiential Learning New Material Technology in Pedagogical Context Crafting Cultural Identity Human, Machine and Robotics Innovative Design and Making Process in Craft, Design and Technology Learning Entrepreneurship Education in Craft, Design and Technology Craft process in maintenance and development of action competence Phenomenal learning in the context of everyday technology	16 ECTS	A student has to choose 4 courses out of 8 courses, each 4 ECTS

Table 3. Craft, design and technology education (Craft Education), major discipline (70 ECTS CREDITS): advanced studies including master's thesis.

Participation in Research and Development Projects in Craft, Design and Technology Education (Table 3) from autumn 2014 offer the CDTE teacher students and groups of them opportunities to act as active developers in research projects. By taking part to the projects the students will get the newest knowledge in the area and can join practical development and research work at schools on various content and material areas of CDT. The master's theses are part of this development work. At the moment student teachers' master thesis topics are e.g. multi-material CDT and co-teaching on 5th grade, safety audit in CDT learning environment, teachers' attitude to safety issues in CDT, internet materials as supporters of design, special needs pupils in CDT, QR-codes in the use of digital library in orientation to machine manufacture, pupils attitudes to automation technology learning, a laser cutter – new possibilities for CDT, learning experiences in 3D printing.

Conclusion

In the future the research will be conducted to get a feed-back if the research based practical development work will help becoming teachers to develop the CDT subject content as well as teaching and learning models at school in practice. In this way master degree in CDT will act as a promotor of craft, design and technology education in basic education. The future research will show how the combination of multi-materiality, active participation to research and development projects together with master's thesis will broaden becoming teachers' competence to renew the CDT. If the content of advanced studies in master's degree will prove out to be a successful combination, the new teachers will have the competence to implement the new curriculum 2016 (NCCBE, 2014) and the gender-based tradition (figure 1) of teaching and learning craft, design and technology can be finally cut out.

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The relationship between primary technology & engineering camp participation and the likelihood of pursuing future education in technology & engineering related subjects

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Abstract

This study investigated the relationship between primary school-age children who attended extracurricular summer camps about technology & engineering subjects and the likelihood that those students opted for advanced education in technology & engineering subjects with aspirations toward careers in those professions. For the past 21 years, Millersville University of Pennsylvania has offered informal learning experiences in the form of summer camps for primary and secondary students on various technology and engineering-related topics. Those students who attended the technology & engineering camps in the summers of 2008 and 2009 were surveyed in the fall of 2014 to determine their career aspirations and if attending a summer technology & engineering camp earlier in life may have affected their career decisions in high school. Data acquired from the majority of camp participants who responded to the survey indicated that camp participation was a positive predictor of future educational endeavors and career aspirations.

Keywords

Technology camp, engineering camp, informal learning, career choices

Introduction

This study investigated the relationship between primary school-age children attending extracurricular summer camps about technology & engineering subjects and the likelihood that those students opted for advanced education in technology & engineering with aspirations toward careers in those professions. For the past 21 years, Millersville University of Pennsylvania (MU) has offered informal learning experiences in the form of summer camps for primary and secondary students on various technology and engineering-related topics. The camps were originally created to generate exposure for the Department of Applied Engineering, Safety & Technology and its technology teacher preparation program. The initial concept of the camps was to use them as a recruitment tool, but the camps did not draw well at the secondary level. However, they quickly gained popularity at the upper primary level and have grown ever since. Throughout those years a question has persisted. Does participation in the camps serve as a predictor with regard to pursuit of technology or engineering-related schooling or careers later in life? With this question in mind, children who attended the technology & engineering camps in the summers of 2008 and 2009 were surveyed in the fall of 2014. The intent of the survey was to determine if there were any differences between camp participants and the entire population of Pennsylvania school children of a similar age in terms of their intent to pursue higher education with aspirations toward employment in technology & engineering-related careers.

Review of literature

A review of literature was conducted to determine if prior correlational studies existed about linkages between children attending informal learning environments like summer camps and future career aspirations. Most of the literature about technology & engineering camps focused on how to start such camps (Yilmaz, Ren, Custer,& Coleman, 2010), (Litowitz & Baylor, 1997). Other articles focused on the curriculum for specific camps (Moutseous & Heckel, 2012). Some articles focused on how to use extracurricular camps for recruitment purposes (Bischoff, Castendyk, Gallagher, Schaumloffel and Labroo, 2008). The study that came closest to the intent of this study was one that was recently published in the *International Journal of Science Education* (Kong, Dabney and Tai, 2014). Several of the survey questions used in the Kong, et al. study were replicated in the survey used to conduct this study as described later in the methodology section. According to the conclusions of the Kong et al. study, camp participation in science prior to college significantly increased career interests in science. Another study concluded that a series of activities in a summer camp program correlated to increased interest and attitudes among students enrolled in the camp (Hayden, Ouyang, Scinski, Olszewski and Bielefeldt, 2011). An additional article concluded that gender tended to be a crucial factor when choosing careers, along with parental influences (Bhattcharyya, Nathaniel & Mead, 2011). Therefore, information about gender and parental occupations was requested in the survey used for this study. Another study concluded that camps were effective in increasing female participants' knowledge of engineering, however, the article stopped short of analyzing the influence of the camp on the participants' career aspirations (Weavers, Bautista, Williams, Moses, Marron & LaRue, 2011). The authors of this study attempted to perform a longitudinal study to track the camp participants' later career interests, but the study was cancelled due to a lack of participation. One final study concluded that summer camps had increased participants' knowledge of the camp content, but the study did not draw any inferences about the relationship between camp participation and future career aspirations (Gűlsah, 2013).

In summary, few studies existed regarding the relationship between informal learning experiences like summer camps and future career aspirations of children in any subject area. Those that did exist often stopped short of identifying a direct linkage between camp participation and future careers for three reasons:

1. It was difficult to track camp participants over time,
2. It was difficult to compensate for external factors like the careers of parents or other predispositions that might lead to a direct interest in subjects like technology and/or engineering regardless of camp participation, and
3. It was difficult to locate data that would allow for an accurate means of comparison. High schools in the United States routinely track the percentage of graduates that go on for post-secondary schooling, but not necessarily what subjects they select as a major.

One study did indicate a strong correlation between camp participation and future careers in the sciences, even when factoring in external variables like a predisposition to science prior to camp participation. This study was used to formulate several of the questions posed in the survey mailed to MU camp participants from the summers of 2008 and 2009.

Primary research question

RQ 1. Did participation in a MU summer technology & engineering camp as a child influence later interest in technology & engineering course work and careers?

Additional research questions

RQ 2. Were those who participated in MU summer technology & engineering camps likely to have had significant interest in technology & engineering-related subjects prior to attending the camps?

RQ 3. Did parents' occupations in technology & engineering-related fields indicate a correlation with their child's participation in MU technology & engineering camps?

RQ 4. Did MU technology & engineering camp participation positively influence the participants' socialization skills?

Hypothesis

Previous participation in summer technology & engineering camps is a positive predictor of future interest in technology & engineering course work and career choices.

Population

All *MU Technology & Engineering Camp* participants from the summers of 2008 and 2009 were included in this study. Camp participation in those two combined summers was well over 200 students, but the population only included 160 unique registrants since many camp participants registered for multiple camps over the course of those two summers. Their age ranges spanned from 10 to 17 during 2008 and 2009, and their average age at the time they completed the survey in the fall of 2014 was 16.29 years old. Of those who responded to the survey, 79% were male and 21% were female. This is quite similar to the gender registration patterns of the MU Technology & Engineering camp programs at large.

Methodology

A survey of all 160 unique camp participants was conducted in the fall of 2014. The survey was mailed to the homes of 2008/2009 camp participants along with a self-addressed return envelope and a parental consent form for participation in the study as required by institutional protocol. A follow-up to the initial request for participation was performed via e-mail to yield a greater representative sample.

The survey included demographic data and a series of six questions that addressed the essential research question while also collecting information that would allow for discussion about variables such as prior interest in technology & engineering before taking a camp. Each question included a five point Likert scale with responses ranging from *Not at All* (1) to *Very Likely* (5). The aggregate data from the camp participants who responded to the survey was compared to aggregate data collected by the United States Census Bureau with regard to Pennsylvania college graduates. This provided a means of comparison between the *experimental group* of camp participants and the *control group* consisting of all Pennsylvanians. Frequency distribution and statistical analysis was performed to determine if those students who participated in the *MU Technology & Engineering Camp* program had a greater likelihood of pursuing technology & engineering careers than the entire population of Pennsylvanians.

Limitations

1. The survey results and subsequent discussion were limited to this particular population of students having completed a technology & engineering camp at Millersville University of Pennsylvania in the summers of 2008 or 2009 or both.
2. The term *technology* was difficult to define. Technology has been referred to as everything from computer applications and programming to manufacturing, communication, transportation and more. This made it difficult to define what *is* or *is not* a technology-related career.
3. The aggregate data for Pennsylvanians was based on 2009 United States Census Bureau data of college graduates. This data made no claims about those residents who pursued degrees in particular subjects, but did not earn degrees in those subjects.

Findings

The survey yielded 48 responses from the 160 camp participants in the summers of 2008 & 2009. This represented only a 30% response rate that resulted in a 90% confidence level with a 10% margin of error for the aggregate data provided in this study. All camp participants were asked to provide information about their age, gender, race, school district and parents' occupations. Although the demographic information was voluntary all respondents chose to complete these portions of the survey. Of the 48 respondents, 37 (79%) were male and only 11 (21%) were female. Additionally, only seven (15%) of the respondents indicated their ethnicity as something other than white. As a result of the low number of responses from females and minorities, no analysis was performed that addressed any issue related to gender or ethnicity. These demographic results were not unexpected as the vast majority of

MU camp participants were white males. Almost 50% of the survey respondents indicated that one or more parents were employed in a technology-related field. For the purposes of this study, *technology-related fields* were operationally defined by the researcher as anything technical from a manager of information technology to an engineer or a construction foreman. This indicated that children of parents who were employed in technology-related fields were no more or less likely to attend the MU summer technology & engineering camp program than children of parents employed in other fields.

The first survey question addressed student's prior interests in technology & engineering. It read: *Did you have interest in technology & engineering related subjects prior to attending a Technology/ Engineering camp at MU? Responses were as indicated in Table 1 below.*

Table 1. Responses to survey questions (N=48)

	1 Not at All		2		3		4		5 Very Likely		No Response			
Q	*N*	*%*	*N*	*%*	*N*	*%*	*N*	*%*	*N*	*%*	*N*	*%*	*M*	*SD*
1	3	6%	5	10%	13	27%	17	35%	10	21%	0	0%	3.2	1.12
2	2	4%	5	10%	9	19%	16	33%	16	33%	0	0%	3.78	1.14
3	0	0%	1	2%	6	13%	25	52%	16	33%	0	0%	4.0	0.72
4	1	2%	3	6%	10	21%	13	27%	18	38%	3	6%	3.98	1.06
5	0	0%	2	4%	13	27%	16	34%	16	34%	1	2%	3.91	.9.90
6	0	0%	6	13%	6	13%	12	25%	24	50%	0	0%	3.96	1.06

As shown by these results, more than half of the camp participants had an interest in and bias toward technology & engineering-related content prior to attending the camps. The second survey question read: *In your opinion, did attending a Technology/Engineering camp as a child play a part in your current thinking about a career?* This question was at the heart of the study and related directly to the primary research question of the study. MU camp participants indicated that the camps played a part in their thinking about careers, with 66% providing ratings of 4 or 5 (very likely).

The third survey question read: *Do you feel that you extended your knowledge of technology, engineering or science as a result of your camp experience?* Responses to this question showed a strong correlation between camp participation and knowledge gained as seen in Table1. The mean response to question three yielded a 4.0 cumulative response on a 5.0 scale, with 87% of the respondents providing ratings of 4 or 5 (very likely). This question resulted in the most positive response for all of the six survey questions.

The fourth survey question addressed socialization aspects of camp participation and was tied to RQ 4. It was phrased as follows: *Camp activities were often performed in teams of two or more. Do you feel that you gained any positive socialization experiences through your camp participation?* This question was included on the survey because one of the goals of the camp program was to increase participants' socialization skills. The mean response to this question was a 3.98/5.0 as seen in Table 1. These results indicated that in addition to improving technical knowledge of the camp participants, the camp program also increased socialization skills by requiring the campers to work with partners they had likely never met before to solve problems.

The fifth question read: Did you or are you likely to have chosen more technology & engineering-related courses in high school as a result of your camp participation at a younger age? Far more students responded in the "neutral" to "very likely" categories than in the lower categories, indicating that the camps did play a part in influencing the selection of technology and engineering courses as elective subjects in high school. The mean response to this question was 3.91/5.0.

The last question on the survey asked the respondents about their future career plans. Due to the variation in age ranges, the oldest of the survey respondents had already started college while the youngest respondents were in high school and likely contemplating their future careers. The question read: *At this point in time how likely are you to pursue a technology or engineering-related field of study once you graduate from high school?* Responses to this question are provided in Table 1 above. The results to this survey question indicated a strong correlation between MU technology & engineering camp participation in the primary years and the likelihood of choosing to pursue a career in a technology or engineering-related field in the later years.

Discussion

From the data collected, it was evident that participation in one or more MU technology & engineering camps in the primary years influenced future interest in technology & engineering course work and careers. This result was anticipated in the hypothesis of the study for a number of reasons. One reason was that, unlike required courses that must be taken in school, informal learning environments like camps are selected by choice. Another reason was that prior studies of a similar nature had found that camp participants were generally biased toward the camp subject matter. This was the case in this study as well, as was indicated in the responses to the first survey question. Therefore, MU camp participation was not the only factor that influenced the students' future interest in technology & engineering course work and careers. An additional positive aspect of the MU camps was the influence camps had on students' social skills. This outcome was accomplished by requiring the camp participants to work in teams of two or more for many of the camp activities. Interestingly, parental occupations seemed to have less impact on the students' taking a technology & engineering camp than had been anticipated based upon findings from prior studies. More specifically, students with parents employed in technical occupations enrolled in the MU camps at the exact same rate as students of parents employed in other occupations. In response to the final survey question about the likelihood of pursuing technology or engineering-related occupations upon graduation from high school, more than 80% of the survey respondents indicated they were likely or very likely to do so. This represents a much greater percentage than the 7.3% of Pennsylvanian's who have earned degrees in engineering and the 9.6% of Pennsylvanians who have earned degrees in technology-related fields as indicated by United States Census Bureau data from 2009 (United States Census Bureau, 2012).

Conclusions

Most of the MU camp participants indicated that camp participation played a part in their current thinking about a future career. MU camp participants not only increased knowledge of technology, engineering, or science, but also enhanced their socialization skills. Most former camp participants were influenced to take technology & engineering courses in high school as a result of their camp participation experience earlier in life. Of the 48 students who participated in the survey, 35 (73%) had no change of opinion between question one that addressed a bias toward technology and engineering content prior to camp participation, and question two that asked the students if camp participation played a part in their future career aspirations. The remaining 13 students (27%) all changed their opinion in a positive direction toward future careers in technology and engineering. Although the sample population is limited, this is evidence of a directional shift and not a random shift with a p value = .000. For the majority of students who completed an MU technology & engineering camp, that camp participation was a good predictor of future career aspirations in technology & engineering related fields.

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Appendix

Millersville Technology & Engineering Camp Survey

Demographic Information

Age _______________ Race: ☐ Black ☐ White ☐ Asian Current Grade ___________

☐ Hispanic/Latino ☐ American Indian

Sex________________ School District ____

Mother's Occupation __________________________ Father's Occupation______________________

Survey Questions

Did you have interest in technology & engineering related subjects prior to attending a Technology/Engineering camp at MU?

(Not at All) 1 2 3 4 5 (Very Likely)

In your opinion did attending a Technology/Engineering camp as a child play a part in your current thinking about a career?

(Not at All) 1 2 3 4 5 (Very Likely)

Do you feel that you extended your knowledge of technology, engineering or science as a result of your camp experience?

(Not at All) 1 2 3 4 5 (Very Likely)

Camp activities were often performed in teams of two or more. Do you feel that you gained any positive socialization experiences through your camp participation?

(Not at All) 1 2 3 4 5 (Very Likely)

Did you or are you likely to have chosen more technology & engineering related courses in high school as a result of your camp participation at a younger age?

(Not at All) 1 2 3 4 5 (Very Likely)

At this point in time how likely are you to pursue a technology or engineering related field of study once you graduate from high school?

(Not at All) 1 2 3 4 5 (Very Likely)

If you would like to receive an electronic copy of this study please provide an e-mail address here:

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Gender and age analyses of PhD students' perceptions toward the technology education profession

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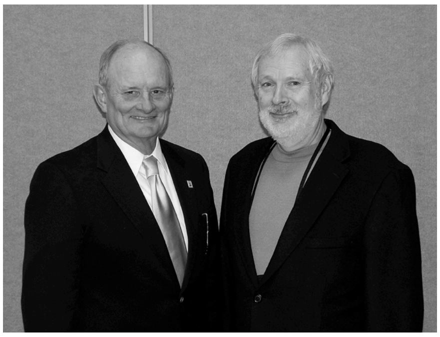

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Abstract

The future of the technology education profession rests on the scholarship and service commitments of its members. This research reports the findings of a study based on a purposely-selected sample of currently enrolled PhD students who intend to seek gainful employment in the technology education teacher education field. A cross-sectional survey research design was used to seek responses from PhD students at US universities. The focus of these analyses was on students' perceptions related to the content to be taught in teacher preparation, instructional strategies used for students to best learn this content, who the audience should be for technology education instruction, publications read and future plans for publishing, licensure of teachers, how teacher education will be delivered, avenues for professional development, association memberships, conference attendance, professional organization service, and research and publication interests. This paper will report on the results of this study while demonstrating/documenting the connections between the core values of technology education and student perceptions of the future of technology education.

Keywords

PhD student perceptions, future of technology education, leadership

Introduction

Teacher educators have contributed much to the development of the technology education profession. They have explored and shared philosophies on the purposes and content of this school subject (de Vries & Mottier, 2006). They have researched the contributions that technology education offers to individual learners (Jones & de Vries, 2009). Technology education teacher educators have designed programs and activities that can deliver their visions of technology education to learners (Barak & Hacker, 2011; Stables, 1997). In addition, they have prepared teachers who can implement this school subject throughout the K-12 schools of the world (Williams, 2012).

An important contribution that technology education teacher educators have made is providing leadership to the organizations that have guided the progression of this teaching profession. If one were to review the historical development of the technology education school subject, they would find names like Pestalozzi, Froebel, Cygnaeus, Della Vos, Woodward, and Dewey (Martin, 1979). These early teacher educators espoused philosophical opinions and led others to support technology education in schools. Others took up this leadership in countries where they believed the study of industry and technology was good for all. Today major supporters and leaders of technology education can be found in most countries. Many of these leaders believe that this school subject has a mission of general technological literacy education for all.

Leaders project their ideals for this profession. During the past 50 years, differing philosophical views have guided the development of the technology school subject. These philosophical beliefs have progressed from our early roots as vocational preparation (Martin, 1979; Williams, 2011), to the study of industry (Cochran, 1970), to technological literacy (DeVore, 1980; ITEEA, 2007). Today this literacy is also being impacted by the concepts and principles of engineering design (Householder & Hailey, 2012), and it is being used to support interdisciplinary approaches to STEM knowledge and literacy (Sanders, 2009).

In addition to the changing mission of technology education, the methods of content delivery have been refined from a focus on skills development through hands-on projects to the formation of practical and abstract concepts that can be enhanced through contextual learning, design, and problem-based learning strategies. These methods have resulted from maturation of philosophical beliefs and research on student developmental needs. The role of technology teacher preparation continues to evolve as these philosophical views morph.

Research problem

Although research and philosophical views continue to evolve, the number of technology teachers and professors in this field appears to be declining. Martin, Ritz, and Kosloski (2014) and Ritz and Martin (2014) have studied this transition in the US. In this current study, the authors chose to compare the perceptions of current PhD students by gender and age to see if there were difference between these groups' views regarding the school subject of technology education and commitment to the professions that support this school subject.

Research questions

This study was guided by the following research questions:

RQ_1: What are doctoral students' opinions concerning the focus of content to be learned in K-12 technology and engineering education?

RQ_2: How do these scholars believe technology and engineering teachers will be prepared in the near future?

RQ_3: What is the commitment level of these scholars to their technology and engineering teaching professions?

RQ_4: What do these populations expect to occur in the future to the technology and engineering teaching professions?

Procedures

A 12-question survey, plus five additional demographic questions, was administered to a purposely-selected group of technology and engineering education PhD students enrolled at five United States' universities. A letter of invitation was sent to qualified students who had been nominated by a lead professor at their university. Upon receiving a confirmation from the invitees (N = 34) that they would participate, they were sent a URL to complete the survey. All 34 invitees completed the survey for a 100% response rate.

Findings

Data were collected from 34 (females, n = 16, 47.1%; males, n = 18, 52.9%) participants' responses to a 12-question survey. The data were analyzed by gender and age groupings: 20-30 years, 31-40 years, 41-50 years, 51-60 years, and 61+ years. All participants identified the United States as their home country and all were studying in the United States at the time of the survey.

The following narrative reports on data related to an analysis of the responses to the survey questions by gender and age. The data are also presented following the same categories used in the survey – Part 1 and Part 2. Data collected for Part 1 focused on Research Question 1 and data collected for Part 2 focused on Research Questions 2, 3, and 4. Due to space limitations, a narrative of the data collected for all of the survey questions is not provided.

Part 1 contained four questions that focused on Research Question 1. Specifically, the participants were instructed to respond to questions relating to the (a) content taught in a formalized K-12 technology and engineering education program; (b) instructional strategies offered in a formalized K-12 technology and engineering education program; (c) primary audience for a formalized instructional program in technology and engineering education; and (d) professional publications frequently read. As it relates to the focus of content taught in a formalized K-12 technology and engineering education program, the most often selected choice by females was technological literacy (n = 13, 81.3%) and by males was STEM (n = 15, 88.2%). Since they could "select all that apply", another area of agreement is the choice of engineering design (females: *n* = 11, 68.8%; males *n* = 12, 70.6%) as the content focus. When responses were analyzed by age, technological literacy was selected most often by people in the 20-30-age range (*n* = 5, 71.4%) while people selected STEM most often in the 31-40 (*n* = 9, 90.0%), 41-50 (*n* = 6, 75.0%), and 51-60 (*n* = 8, 100.0%) age ranges.

The second survey question focused on instructional strategies. Females believed that strategies focusing on designed-based (*n* = 13, 81.3%) and contextual learning (*n* = 13, 81.3%) should be the focus of instructional strategies. A third strategy, project-based learning, also received their attention (*n* = 12, 75.0%). Males believed that strategies should focus on design-based learning (*n* = 15, 83.3%) while giving some attention to project-based learning (*n* = 12, 66.7%) and conceptual learning (*n* = 12, 66.7%). When the focus of instructional strategies was analyzed by age, respondents in the 20-30 age range believed the focus should be on project-based, design-based, and contextual learning (*n* = 5, 62.5%); respondents in the 31-40 age range believed the focus should be on design-based (*n* = 9, 90.0%) followed closely by project-based and contextual learning (*n* = 8, 80.0%); respondents in the 41-50 age range were evenly divided among project-based, design-based, and contextual learning (*n* = 6, 75.0%); and respondents in the 51-60 age range believed the focus should be on design-based learning (*n* = 8, 100.0%).

Another question asked participants to identify the primary audience for a formalized instructional program in technology and engineering education. Females (*n* = 9, 56.3%) and males (*n* = 11, 61.1%) are in almost total agreement that the primary audience should not be limited to a specific group but should be inclusive of all grade levels. As it pertains to age, six (75.0%) participants in the 20-30 and 51-60 age ranges believed the primary audience should be all inclusive while four (40.0%) in the 31-40 and 41-50 age ranges believed the primary audience should be all inclusive.

The final question in Part 1 focused on getting the participants to identify the professional publications that best described them as a regular reader. Since the participants were all from the United States, it is not surprising that 22 (64.7%) identified the *Technology and Engineering Teacher* and 15 (44.1%) identified the *Journal of Technology Education*. *The International Journal of Design and Technology* was identified by four participants (11.8%).

Part 2 of the survey consisted of a series of questions related to the future of the profession. Specifically, the participants were instructed to place themselves in the year 2025 (approximately 10 years after they will have graduated and should be practicing in their career). The first question focused on the qualification routes of future technology and engineering educators. There is general agreement among females and males that teachers will be prepared with a discipline degree followed by a teaching diploma (females, *n* = 7, 46.7%; males, *n* = 8, 47.1%) and by a combination university – school-based program (females, *n* = 6, 40.0%; males, *n* = 7, 41.2%). There is unanimous agreement that students will not become teachers by documenting qualifications through professional testing. When viewed by age, the 31-40 age group clearly believed that students will become future teachers through distance learning technologies (*n* = 8, 88.9%) and the 41-50 (*n* = 6, 75.0%) and 51-60 (*n* = 5, 62.5%) age range groups believe the method to becoming a future teacher is through a combination of university – school-based program.

The next question focused on the location or "where" education/qualifications will be received. There is general agreement (females, *n* = 14, 93.3%; males, *n* = 16, 94.1%) that hybrid systems that blend on-campus and distance learning modes will dominate instructional delivery systems. However, females (*n* = 9, 60.0%) also believe that brick and mortar university classrooms/laboratories will be a significant factor. This view is not shared by the males (*n* = 6, 35.3%). When location is analyzed by age range of the groups, it is clear that hybrid systems dominate the choice of all four age range groups. The 41-50-age range group also supports brick and mortar university classrooms/ laboratories (*n* = 5, 62.5%) and distance learning technologies (*n* = *5*, 62.5%).

Another question focused on "who" will provide professional development training once a teacher is qualified and working. Teacher education institutions were chosen most often by females (*n* = 13, 81.3%) and males (*n* = 13, 76.5%). Females (*n* = 7, 43.8%) reported less of a role for distance learning providers than males (*n* = 11, 64.7%) and females (*n* = 10, 62.5%) also reported less of a role for professional associations than males (*n* = 13, 76.5%). Examining the data by age groupings revealed that all age groups believe that teacher education institutions will play a significant role in professional development with the participants in the 51-60 age group (*n* = 8, 100.0%) reporting the highest percentage. Interestingly, the 31-40 age group believes that distance learning providers (*n* = 7, 77.8%) and professional associations (*n* = 7, 77.8%) will be the professional development providers in 2025.

Will our future educators be members of professional technology and/or engineering associations in 2025? There is strong support among females (*n* = 13, 86.7%) and males (*n* = 17, 94.4%) to be members of the International Technology and Engineering Educators Association (ITEEA) and some support among females (n = 10, 66.7%) and males (n = 10, 55.6%) to be members of the American Society for Engineering Education (ASEE). Males (n = 14, 77.8%) appear to want to be members of STEM associations more than females (n = 7, 46.7%). When the participants' responses were analyzed by age groupings, only the ITEEA received strong support, ranging from 71.4% to 100.0% across all age groups while membership in the ASEE received support from the 20-30 (n = 75.0%), 41-50 (n = 57.1%), and 51-60 (n = 6, 75.0%) age groups.

Attendance and participation in professional conferences is an important responsibility and commitment of every professional educator. Which conferences did the participants plan to be regular attendees in 2025? Since the sample for this study was 100.0% Americans, it is not surprising that females (n = 12, 80.0%) and males (n = 14, 82.4%) selected the annual ITEEA conference and national/regional/state level technology and engineering conferences (females, n = 10, 66.7%; males, n = 10, 58.8%). And, not surprisingly, support for attendance at ITEEA conferences appears to be strong across all age groups ranging from 71.4% for the 41-50 age group to 100.0% for the 20-30 and 51-60 age groups.

One would assume that if educators are members of professional associations and attend conferences sponsored by the associations, then they would also plan to publish in journals sponsored by the associations. This is clearly the case if the journals are the *Technology and Engineering Teacher* (females, n = 13, 81.3%; males, n = 14, 87.5%) and the *Journal of Technology Education* (females, n = 15, 93.8%; males, n = 12, 75.0%). Interestingly, regardless of gender, while educators plan to be members of and attend the annual conference of ASEE, they do not plan to publish in the ASEE sponsored *Prism* journal (females, n = 2, 12.5%; males, n = 5, 31.3%). When analyzing data across all age groupings, there is strong support for the *Technology and Engineering Teacher* and the *Journal of Technology Education*. There is also support among the 21-30 age group for publishing in the *International Journal for Technology and Design Education* (n = 4, 50.0%) and the *Design and Technology Education: An International Journal* (n = 4, 50.0%).

Finally, the participants were asked to respond to what they see happening to the technology and/or engineering profession by the year 2025. Females (n = 13, 81.3%) and males (n = 17, 94.4%) believe the profession as it is known today will be integrated into a STEM organization. Participants do not believe the profession will be similar to what it is today. However they do not believe it will be integrated into the science profession, and they do not believe it will disappear as a teaching profession. See Table 1 for a summary of data.

Conclusion and discussion

Based on the data analyzes of this population of 34 current PhD students, females believed the content to be learned in K-12 technology and engineering education programs should align with a philosophy based upon achievement of technological literacy (81%) while males believed the focus should be one based upon STEM integration (88%). These differences could be based upon the purpose that the students seek the PhD or come from the philosophies of the professors who teach at the universities they attend. By age, the majority of participants (n = 23), aged 31-60, believed that STEM integrations should be the focus of technology education programs. The researchers believe that this could cause further erosion of the identity of technology education programs.

Their beliefs of how technology and engineering teachers will be prepared in the future continues to follow current practices with hybrids of distance learning being integrated into campus-based programs. School based learning will also continue to be a major component of this preparation.

Table 1

Summary of responses by gender and age

	Gender				Age							
	Female		Male		20-30		31-40		41-50		51-60	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Content												
Tech. Lit.	13	81.3	8	47.1	5	71.4	6	60.0	5	62.5	5	62.5
Eng. Design	11	68.8	12	70.6	3	42.9	8	80.0	5	62.5	7	87.5
STEM	12	75.0	15	88.2	4	57.1	9	90.0	6	75.0	8	100.0
Workforce	6	37.5	3	17.6	1	14.3	3	30.0	3	37.5	2	25.0
Instructional Strategies												
Project-base	12	75.0	12	66.7	5	62.5	8	80.0	6	75.0	5	62.5
Design-base	13	81.3	15	83.3	5	62.5	9	90.0	6	75.0	8	100.0
Contextual	13	81.3	10	55.6	5	62.5	8	80.0	4	50.0	6	75.0
Conceptual	8	50.0	12	66.7	3	37.5	5	50.0	6	75.0	6	75.0
Audience												
Elementary	1	6.3	0	0.0	1	12.5	0	0.0	0	0.0	0	0.0
Middle Sch.	1	6.3	4	22.2	0	0.0	3	30.0	2	25.0	0	0.0
High School	1	6.3	0	0.0	0	0.0	1	10.0	0	0.0	0	0.0
Secondary	3	18.8	3	16.7	1	12.5	1	10.0	2	25.0	2	25.0
Post-second	1	6.3	0	0.0	0	0.0	1	10.0	0	0.0	0	0.0
All Levels	9	56.3	11	61.1	6	75.0	4	40.0	4	50.0	6	75.0
Qualification Route												
Campus Prog	2	13.3	2	11.8	2	28.6	1	11.1	0	0.0	1	12.5
Discip. + Tch.	7	46.7	8	47.1	3	42.9	8	88.9	2	25.0	2	25.0
Prof. Test	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Combo	6	40.0	7	41.2	2	28.6	0	0.0	6	75.0	5	62.5
Provider of Education												
On-Campus	9	60.0	6	35.3	2	28.6	5	50.0	5	62.5	3	42.9
Dist. Learn.	5	33.3	5	29.4	1	14.3	2	20.0	5	62.5	2	28.6
Hybrid	14	93.3	16	94.1	7	100.0	10	100.0	6	75.0	7	100.0
External Org.	2	13.3	1	5.9	1	14.3	0	0.0	1	12.5	1	14.3
School-based	4	26.7	3	17.6	2	28.6	1	10.0	3	37.5	1	14.3
Prof. Devel.												
Supervisors	8	50.0	9	52.9	5	62.5	4	44.4	3	37.5	5	62.5
Vendors	6	37.5	4	23.5	2	25.0	3	33.3	3	37.5	2	25.0
Prof. Assoc.	10	62.5	13	76.5	5	62.5	7	77.8	6	75.0	5	62.5
Tch. Ed. Inst.	13	81.3	13	76.5	5	62.5	6	66.7	7	87.5	8	100.0
Dist. Learn.	7	43.8	11	64.7	3	37.5	7	77.8	3	37.5	5	62.5
Future Direct.												
Similar Today	2	12.5	0	0.0	1	12.5	0	0.0	1	12.5	0	0.0
Integr. STEM	13	81.3	17	94.4	7	87.5	9	90.0	7	87.5	7	87.5
Integr. Sci.	0	0.0	1	5.6	0	0.0	1	10.0	0	0.0	0	0.0
Disappear	1	6.3	0	0.0	0	0.0	0	0.0	0	0.0	1	12.5

N = 34. Respondents could select more than one response to each item area.

The commitment level of these scholars to their technology and engineering teaching professions is positive. They plan to continue to participate in technology education (n = 26), STEM education (n = 21), and engineering education (n = 20) professional organizations. Many plan to deliver papers at the conferences of the International Technology and Engineering Educators Association and to publish mainly in American published international journals for technology education (n = 27) as compared to a limited number of participants who expect to publish in engineering education journals (n = 7).

Both the females (81%) and males (94%) believe the profession as it is known today will change its main affiliation and be integrated into a STEM professional organization. Do we actually believe this to be true? Will we be attending international professional meetings where we will work more closely in science, engineering, and mathematics professionals?

This is a report of one study of technology and engineering education PhD students. Other studies are underway including students in the Pacific-rim and European nations. Future reports will analyze what PhD students perceive in these nations to determine if there are differences in perceptions toward technology and engineering education.

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Teacher perspectives on pedagogical modelling and explaining in Design & Technology: a Q Methodology Study

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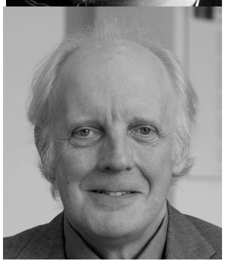

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Abstract

The demonstration has been a long-standing signature pedagogy and teaching style in design and technology, its precursors and practical education as a whole. However, the body of literature outlining the theory and practice of teacher modelling and explanation within the 'field' is somewhat limited. As a practical and creative subject, with a complex epistemology, engaging learning objectives from within the cognitive, affective and psychomotor domains, the modelling of designing and making tools encompasses the interaction between thought and action. Therefore, the authors assert that, the 'demonstration' in D&T is multifaceted and effective teachers adopt and adapt a range of skills and values to scaffold learning. The aim of this study is to investigate the subjective values of practicing teachers towards the demonstration of design and technology knowledge and skills. Q Methodology is used to compare and analyse the responses of the participating teachers, to investigate shared ad contrasting values. A Q Set of statements, developed and refined with D&T teacher educators, relating to modelling and explaining, representing the concourse of opinions and perspectives. The sample is purposive, comprised of practicing teachers who are engaged with mentoring D&T Initial Teacher Education (ITE) trainees. The findings will represent a snapshot of subjective values of practicing teachers, as part of a wider, and developing, discourse on signature pedagogies in design and technology education.

Introduction

> "When education… fails to recognize that primary or initial subject matter always exists as matter of an active doing, involving the use of the body and the handling of material, the subject matter of instruction is isolated from the needs and purposes of the learner... Recognition of the natural course of development, on the contrary, always sets out with situations which involve learning byd'oint." (Dewey, 1916, p. 178)

We take from this that the demonstration is an essential first step in learning by doing. As a practical and creative subject, the demonstration has been a staple of the design and technology teachers' repertoire for the past two to three decades since the introduction of the subject within the National Curriculum for England in the 1990s (DFE, 2013; QCA, 2007; QCA, 2004; DfEE, 1999; DFE, 1995; NCC, 1990). This paper is an initial exploration of the pedagogy of demonstrations in design and technology, as what the authors view as an under investigated area. The aim was to facilitate a dialogue on effective pedagogy within the design and technology educator community, and as a pilot study in which to begin to develop a framework for teaching and learning.

The demonstration is seen as important in science (Milne and Otieno, 2007) and physical education (Mosston and Ashworth, 2002) building on the traditions of apprenticeship and craft education of "demonstration, observation and constant practice" (Mason and Houghton in Sayer et al, 2002, p. 44). And Petrina comments on the significance of demonstrations for technology education: *"Demonstrations are the single most effective method for technology teachers"* (Petrina, 2007, p. 1).

Literature review

The demonstration: signature pedagogy for design & technology?

With this in mind, it is an anomaly to find a virtual absence written about the praxis (theory and practice) of demonstrating in the subject. One might speculate that this may be because it is considered to be such an elementary skill or it is considered such a tacit skill learnt in initial teacher training; working alongside and mimicking experienced teachers in schools, colleges and universities in a diffuse community of practice (Wenger in Illieris, 2009; Duguid, 2008; McLain, 2012; Lave and Wenger, 1991). However, it may be that the act of demonstrating is a multifaceted skill, comprised of layers of explanation, modelling and other established pedagogical techniques and from this perspective has received little specific attention in literature. If true, the act of demonstration needs to be analysed to reveal the complexity within the tacit skill view. If design and technology pedagogy is to stand distinct from context-based, situated cognition, and identify theoretical, practical and portable, endogenous skills shared and understood by the wider community of teachers, then conceptual frameworks and typologies need to be discussed and debated (Sennett, 2009; Kimbell and Stables, 2007; Petrina, 2000).

Before we look at the elements the make an effective demonstration, it is appropriate to define what we mean by 'demonstration'. We begin with an assumption that a demonstration includes a combination of teacher *modelling*, *explanation* and other pedagogical skills such as *questioning*, each of which do not define demonstration, in themselves, but are pedagogical strategies that a teacher of design and technology employs when demonstrating. The National Strategies Pedagogy and Practice, an initiative to develop the teaching workforce within state schools in England in the mid-2000s, gave the following definitions:

> "Modelling is an active process, not merely the provision of an example. It involves the teacher as the 'expert', demonstrating how to do something and making explicit the thinking involved." (DfES, 2004a, p. 3)
>
> "Whether helping learners to acquire basic skills or a better understanding to solve problems, or to engage in higher-order thinking such as evaluation, questions are crucial." (DfES, 2004b, p. 2)
>
> "The purpose of explaining a process or procedure is to help pupils understand how things happen or work. The emphasis is on sequence and connectives such as first, next, then and finally are important. (DfES, 2004c, p. 3)

It is also important to note that the skills demonstrated in design and technology cover a wide range of domains, from the manipulation of *physical tools and materials* (making), to *virtual tools* (software, including computer-aided manufacture) and *cognitive tools* (design thinking and problem solving). Each of these skill domains has similar features as well as distinctive differences relating to the learner, context, equipment and materials.

The planning of effective demonstrations

If the demonstration is, as we have suggested, a complex activity involving a range of skills, some of which are conscious and deliberate, other that are subconscious, intuitive and automatic (Wood, Rust and Horne, 2009; Race, 2007, pp. 17-20; McCormack, 1997; Luft, 1982), then it is essential that in the design and technology education community we understand and name our practice. It is important, in particular for training, newly and recently qualified teachers, to plan each demonstration, visualising and rehearsing the key steps and processes. Where the pedagogical and practical skills are tacit and the teacher is able to focus on learners and learning - somewhat analogous to driving a car – but to reflect on practice and make and evidence-based improvements a degree of consciousness of practice is necessary (Banks et al, 2004; Jay and Johnson, 2002).

The precise format and structure of each demonstration will differ according to the *content* and the *learners*, as there is no one "universal sequence" but there are several common components (Figure 1; Petrina, 2007, p. 14) where health and safety and safe working practices are embedded throughout the process. These could also be synthesised into four elements, or 4Cs: coverage, context, content, and conclusion (McLain, Bell and Pratt, 2013).

Figure 1. Common components of a demonstration (Petrina, 2007, p. 14)

1. Introduction (What will be demonstrated?)
2. Relevance (Why demonstrate this?) (Use Questions, Story, Description, etc.)
3. Use of application, instrument, machine, process, or tool (How to effectively and safely do or use this?) (Actual execution of proposed process)
4. Conclusion (Recap-Summarize, What was covered-Where to go next?)

Visual communication in demonstrations

> "First and foremost, the goal of a demonstration is to communicate and model how to do something and how to talk about the task or technology at hand... The demonstrator must demystify the tool or process, explaining what is to be accomplished, what knowledge is applied and the roles of certain skills and senses." (Petrina, 2007, p. 14)

It is commonly accepted that a significant proportion of human communication is *non-verbal*, and for millennia mankind, and our hominid ancestors, have used symbols, signs and actions to communicate (Engeström, 2009; Vygotsky, 1934/1986, 1978, cited in Tappan, 1997; Wertsch, 1985, 1991, cited in Tappan, 1997).

Visual processing, and interpretation, is sophisticated with the mind constructing and reconstructing what we see into something that we can understand. That being said, individuals perceive and understand in different ways from differing perspectives (physical and cognitive), so the effective demonstrator should consider the important aspects of the activity that the observers need to see. To quote Barlex and Carré (1985), *"We do not see things as they are, we see them as we are"* (p.4). A *maxim* for effective visual communication might be: make sure that the learners can see what you can see, where at all possible. There are several ways in which this can be achieved through arranging the learning environment to using technology, such as the use of a video camera and screen. The complexity and intricacy of the skills being demonstrated; as well as the novelty or familiarity of the activity to the learners affect pedagogical choices. A simple approach to overcome an issue of visibility may be to gather learners around as close as possible to the demonstration station as practicable. Two factors to consider in opposition to this are: (a) the potential disruption of learners being in close quarters and (b) the configuration of the teaching environment, including resources and equipment.

Verbal communication in demonstrations

> "The necessity of a demonstration derives from the inadequacy of words [alone] to depict technological processes." (Petrina, 2007, p. 14; addition/emphasis ours)

With our adaption of Petrina's statement to "… the inadequacy of words [alone]…" and the demonstration treated as a complex and holistic interaction between the teacher and the learner, the use of *verbal* communication can make or break a demonstration. When explaining a process, it is important that the critical stages or steps are *identified* and *presented* effectively using age-appropriate as well as technical language. Pedagogical choices, made by the teacher, fall along an *expansive-restrictive continuum* (Fuller and Unwin, 2003), when planning and differentiating explanations and questioning strategies. In other words, the skillful teacher will tailor depth of knowledge and skill being demonstrated to suit the learner, adjusting the balance and detail of modelling, explanation and questioning. In some circumstances, for example with younger learners or with new concepts, the choice might be to adopt a more *restrictive* and teacher led approach, with questions being used to gauge *recall* and *understanding*.

On the other hand, as learners become more independent and extend their knowledge and understanding or when revisiting concepts, a more *expansive* approach might be adopted. For example, questions may be used to *prompt* recall, *probe* understanding during the demonstration or encourage speculation. As the learners become more skilful, the teacher may chose to use learner demonstrations or narrations, or microteaching (Hattie, 2009, pp. 112-113). These approaches to the *scaffolding* of learning involve the teacher making decisions to support and facilitate learners as they mentally *construct* an understanding of the skills being demonstrated. Illustrating the complexity of choices that are underpinned by the pedagogical knowledge and skill of the teacher, involving interplay between subject and pedagogical knowledge.

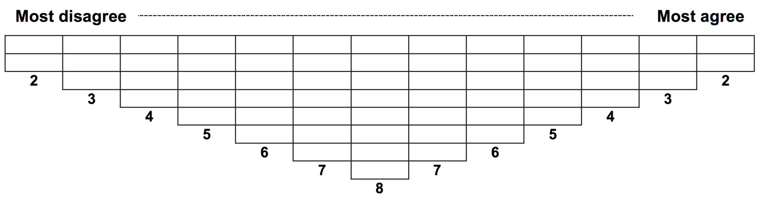
Research method

The research question for this study was: What do teachers of design and technology believe to be effective pedagogy when demonstrating skills and knowledge?

The overarching philosophical and conceptual framework for this investigation is pragmatic and constructionist in the traditions of Dewey, Pierce and James (Watts and Stenner, 2012: 24-46). The research paradigm is ontologically relativist, recognising the subjective nature of realities for individuals, which are multiple (Guba, 1990, pp. 17-27; Guba, 1981, p. 77). As a Q Methodology study (Watts and Stenner, 2012), the focus is on subjectivity ("mind-stuff") and the individual in relation to the objectivity of teaching and learning practice ("world-stuff") (p. 29). In this aspect the intentions of the Q Method are interpretive and qualitative, using Peirce's "abduction", where observation of facts are used "in pursuit of an explanation and new insight" (p. 39).

Working within a social constructivist framework, the epistemological position adopted in this paper is subjectivist, recognising the role of the researchers as a co-constructers of theory and knowledge with the participants, or actors, in the study. However, the research perspective adopted is that human beings' perceptions of reality are socially and culturally constructed, but that this does not necessarily mean that concepts such as truth and reality do not exist. Thus taking a pragmatic approach that does not deny objective truth or reality, but acknowledges that we perceive and share conceptual constructs. As a speculative ontology there are similarities with the critical realist ontological positions of post-positivist or critical theory (Guba, 1990, p 20-25), although the pragmatic and working ontological position to adopted in this study is that of relativism, in that the concern is with perception and experience or realities (Guba, 1981, p. 77).

Figure 2. Q Sort distribution



Q Methodology originates from psychology research and "focuses on subjective or first person viewpoints" (Watts and Stenner, 2012, p. 4). As such it does not purport to generate or confirm generalizable concepts and principles. With its roots in pragmatism, it draws on inductive and abductive reasoning with the support of mathematical modelling (factor analysis) to explore qualitative data through quantitative methods. In Q Methodology the comparison focuses on the similarities and differences between the participants, rather than their responses as is common within tradition factor analysis. A series of statements, or Q Set, that represents the broad range of opinion or belief (concourse) potentially held by the population that the sample is being drawn from. The participants then undertake a Q Sort activity. This is typically a two stage process involving a pre-sort into three categories (essential, desirable and optional, in this study), followed by the main sort where the Q Set statements are sorted into a *forced-choice frequency distribution* (Figure 2; p.16-17) ranging from most agree to most disagree (note: the statements in this study were not designed to generate disagreement, so the 'most disagree is relative).

The initial Q Set was developed through a focus group of six design and technology mentors, working with initial teacher education trainees in the North West of England, and refined by the authors through a teacher educator email discussion group. The list was divided into 10 categories to aid the presentation and interpretation of the 62 statements (Appendix).

Seven teachers from a range of backgrounds and design and technology disciplines, and not part of the focus group (above), completed the online Q Set. The stated design and technology specialisms of each of the participants ranged from electronics and control (n=1), engineering (n=1), graphic design (n=2), product design (n=2) and textiles and fashion (n=1); each having links with the initial teacher education (ITE) institutions represented by the research team, as an ex-trainee and/or mentor for trainee teachers. Five of the participants are currently involved with initial teacher training (ITT) with management responsibilities that involve working both within and outside of their place of employment; Participant 4 and 7 being Recently Qualified Teachers (RQTs).

The Q Sort for this study was conducted using an online questionnaire tool, QSortWare (Pruneddu, 2014), to enable wider participation across institutions. The population for the study was experienced teachers of design and technology engaged with the mentoring of ITE trainees and with links to members of the institutions that the research team represent; with the sample being purposive (Guba, 1981). The factor analysis for data analysis was conducted using the PQMethod (Schmolck, 2014) software.

Findings and interpretation

As a study in the subjective beliefs, values and practice the small sample size does not pose a problem (Watts and Stenner, 2012, p. 73), as the findings are not being used to infer generalizable theoretical principles. Rather to explore existing practice with the view to refine the Q Set of 62 statements (Appendix) relating to modelling and explaining within the subject. Use with a larger sample would then be appropriate and perhaps be able to be used to establish a recognised orthodoxy with regard to demonstrations in design and technology.

Figure 3. Correlation matrix between Q Sorts (n=7)

1	100	44	25	20	-3	16	16
2		100	21	17	-1	11	42
3			100	17	0	12	24
4				100	6	8	28
5					100	-2	9
6						100	-3
7							100

The initial correlations between Q Sorts (Figure 3) from the PQMethod software (Schmolck, 2014) indicate a superficial correlation between the participants ranging from 44 (Participants 1 and 2) to -1 (Participants 1 and 5), with Participant 5 showing the lowest correlation to the overall. This reinforces the perception that the nature of teaching and learning is complex, with no 'one size fits all' approach.

Figure 4. Factor Matrix with X indicating defining sort (n=7)

Factor Loadings Q Sorts	Factor 1	
Participant 1	0.65	X
Participant 2	0.58	X
Participant 3	0.40	X
Participant 4	0.38	X
Participant 5	0.03	
Participant 6	0.16	
Participant 7	0.64	X
Eigenvalues	1.51	
Variance	21%	

PQMethod was used to extract factors (Figure 4) and reduce the data, with the Eigenvalues (EV), or Kaiser-Guttmann criterion, above 1.00 used to indicate the statistical strength (Watts and Stenner, 2012,

p. 105). Watts and Stenner advise that Q Methodology researcher try to extract one factor for every 6 to 8 participants (p. 107). In this study, with only seven participants, two factors were extracted, but only the EV for Factor 1 (1.51) indicating potential explanatory power (i.e. >1.00) and the presence of a single common factor in the study – i.e. Factor 2 was discounted as insignificant.

The factors are the rankings of items (Q Set statements) in comparison to the participants, with the items being treated as the sample rather than the participants. These factors are the building blocks of the participants' responses to the Q sort activity, when their responses are compared. Whilst the EV for both factors indicate potential explanatory power, the factor loadings above 0.33 for each participant (Figure 5) indicate a significant loading in the responses for all except Participants 5 and 6. Brown's (1980, pp. 222-3) calculation, below, was used to identify significant factor loadings:

$$=2.58 \times 1 \div No.\ of\ items\ in\ Q\ Set$$

The 'Variance' (Figure 4) provides and indication of percentage of "common variance" (Watts and Stenner, 2012, p. 105). Therefore Factor 1 accounts for about one fifth of everything that the Q Sorts (the individual participants' arrangements of the Q Set items) have in common.

The factor arrays (Appendix) provide a useful ranking of the Q Set items enabling common themes to be identified. They are presented with the 62 items (statements) in the Q Set ranked from +6 to -6, in a similar distribution to the 'forced-choice frequency distribution' described above (Figure 2). However, it is important to note that the items that are ranked at the minus end of the spectrum do not represent disagreement, but rather that the participants arrange the items in a continuum from most agree to most disagree, indicating the degree to which each are essential or desirable (respectively).

Discussion: competent management of the learning experience

As highlighted above, this is a single factor Q Methodology study due to the small sample size. The factor as an eigenvalue of 1.51 and explains 21% of the study variance. Five of the seven participants are significantly associated with the factor. There were five male, four of whom are associated with the factor, and two female participants, one of whom is associated. Two of the associated participants identify themselves as *Product Design* specialists, two as *Graphic Design* and one as *Electronics and Control*. Of the non-associated participants, one identifies herself as *Textiles and Fashion* and the other did not specify; no *Food* specialists responded to the study. Four of the participants are affiliated to one of the ITE institutions; two being design and technology teacher educators (who also share the highest factor loadings) the other two are recently RQTs.

The highest rated statements relate to **competency** (37: +6) and **clarity** (1: +6) in relation to **subject knowledge** (Figure 5 and Appendix). Similarly the next layer of statements relate to the clarity of communication in relation to health and safety information (38: +5), learning outcomes (5: +5), explanations of processes and procedures (11: +5) and identification of the main teaching points or steps (17: +5). Other key messages emerging in the top ten items (Figure 5) relate to **classroom management** and **expectations** of learning. The classroom management items are preparation for the demonstration area (32: +4) and the teacher monitoring or scanning the class to ensure that learners are safe (47: +4). Ranked outside the top ten (at 12) was scanning the class to monitor progress (53: +3), although this would require some further exploration to define how the participants measure progress during and following a demonstration. The participants' expectations related to high standards in designing and making (39: +4) and explanation of how learners will make progress (59: +3).

Figure 5. Ten guidelines for demonstrating in design and technology

1. Be competent to use equipment safely
2. Provide learners with an overview of the skills or knowledge being demonstrated
3. Make appropriate information about risk is readily available to learners
4. Present the learning outcomes, explaining what learners will be able to do
5. Give clear verbal explanations of processes and procedures
6. Identify the main points or steps for the learners
7. Prepare the demonstration area in advance
8. Scans and monitor the group to ensure that learners are safe
9. Sets high standards and expectations for the learners in designing and making activities
10. Explain what learners are expected to do to make progress

Two interesting features emerge, the first relating to the **consolidation of learning**, within the mid-range of statements (+2 to -2), and the second relating to **learner choices** and **independent learning**, in the lower-range (-3 to -6).

In the mid-range statements, relating to the consolidation of learning, two themes emerge relating to the teacher's role in probing learners' understanding concepts and processes (27: 1) to recall (26: -2) and apply knowledge from both within (26: -2) and outside of the immediate learning experience of the current unit being taught (23: +2), other design and technology units (24: -1) and from other subjects (25: -2). In addition, the teacher's role in using questioning to ascertain what learners understand (58: 0) and addressing their misconceptions as they arise (21: 1); both of which require a secure level of subject knowledge from the teacher in addition to pedagogical skills. The second theme relates to learners' emerging independence facilitated by the teacher allowing them to attempt a task, following a demonstration, before intervening (54: 0) and the use of peer learning to demonstrate skills/knowledge to each other (43: -1) and provide support before seeking the teacher's assistance (55: -1). This requires a degree of self-discipline from the teacher to defer intervention and to invest time to develop a collaborative learning environment.

Statements relating to the consolidation of learning continue to emerge in the lower-range statements. However they begin to focus on learners' choices. The ranking of these items in the lower-range does not necessarily indicate a lack of importance or value placed on the independent learning, although this may be the case and would suggest the need for further study; it could also be the result of the necessarily restrictive nature of the demonstration of skills and knowledge requiring learners to follow defined and predetermined processes. This can be seen in psychomotor domains of taxonomies for learning objectives, such as Simpson (1972) or Dave (1967), developed following the development of the cognitive domain by Bloom et al (1956) and the affective by Andersen and Krathwohl (2001). As the principle investigator, Simpson drew from expertise in practical subjects (Industrial Arts, Agriculture, Home Economics, Music, Physical Education and Art), identifying adaption and origination as the highest levels (Figure 6).

Figure 6. Simpson's psychomotor domain

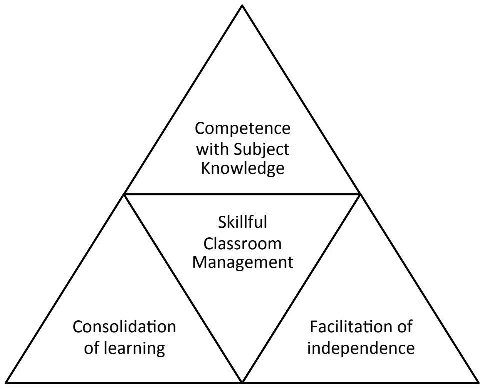
Perception	Observation and general perception
Set (or mindset)	Cognitive readiness for action
Guided Response	Imitation and mimicry when practicing actions
Mechanism	Emerging competence/proficiency, leading to independence
Complex Overt Response	Independence, automatic and accurate performance
Adaptation	Mastery and the ability to transfer skill/knowledge to other settings
Origination	The ability to create new approaches to activity

Traditionally these levels of competence have been considered to belong to the craftsman through a lengthy apprenticeship (Sennett, 2009). So it is not surprising to see the role of the demonstration as a signature pedagogy in design and technology, within a subject-based national curriculum espousing a "balanced and broadly based" (DFE, 2013, p. 5) learning experience. The ranking of items relating to the role of the teacher to make learners aware of choices (41: -3) or alternative actions (41: -3), encourage them to speculate on the next steps (28: -3) or 'think-out-loud' to consolidate knowledge (50: -5), indicates that these pedagogical strategies are less common and/or desirable.

Conclusion

Teacher modelling and explanation is complex and nuanced, drawing on both generic as well as subject specific pedagogical praxis that rely on a high level of subject knowledge. Whilst this study does not provide a solid basis to devise a theoretical framework or typology for teacher modelling and explaining, it does begin to build on Petrina's common components (Figure 1), in particular 'relevance' and 'application' (relating to the teacher's specialist knowledge) and identify features of effective practice for both trainee and experienced teachers. The participants responses in this small-scale study support the belief that competence with subject knowledge is fundamental to effective teacher modelling, supported by skilful pedagogical knowledge to manage the classroom experience; with the more sophisticated and nuanced skills to consolidate learning and facilitate independence being employed as appropriate to the age and ability of the learners (Figure 7).

Figure 7. Model representing participants responses



As a Q Methodology study, the analysis of the findings indicates the common ground between the participants in response to the 62 predefined statements on teacher modelling and explanation in design and technology. This was an initial and exploratory small-scale study into a hitherto under-researched aspect of design and technology pedagogical practice; and as such provides a useful insight into the beliefs of the participating teachers about teacher modelling and explanation within the subject. Further study is required to investigate the voracity of the emerging patterns of beliefs about teacher modelling and explaining in design and technology. A larger study could be used develop and refine of a more concise Q Set. However the highest ranking items from this study, in the form of the 'top ten' (or more) guidelines (Figure 5), could be useful for initial teacher education when introducing the basic concepts of demonstrations of design and making within design and technology; as well as training school-based mentors.

Appendix

Q Set – 62 items (statements) relating to teacher modelling, explaining and questioning in design and technology, with factor arrays (ranking):

No.	Item	Category	Array
1	The teacher gives an overview of the content of the skills or knowledge being demonstrated	Content	6
2	The teacher uses technical language/terminology and key words	Content	3
3	The teacher presents their expectations	Content	3
4	The teacher presents the learning objectives (knowledge/skills)	Content	3
5	The teacher presents the learning outcomes (i.e. what learners will do or be able to do as a result)	Content	5
6	The teacher refers to the application, of what is being demonstrated outside the classroom context	Content	1
7	The teacher demonstrates skills and knowledge that learners will apply within the lesson	Content	1
8	The teacher uses staged demonstrations, breaking down more complex process into separate (linked) demonstrations	Planning	2
9	The teacher models/explains the whole process in one demonstration	Planning	-6
10	The teacher adapts their approach and style of demonstration to the learners, dependent on age, ability, prior experience, etc.	Planning	1
11	The teacher gives clear verbal explanations of processes and procedures	Explanation	5
12	The teacher provides a running commentary through the demonstration	Explanation	0
13	The teacher gives clear models/examples processes and procedures	Explanation	2
14	The teacher makes reference to relationships with other related concepts (e.g. mathematical, scientific, technological, etc.)	Explanation	-1
15	The teacher make reference to cause and effect of decisions and/or actions	Explanation	-2
16	The teacher uses examples, analogies and/or similes to explain processes and procedures	Explanation	-2
17	The teacher identifies the main points/steps for the learners	Explanation	4
18	The teacher 'signposts' or indicates the next steps (i.e. "later in the lesson…" or "in next lesson…")	Explanation	0
19	The teacher models diagnostic processes, such as using testing equipment to fault-find or the application of scientific knowledge from an observation	Explanation	-2
20	The teacher uses ICT to simulate or model process or products	Explanation	-5
21	The teacher addresses learners misconceptions as they arise	Explanation	0
22	As part of the planned demonstration, the teacher addresses common misconceptions around technical terms, concepts, etc.	Explanation	-1
23	The teacher uses questioning to probe learners' prior knowledge from within the unit/project	Questioning	2
24	The teacher questioning to probe learners' prior knowledge from previous D&T units/projects	Questioning	-1
25	The teacher questioning to probe learners' prior knowledge from other subjects	Questioning	-2
26	The teacher uses questioning to enable learners to recall aspects of the process demonstrated	Questioning	-2
27	The teacher uses questioning to probe understanding of concepts, process and procedures	Questioning	1
28	The teacher uses questioning to encourage learners to speculate (e.g. predicting the next step in a process)	Questioning	-3
29	The teacher uses visual resources, such as images, photographs and diagrams, to enhance their demonstrations	Resources	-4
30	The teacher prepares and uses examples of the products/outcomes being demonstrated	Resources	0

No.	Item	Category	Array
31	The teacher prepares examples showing the steps/stages of the process being demonstrated	Resources	-1
32	The teacher prepares the demonstration station/area in advance (e.g. before the lesson)	Resources	4
33	The teacher uses resources, such as instruction sheets, slideshows or videos, after the demonstration to support learners	Resources	-3
34	The teacher uses other support staff (i.e. technician or teaching assistant) during, and after, the demonstration to support learners	Resources	-4
35	The teacher identifies hazards and risks for the learners	Health and Safety	1
36	The teacher prompts learners to identify hazards and risks for themselves	Health and Safety	2
37	The teacher is competent to use equipment safely	Health and Safety	6
38	Appropriate information about risk is readily available to learners	Health and Safety	5
39	The teacher sets high standards and expectations for the learners in designing and making activities	Challenge	4
40	The teacher identifies alternative actions or choices learners can or need to do (e.g. design, make, evaluate)	Challenge	-6
41	The teacher enables learners to identify alternative actions or choices that they can make (e.g. design, make, evaluate, etc.)	Challenge	-3
42	The teacher plans and uses extension or enrichment activities for able learners	Challenge	-4
43	The teacher encourages/supports learners to demonstrate skills and knowledge to their peers	Challenge	-1
44	The teacher encourages learners to participate in fault finding and quality control	Challenge	-2
45	The teacher ensures that they make eye contact with members of the whole group	Engagement	0
46	The teacher scans and monitors the group, as they are teaching, to ensure that the learners are engaged	Engagement	2
47	The teacher scans and monitors the group to ensure that learners are safe	Engagement	4
48	The teacher has 'presence' within the classroom	Engagement	-1
49	The teacher can modify their tone when talking to/with different sized groups and in different situations	Engagement	-3
50	The teacher encourages learners to 'think-out-loud' to consolidate knowledge and understanding	Engagement	-5
51	The teacher explains the function and/or context of the matter (i.e. knowledge and/or skill) being demonstrated	Engagement	-5
52	The teacher encourages learners to reflect on values (e.g. the impact of a technology on society, the environment, etc.)	Engagement	-3
53	The teacher scans the room after the demonstration to monitor learners' progress	Learning	3
54	The teacher waits for learners to attempt a task before intervening	Learning	0
55	The teacher encourages learners to support each other before seeking the assistance of the teacher	Learning	-1
56	After the demonstration, the teacher moves around the room to support learners	Learning	1
57	The teacher shows/explains the process/skill to individuals who have misunderstood processes or concepts shortly after a demonstration	Learning	-4
58	The teacher uses questioning to ascertain what a learner understands, when they have not fully understood the demonstration	Assessment	0
59	The teacher explains what learners are expected to do to make progress	Assessment	3
60	The teacher makes his/her expectations of the learners' outcomes clear	Assessment	2
61	The teacher provides examples of outcomes of a process that exemplify the skills being modelled	Assessment	0
62	The teacher ensures that all learners know what they need to do to make progress	Assessment	1

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It takes a village: the value of partnership working in design & technology teacher education

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Abstract

This paper discusses the rationale for one Teacher Education Institute engaging with a variety of partners when working with Design and Technology student teachers. Scottish education policy guidelines promote the benefits of partnership working and interdisciplinary learning and yet there appears to be little empirical evidence to suggest that policy is based on research. It seems it is a 'good idea' and has advantages for all those involved. This paper does not purport to address this lack of research evidence. It does, however, intend to examine the perceived worth of partnership initiatives undertaken in the context of Design and Technology teacher education at the University of Edinburgh. The approach to the review adopts a phenomenological approach and examines the perceived value of partnership through the critical lens of current and past Design and Technology student teachers, the partnership agencies, and the university staff who evaluated the projects and discussed the issues encountered.

Keywords

Partnership working, interdisciplinary learning, teacher education, design & technology, student teachers.

Design & technology teacher education in Scotland

Donaldson (2011) suggests that the purpose of Initial Teacher Education is to provide a strong foundation for personal and professional development from which a beginning teacher can embark on their new profession with the intellectual confidence and capabilities to plan, teach and create valuable learning experiences for the youngsters in their care. In Scotland, this then is the key aim for the 36 week full-time Professional Graduate Diploma in Education, PGDE. Cohorts of PGDE Design and Technology (D&T) comprise professional graduates from design, engineering, architecture, and construction related degrees with industrial experience. To qualify for provisional registration with the General Teaching Council of Scotland (GTCS, 2012), students are required to fulfil professional studies involving research, curriculum and pedagogy, and school placements where students evidence professional practice, reflection and research. Central to this process are the partnerships between the universities, whose programmes are accredited by the General Teaching Council of Scotland, and the schools who support the development of the student and probationary teachers.

A successful probationary year in school, in addition to a PGDE, satisfies the 'Standards for full registration' (GTCS, 2012). These explicitly require teachers to consider interdisciplinary learning and work with the community beyond their educational establishment. They emphasise the importance of relevance, authenticity and social justice by requiring teachers to demonstrate a commitment to engaging learners in real world issues to enhance learning experiences and outcomes. Student teachers are required to "demonstrate an awareness of connections with other curricular areas.. ." (GTCS, p.6), and "know how to develop realistic and coherent interdisciplinary contexts for learning, particularly in relation to sustainability" (*ibid*. p.7). For full registration teachers must "know how to identify and highlight connections with other curricular areas…, promoting learning beyond subject boundaries" (*ibid*. p.6), "know how to work collaboratively with colleagues to facilitate interdisciplinary learning"' and "know how to work with the local and global community to develop realistic and coherent interdisciplinary contexts for learning, particularly in relation to sustainability" (*ibid* p.7).

The 'standards' also ask teachers to work collegiately with educational communities with adaptability and constructive criticality. Students are required to analyse the education context, construct, policy and curriculum, and yet they are also expected to work within the system to develop the professional and personal skills, knowledge and understanding to allow them to plan, teach and offer worthwhile and meaningful learning experiences. The students are introduced to policy documents, e.g. Building the Curriculum series 1-5 (Scottish Executive 2006, 2007; Scottish Government, 2008, 2009, 2010) which outline the principles that underpin the framework for curriculum development for 3-18 year olds, entitled Curriculum for Excellence (CfE).

It is in this context, this paper presents a study relating to partnership working and interdisciplinary learning.

Partnership and interdisciplinary learning

One of the most penetrating (and most evaluated, e.g. Brownlow et al, 2004; Deuchar, 2004; Paterson, 2009) education initiatives regarding partnerships is 'Determined to Succeed'. This urged educationalists to form wide-ranging partnerships with the business sector in order to raise awareness of the opportunities offered by education-business partnerships in terms of enterprise activities, staff training and opportunities for an exchange of information and expertise between the education and business sectors, public sector services and voluntary organisations (Scottish Executive, 2002; LTS, 2005; Scottish Executive, 2007). Smith and Brownlow (2005) identified several mutually beneficial reasons for engaging in education-business partnerships. These include making learning purposeful and relevant, sharing responsibility for learning with other adults and offering challenges which encourage the focus to be on young people sharing responsibility for their learning and looking outwards to the 'real' world for solutions and guidance. The value of such authenticity in Design and Technology has been argued over the years e.g. Hill & Smith (1998), Hennessey and Murphy (1999), Turnbull, (2002); Snape and Fox-Turnbull (2013).

The benefits of education-business partnership for outside agencies include gaining insight into the knowledge, skills and attitudes of children, young people and teachers, and keeping up to date with educational developments. It is also considered useful in terms of raising awareness of the role of their organisation. However, Smith and Brownlow (2005) caution, in order to ensure maximum impact from any partnership, schools need to consider specific curricular needs, and enable learners themselves to recognise the relevance of the skills and knowledge they develop to their present and future lives.

The current framework for education in Scotland, Curriculum for Excellence, aims to provide space for imaginative teaching that makes learning relevant, lively and motivating. Building the Curriculum 3 (Scottish Government, 2008, p.29) claims that the guidelines for 'learning outcomes and experiences' have 'been written in ways which will help staff to adopt engaging, enterprising and active learning approaches in a variety of contexts to promote effective learning and enable personalisation and choice'. Interdisciplinary learning (IDL) and partnership working are also promoted as good practice in achieving teaching and learning that follows these principles (Scottish Government, 2008, p.24). Donaldson (2011, p.47) argues that 'In order to implement Curriculum for Excellence successfully, schools and individual teachers need to work with partners when designing learning experiences.' IDL promotes higher-order thinking skills such as creativity, critical and systems thinking, synthesis, evaluation and analysis and that it benefits from co-operative, inquiry-based, and contextual learning (Harvie, 2012). However, Graham (2014) acknowledges, the success of IDL is strongly dependent on the skills of the teacher and their understanding of the *nature* of IDL, expertise in curriculum design, breadth and depth of subject knowledge and a number of practical logistics. Graham argues,

> "Teachers need the time to think, plan and develop IDL. By tackling these challenges through the creation of strong, interconnected support systems and the establishment of creative partnerships, a roadmap can be created to enable Scotland to be a world leader in interdisciplinary learning.' (Graham, 2014, p. 4)

Albeit a brief review, there is consensus in sentiment that partnership working and IDL can make a positive contribution.

Partnership and idl in design & technology teacher education

'Real world' D&T contexts very rarely present one distinct and exclusive learning focus, therefore the premise adopted for any partnership project for D&T teacher education is that of authentic interdisciplinary learning. Although several other partnerships encourage the students to look sideways and work collaboratively, the main focus for this paper is the *Natural Partners Project: Learning for Sustainability* which involves student teachers of Physics, Chemistry, Biology, D&T, and Geography in a joint partnership with four agencies: Forest Research, Forestry Commission Scotland, Forestry Engineering Group, and the Ellen McArthur Foundation. The project begins with STEM students, participating in a forest-based fieldtrip. Individually, the students devise units of work which serve to enhance understanding of topics of their choice, related directly to, or stimulated by, the partnership inputs during the fieldtrip.

The next section explores the nature and value of this partnership to the D&T students, and other participant stakeholders. It examines the reasons the partner agencies provide their time and expertise, input and effort. The student response is reviewed in the short and longer term, as is that of university colleagues.

Method of the study

A phenomenological approach (Cohen et al, 2000; Smith et al 2009) was adopted. The study examined perceptions of partnership experiences and projects. The participants recorded their personal interpretation of what they gained out of their direct interaction with the 'phenomena' through descriptive and reflective responses to the 'lived experience' in various ways, including their learning journals entries (students), through evaluation surveys (students and stakeholders), and interviews (university tutors). In the longer term, student interpretation and response is also evident in their selection of the contexts for their own planning, including choice of content and pedagogical approaches for their own teaching, and their willingness to continue with collaboration, IDL and partnership projects on entry to the profession.

Findings

Responses to date have been gathered from 91 student participants, 5 external partners, and 4 university tutors over the past 3 years. The illustrations which follow provide a sample of response from firstly, students, secondly agency partners, and lastly university tutors.

The response has been positive by the majority of students from all disciplines involved. This is reflected in evaluations, reflective journals and project outcomes. Two major themes emerged from the student response.

They are particularly positive about the novelty and value of working with a graduate from a different discipline and noticing how differently their peers reacted and what they brought to the same 'phenomena'.

> ' As well as enjoying the interdisciplinary part of the day (It was really enjoyable and eye opening to see what the Biologists gleaned from a task, and sharing that with me, which lead me to think about it in a different way - Particularly with regards to the "Carbon Products" workshop.)
>
> 'I found the trip to Glentress a thoroughly enjoyable experience. Our group was made up of Chemists, Biologists and Design and technologists. It was really interesting to see what tasks were preferred by each discipline (there were differences).'
>
> 'I enjoyed getting to know the other subject teachers and getting to hear their opinions and views on things. …….It also made me think back to my own education and I began to wonder why our Biology and Geography teachers never worked together.'
>
> 'I got a lot out of the cross-disciplinary discussions at the end of each session. This time was a great way to go through some of the points that were made in the workshops and I enjoyed getting opinions and insight from students of other teaching disciplines.'
>
> '…One chemistry PGDE taught me a lot about the extraction process for plastics, I had not much previous knowledge on. This gave me insight into an untapped resource for beginning and idea generating'

"Working with others from different backgrounds is very enlightening, hearing multiple points of view on a single issue or area has raised awareness in myself and in the other Design Technology Students that although we might consider ourselves quite adept at "thinking outside the box", someone from a different subject area can look at the same thing through a completely different spectrum."

Comments from a physics student (2014-15 cohort) indicates a less positive response, *'I enjoyed the practical session, in which actual classroom experiments and activities were demonstrated, as a good resource to take forward into our classrooms to use when teaching about wood. This was the only aspect which I found had direct relevance to physics, in calculating the moments of inertia, etc. I didn't enjoy the other sessions, I found they were not particularly relevant, and struggled to glean useful content'*. This student, with further input and support on campus, presented subsequent difficulties in developing an IDL and sustainability related project. He declares his interests lie with Physics alone.

The second theme is the inspirational nature of the context.

"Being inspired about how interdisciplinary connections can be made and gaining some new knowledge about the 'clients' and their work that I hadn't previously known."

"I enjoyed the interdisciplinary and outdoor learning. They have given me great ideas for teaching and highlighted the importance and advantages of such learning."

"Seeing how different subjects can be taught at the same time though a topic such as sustainable development.'

"I watched Ken Robertson's TED talk: "How Schools Kill Creativity" which linked in with the idea that cross-disciplinary thinking can be used to enhance learning and to promote creativity. His point that "Creativity, the process of having original ideas that have value, more often than not comes about through the interaction of different disciplinary ways of seeing things." I found particularly interesting and strengthened the importance of the work we had started at Glentress (forest) to develop cross-disciplinary learning for the STEM subjects."

The conceit of the *Natural Partners Project* is curriculum development, not only for the student teachers, but also for the partner agencies who aim to enhance their own portfolio of outreach activities which focus on wood, forestry, STEM and Education for Sustainability. The student teachers demonstrate their appreciation of how STEM and sustainability can feature so naturally in an IDL partnership model through the wide range of creative curriculum development ideas which are presented as work in progress for critique and feed-forward from peers, partners, tutors and other stakeholders, trialled in school and developed further.

The partners report that they take the time, energy and effort to develop working partnerships with teacher educators and student teachers primarily to work 'smarter', trial new ways of working with schools, and explore ways of engaging young people in STEM subjects. In addition, Steve Penny, Forest Research, the Natural Partners Project instigator noted,

" […] we wanted to target new teachers about to head into High Schools. In this way the project could have a far greater impact on young people and start to (hopefully) change other areas within the school. Within a very few years we could probably have a teacher who had been through this project in almost all High Schools in Scotland. This was far more effective that trying to engage directly with pupils ourselves which would be far too resource intensive and not possible. This approach has been applauded by many observers …from public to government."

Sally York , Education Policy Advisor at Forestry Commission Scotland, was keen to "'open up links with the STEM subject staff at Moray House; To find out what they need / are doing to deliver Learning for Sustainability /outdoor learning; To have face to face contact with new teachers"

Colin Webster, Education Programme Manager, Ellen MacArthur Foundation, acknowledged the reason for partnership in this particular project was '

"Partly to support an on-going relationship between EMF and the Natural Partners project leader and partly because of the proposal behind the project – that it is the interdisciplinary, STEM-related conceit and is a relevant platform for the circular economy.' He continued 'Interdisciplinary learning is key to understanding the circular economy and it is key to CfE, so a project like this which expects an IDL approach from the outset – at the start of a teacher's career and at the start of their Moray House experience – is invaluable."

Steve Penny also reported that the Forestry Engineering Group members, who provide funding for the project,

> "have been extremely pleased with the outcomes from the project and are convinced that this project has had more benefit to young people than any other that they have tried to move forward over a good number of years.' They intend to continue to support the project. From a Forest Research point of view, Steve suggests, 'it is difficult to quantify immediate benefit on the ultimate number of students choosing science topics and who will become the scientists of the future. However, for a modest investment in time and energy, this project has allowed us to network into a new area and to be associated with the school curriculum in Scotland. This has had benefits when we work with other research providers in Scotland and the Scottish Government. It has helped to strengthen our relationships with key partners on other topics of mutual interest."

Tutors also voice positive responses. They agree that as a result of the partnership project, students have a significantly greater awareness of the agencies, their role and the potential of working with experts and partners in learning. The Chemistry tutor acknowledged that he should have been paying more attention to partnership and IDL, as evidence supports their effectiveness in driving meaningful learning (cf. Chettiparamb, 2007). Natural Partners offered an opportunity to get into interdisciplinary learning, in the sciences and beyond, in a meaningful way, particularly when, he said, "someone else was willing to do the work". The Biology tutor acknowledged the advantage of connections with outside agencies at this early stage of the PGDE. She was hopeful that all scientists would bring with them prior interdisciplinary experience, but saw "great value of taking students outside their little sphere". She was keen to involve her students as "too often the role biology offers to Learning for Sustainability and STEM often gets lost in technology and engineering". The D&T tutor is keen to exploit the contribution D&T makes to the STEM agenda. Working in partnership, there are opportunities to embark on project-based learning and place based-based learning curriculum developments, where contexts could be explored and developed with a high degree of personalisation and choice– with authentic clients requiring outcomes, and a sense of urgency. Urgency, in the Natural Partners Project, is instilled through the immediacy of the fieldtrip partnership, a directly related partnership outreach event (open to the public), and a showcase of tangible products for the education community.

Conclusion

This paper has argued the importance of engaging student teachers in interdisciplinary learning and partnership working while on their PGDE programme. The experience enables the students to evidence the necessary 'Standards for Registration'. It also demonstrates what beginning teachers offer in terms of curriculum development, with several reporting that they have implemented their *Natural Partners* project during their probationary year. There has also been positive feedback from partnership related discussions during job interviews by those who have secured positions and have subsequently develop partnership projects in school.

Partnership is considered beneficial by stakeholders, particularly when developed through an interdisciplinary learning approach. Students in their early phase of teaching, external agency partners and university teachers recognise the potential it offers, including

- enriching the curriculum and learning experience;
- raising awareness of the range of authentic contexts;
- supporting beginning teachers and university staff beyond their expertise;
- modelling practice which beginning teachers can develop with their own learners, and external partners, when they are school practitioners;
- contributing 'bank' of IDL projects for schools to adopt and adapt;
- sharing responsibilities, activities and purposes of business, charities and 3rd sector

'It takes a village', in the title of this paper, encapsulates the concept of partnership in education well. It draws on the saying believed to have originated from the Nigerian Igbo culture, but is in common usage throughout Scotland. It conveys the importance of collective responsibility and enhancement of the lived experience when the community offers their experience, wisdom, creativity and values in the support and development of others. Regardless of policy frameworks that aim to influence Scottish education, the wealth of expertise and goodwill that is available is something not to be overlooked in teacher education. The results indicate authentic learning experiences are created and these serve to influence school practice.

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Manahi's red chocolate sunglasses: the impact of a learning experience outside the classroom on a five-year-old student's technological practice

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Abstract

Knowledge of expert practice is a key element of Technology Education, and this paper which is part of a larger study, investigates the impact a learning experience outside the classroom has on one student's technological practice. This student, who is in his first year at school, visits a chocolate factory with his class to find out how to make a chocolate gift for Mothers' Day.

This study uses a qualitative case study methodology (Stake, 2006). Data were collected and analysed from three interviews, before, after, and six months after the visit to the factory. The student's drawings and stories recorded after the visit were also analysed using themes emerging from the literature of Education Outside the Classroom (Anderson, 2003; Falk, 2004), Technology Education (Compton, 2009; de Vries, 2012; Jones, Buntting, & de Vries, 2013) and the characteristics of young students' learning (Cohen, 2013; Siegler & Alibali, 2005).

The findings from this study identify a significant increase in the student's context specific oral language, his understanding of the individual phases of technological development, and an ability to transfer these understandings to other contexts including those presented six months after the visit. Whilst these developments showed an encouraging improvement in Manahi's technological understandings, there existed a lack of continuity and connectedness (Moreland & Cowie, 2011) through the development of his chocolate gift. This impacted negatively on his perceptions of the purpose of the visit and the final goal of his practice.

Keywords

Technology education, primary, technological practice, education outside the classroom, connectivity

Introduction

The New Zealand national curriculum comprises eight learning areas, one of which is Technology education. This curriculum aims to develop a broad technological literacy through students participating in learning programmes in which they engage in technological practice, and in so doing develop technological knowledge to inform their practice, and gain an understanding of technology as a domain in its own right. Experiencing and exploring contemporary examples of technological practice is recognised as an effective way of developing technological literacy and in this study, students visit a chocolate factory (Candyland) to find out how to make a chocolate gift for Mothers' Day. The broader study, from which this paper is drawn, describes the development of an intervention model which aims to provide guidance for teachers of very young students when planning a technology unit that includes a visit outside the classroom. The intervention model is divided into three chronological phases, preparation before the visit, organisation during the visit and follow-up after the visit.

Themes	*Domain*
Understanding that the gift is for the students' mother Number of identified steps in a technological process Knowledge of materials and their properties The purpose of modelling	*Technology Education*
The purpose of the visit to Candyland	*EOTC*
The use of context specific language Ability to extend learning to new contexts	*Characteristics of 5-year-olds*

Figure 1. Themes for data analysis relevant to this paper

This paper describes the experience of Manahi, a five-year-old student of Maori (indigenous New Zealander) descent, as he progresses through the three phases of the technology project. Manahi is one of 16 students participating in the broader research project and the findings noted that whilst he embarked on this project with a good level of oral language, and a range of prior experiences which supported his engagement with the project, there was a lack of continuity and connectivity (Moreland & Cowie, 2011) between the stages of the product development. This prevented him from fully understanding the purpose of the visit, the links between the phases of the project and realising the final goal of the project.

Key ideas which inform the research

A review of the literature which informs this paper is drawn from three fields of study, Education Outside the Classroom (EOTC), Technology Education, and Child Development specifically the characteristics of 5-year-olds. As outlined in the early work of Falk and Balling (2001) the most valuable and memorable learning experiences outside the classroom are 'novel' experiences – those which are new, high interest experiences. Anderson (2003) argues that this type of memory is "overwhelmingly dominated and mediated by the socio-cultural identity of the individual at the time of the visit" (p. 405) and the lens through which the experience is viewed, strongly influences what is noticed and what is remembered. Building on these ideas, Falk and Adelman (2003) conclude that, closely aligned with student interest in a visit, is their enjoyment the experience. Anderson, Thomas and Ellenbogen (2003) agree but caution that these memories will be influenced by the age of the students, what is important to them and the emotional engagement they experienced at the time.

Research in the field of EOTC suggests that prior knowledge of exhibits at a site and a clear purpose for the visit, helps give focus to the experience and enables a student to engage more readily with the displays that s(he) encounters. Lambert and Balderstone (2000) argue for teachers creating a 'need to know' factor amongst students prior to going on a visit – effectively arming them with an authentic research purpose to be accomplished during the visit. However it is well known that these 'big ideas' can easily be lost on young students in-amongst the busyness of a junior classroom (Benson & Raat, 1995; Moreland & Cowie, 2011). Moreland and Cowie (2011) explore the challenge of maintaining a sense of continuity and connectedness throughout an entire project. Five-year-old students are known to view each phase of a technology project as an end-point in its own right, and do not always grasp the concept that each phase, each activity is but one step in a more extensive process.

The links between the final outcome, the visit, and the research tasks carried out prior to constructing the final outcome, are likely to be strengthened if the supporting adults draw students' attention to the connections between one technological activity and the next, for example, the student's survey and design drawing are intended to inform their final outcome. In this way the links between each phase of the process are maintained.

Method

The research from which this paper is drawn employed a qualitative case study methodology which included interviews with two classes of five-year-old students before their visit to the chocolate factory, after the visit, and again six months after. The students' drawings, stories and models were also analysed according to themes drawn from the literature and from the data. This paper investigates the impact of the learning experience outside the classroom on Manahi's technological practice. In particular evidence which suggests the visit to Candyland influenced his conceptual and procedural understandings of making chocolates, his design decisions, and whether he made a connection between the visit and his technological practice. Data analysis also considered whether there was any significant development in his understanding and use of context specific vocabulary.

Figure 2. The pre-visit activities

Manahi's visit to Candyland was a 'novel' experience. Data gathered prior to the visit indicated that this was the first time he had visited the factory, he was very excited at the prospect of going to the factory and was clearly interested in the context of chocolate-making. However, as a five-year-old boy, what he would be interested in and what he would notice during the visit would impact on the learning that took place.

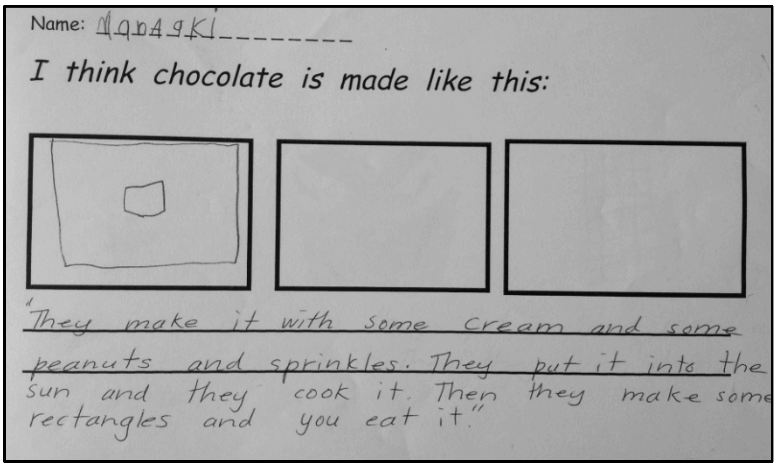

Figure 3. Manahi's prior knowledge of making chocolates

Figure 2 shows some of the activities which were planned as part of the intervention model, and which were intended to prepare students for their visit to Candyland. A key feature was to introduce students to the issue of their technology project. Mothers' Day was approaching and the students were asked what they could do to help celebrate this.

The teachers steered their students in the direction of creating a chocolate gift, and Candyland was identified as a place to visit to find how the students could make their chocolates.

The first document which was analysed was Manahi's drawing and scribed story. This is shown in Figure 3 and detailed his existing knowledge of how chocolates are made. He explained, "They make it with some cream and some peanuts and sprinkles. They put it into the sun and they cook it. Then they make some rectangles and you eat it".

A brief analysis suggests that Manahi had a small number of conceptual and procedural understandings associated with making chocolates. His description indicates that he had had previous experience with baking, and knew that some chocolate products contain peanuts and sprinkles. He was familiar with the use of cream and had possibly seen it used when making other food-stuffs. He associated the sun with melting chocolate and he also appeared to associate heating and cooking ingredients with baking. His reference to rectangles may indicate something of his previous experiences and how he conceptualises chocolate.

The first interview before the visit offered some key information. Manahi and the students from his class were generally unclear about the purpose of their visit to Candyland and appeared to have made no connection between the task of finding out how to make their chocolate gift and physically making it. An important link between these early stages of the project had unfortunately been overlooked.

Figure 4. Student activities during the factory visit

The visit to the factory progressed smoothly and Manahi and his classmates explored the facility viewing the ingredients and equipment required to make chocolates, and the extensive array of shapes and colours of chocolate products which were on display. They gained further information about the process used in the factory to create chocolate products and this concluded with an opportunity for the students to make a small chocolate fish to take home. See figure 4.

A final part of the factory tour was to participate in a presentation in which the factory presenter showed them how to make a lollipop on a stick. This was very popular with the students but proved to be a distraction. Manahi's first memory on his return to school was that of the lollipop presentation. He drew a picture (see Figure 5) and he wrote:

I went to Candyland. I got to make a lollipop. The man put some candy mixture into a machine to roll it out. He put some stripes on it. I twisted my piece and turned it around and put a stick in it. Then I put it in a bag to take home.

The research of Bruck and Ceci (1999) and latterly Cohen (2013) highlight the relative ease with which young children's memories can be altered. They tend to be susceptible to leading questions, suggestions and possibly by what they think a listener wants to hear. From this we can deduce that whilst children's memory can be manipulated by outside influences, the strategies used in these situations can be advantageous when applied to enhancing memory recall in the classroom.

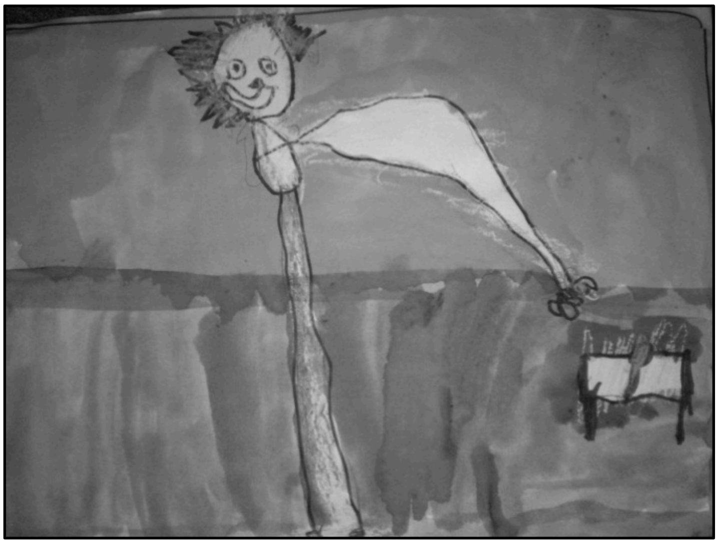

Figure 5. Manahi's drawing showing how he made a lollipop

As part of the intervention plan, and to enhance students' recall of their visit, Manahi and his classmates were to draw a picture and write a story on their return to school. Whilst this was intended to focus on the chocolate-making presentation, the students in Manahi's class were given an open task in which they could draw "something they remembered from the visit". Seven of the eight students, including Manahi, wrote about the lollipops and this again shifted their focus from the intent of the experience – the chocolate-making. This became a lost opportunity to consolidate their new knowledge and to maintain the continuity of their focus through the unit.

The next phase of the technology unit stepped the students through a review and consolidation of the learning achieved during the visit to Candyland, a simple research component in which they presented a survey to their mothers to find out the type of chocolate that she preferred, and followed by the creation of models and drawings showing the chocolate they would make as their Mothers' Day gift.

Manahi duly took his survey home and reported in his second interview that his mum liked milk chocolate and brown chocolate but did not like dark chocolate. (I interpreted her preferred chocolate as being milk chocolate and white chocolate.) Manahi also reported that she liked having peanut and caramel filling in her chocolate.

Manahi's drawing and story describing how he was going to make his chocolate gift showed that he had developed slightly more sophisticated context-specific language and a limited but accurate description of the steps he needed to take in order to create the gift. He explained to his teacher that he would need to, "Put the melting chocolate into a mould and put it into a big machine and then wrap it up". This reflected the process he had observed at Candyland, with "the big machine" being a cooling tunnel into which all the students' chocolate fish were loaded for hardening. Manahi's drawing, however, showed a significant broadening of his ideas and an awareness of the possibilities for colour and shape in his design. Manahi had drawn a picture of a pair of red chocolate sunglasses shown in Figure 6.

The making day followed directly afterwards, and a group of parent-helpers were organised to assist the students to make their chosen design. Although the parents had received information about the visit and had given their consent for their child to participate, they had had not taken part in the visit. It appeared that the intent of the visit, the students' research task, and how these were to connect with the making of the chocolate gifts were not well understood by these parents, and two of the parents unexpectedly made a change to the students' task. The teacher of Manahi's class said, "I think a couple of mothers have said, "Right you're making one for mum and you can make one for yourself". *Figure 6* Manahi's red chocolate sunglasses

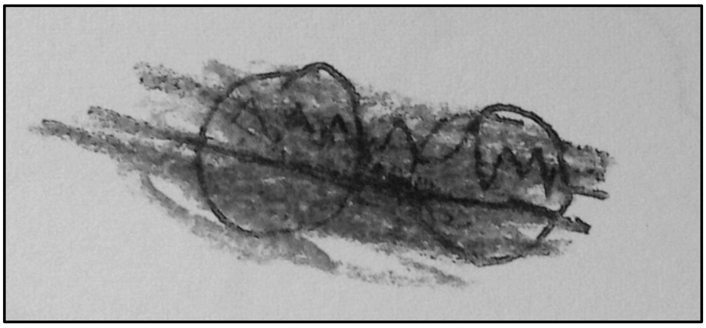

Figure 6. Manahi's red chocolate sunglasses

This created another diversion which prevented the students' from experiencing and understanding the links and connections between the individual phases of their technological practice. Whilst the change was very appealing for the students it shifted their attention away from the original focus of creating the gift for 'mum'.

It was also noted that in-amongst the enjoyment of making the chocolates both the parent-helpers and the students failed to take into account the survey information they had collected and the designs they had chosen. Whilst changing design ideas is to be encouraged in technology, this oversight appeared to impact significantly on Manahi. During his second interview he admitted that after he had made his chocolates he had eaten them.

R	**Did you eat it at school?**
M	Yes.
R	**Did you? Did you take yours home to Mum?**
M	No.
R	**No? Did you eat yours at school?**
M	Yes. I had both, I eated both of them.
R	**Did you?**
M	Yes 'cause I was tricking my mum.

Concluding remarks

The full data set acquired through interviews with Manahi and the analysis of his drawings and stories indicate that over the course of the technology unit he had gained topic-specific language, knowledge of ingredients, machinery and the equipment required when producing chocolate products. He had gained knowledge of the technological process and the steps required to create a product and his drawing of the red chocolate sunglasses for his Mothers' Day gift suggested that he had benefitted from his visit to the factory and had been inspired by the colours and shapes of chocolates that he had seen there. He had not, however, understood the purpose of going to Candyland and was unable to describe any questions he needed to ask during the visit. Whilst he acknowledged that he had learnt "to make the chocolate" during the visit, there was no sense that he connected this with his own practice of making chocolates for Mothers' Day. The diversion created by the parents when the students made their chocolates was sufficient for him to lose sight of the intended final outcome, resulting in an after school feast for a small boy rather than the giving of a chocolate gift on Mother's Day.

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Design teaching and representations of the designer profession: how students' representations can impact their learning activity

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Abstract

Industrial design is a professional practice. The curricula of French Design courses are generally based on a "référentiel de compétences" (a kind of "inventory" of skills and competences) that can be considered as a "representation" (Durkheim, 1898), image or perception of the designer's job.
The study presented in this paper aims to identify and characterise the representations, that product design students develop of their future profession. It aims to show how these representations impact their design activity and the acquisition of knowledge or skills.
This study involved the analysis of a case study of an exercise: a "hybrid situation" (pedagogical/operational) where students having completed two years of design training were asked to respond to a real industrial design brief, whilst under supervision of their teachers (Moineau & Martin, 2012). The students' feedback about the outcomes (notes, drawings, etc.) at the end of the exercise were then semiotically and psychologically analysed (Lebahar, 2007; Tortochot, 2013) and used as a basis for semi-structured interviews conducted with six of the students.
This exercise gave the students an opportunity to enhance and verbalise their own representations of their future professional activity. Their statements also show that they developed strategies in order to acquire skills linked with these representations. This study highlights the importance of considering the relationship between the representations, the development of relevant pedagogic situations and how these impact on students' motivation and efficacy.

Keywords

Design training situation, occupational representation, analysis of design activity, industrial design, vocational pedagogics

Introduction and context

This paper follows a previous one presented in PATT 2012 in Stockholm and is based on the same data related to design students' response to a brief (Moineau & Martin, 2012). The previous paper highlighted the students' perceptions of the nature of this "hybrid situation" (pedagogical/operational). The present study is based on the assumption that, in this particular context, the students' work and feedback could allow us to identify their representations of their future profession of designer.

The activity of industrial design can be considered through several theoretical approaches: Resolving problems (Newell & Simon, 1972) and more specifically "ill-defined problems" (Rowe, 1987, p. 40) but also "constructing representations" for the management of uncertainty (Lebahar, 2007, p. 66). The concepts of "situation" (Dewey, 1938; Vergnaud, 1991, and of "situated action" (Lave, 1988; Suchman, 1987; as cited in Beguin & Clot, 2004) allow Lebahar to define the design situation as a "complex of interactions". The professional designer, at the centre of this "complex of interactions" (Lebahar, 2007, p. 21), is surrounded by the "elements of [the] operative environment" (Lebahar, 2001, p. 43). Taking these as a basis, we also can try to sketch the outlines of product design pedagogy by grounding it in "the project of vocational pedagogy" (Rogalski, 2004, p. 112). So, it could theoretically be based "at the crossroad of cognitive ergonomics and pedagogy area" (Samurçay & Pastré, 1998, p.

125; Rogalski, 2004, p. 110). The concepts of "pedagogic situation" (Brousseau, 1998), of "pedagogic transposition" (Chevallard, 1985), of "relevant professional reference knowledge" (Rogalski & Samurçay, 1994, p. 67) and of "social practices of reference" (Martinand, 1981, p. 154), show the difficulty to produce a model of a complex activity as product design activity.

As a profession, industrial design can be defined in terms of occupational sociology. For example "A set of activities implementing knowledge and specialised know-how, the values of which transcend the particular contexts of its implementation" (Champy, 2011, p. 148). Applying his theory to the field of architecture, Champy (2011) attempts to define the job of an architect. What allows a professional to be recognised as architect, a process as architecture or design, or constraints and requirements ("normative constraints, epistemo-deontic values or cognitive constraints") as such? The "culture of a profession" can be divided in two categories: one of skills concerning the management of design processes and the use of drawing and another more external, more unstable category of knowledge of materials and the works of the past (ibid). According to Abbott: "professions are exclusive occupational groups applying somewhat abstract knowledge to particular cases" (Abbott, 1988, p.8). Through the concept of occupational culture, Zarka (1988) suggests that the identity of a profession is defined by its name although this name can cover a broad range of activities. But social categorisation should also be considered. Collective identity is generated by the group's confrontation with exterior factors (law, other professions…). The profession can also be defined as "a capital of knowledge and skills" that manifests itself in the use of tools or in a "product" (Zarka, 1988, pp. 247-263).

As a future profession, product design can be considered in term of a representation built by the students. In that field, vocational guidance has been informed by occupational psychology studies of the representations that high school students have of professions. These students describe professions in two ways: occupational activities (teaching, treating, driving…) or "objects" of these activities (children, patients, cars…) (Dumora, 2002, pp. 71-72). Students also think of professions in terms of the relationship between themselves and the processes of circumspection that may lead them to modify or abandon their career aspirations (Gottfredson, 1981). This idea is supported by the "Goal Theory" (Bandura, 1991, p. 80): "by making self satisfaction conditional on matching adopted goals people give direction to their actions and incentivise themselves to reach the goals". These "goals" can be relevant indicators of the representations students have of their future profession.

Methodology

Built on the work of Lebahar (2001, 2007, 2008) this study involved the analysis of the design activity of product design students in two different situations: the department of applied arts of a University (situation A) and the department of product design BTS (Brevet de Technicien Supérieur) of a High school (situation B).

The two groups of students, both with comparable design competences (two years of applied arts training after high school diploma), were asked to respond to a real product design brief from a "client", whilst under supervision of their teachers. This situation is what might be called a live project at an English university. The "client" was present at the presentation (brief, product concept, final product) with the group A, but absent at those of the group B.

Teachers selected the "client" using the following criteria: Their willingness to participate in the students' training and the acceptance of planning constraints stipulated by teachers; The "client's" commitment to remunerate the students in the event of commercialization of a product designed within the exercise; The technical simplicity of the products to be designed as well as their nature as domestic products, familiar to students (i.e. kitchen utensils, laundry utensils or drying racks, small garden tools or flower pots) and lastly, the compliance of these products with the constraints of mass production.

All students were asked to keep an individual logbook throughout the exercise. This logbook (Figures 1 and 2) had to present "the successive states of representations" (Lebahar, 2007, pp. 55-57) of the product, i.e. the design process, in an exhaustive and chronological way, using any notes, references, sketches, drawings, plans, models or CAD produced by the students.

In both situations, the exercise ran over comparable periods of times, in Spring 2010. Students worked for approximately 35 hours at school with their teachers and approximately 35 hours on a self-directed basis.

At the end, the students handed in their "logbooks" which were used as the basis for semi-directive interviews of six volunteers from each group. The students' interviews were then transcribed and segmented in "elementary propositions", (Tortochot, 2013, p. 461; Lebahar, 2007, 2008), which were then "semiotically and psychologically" analysed (*ibid*).

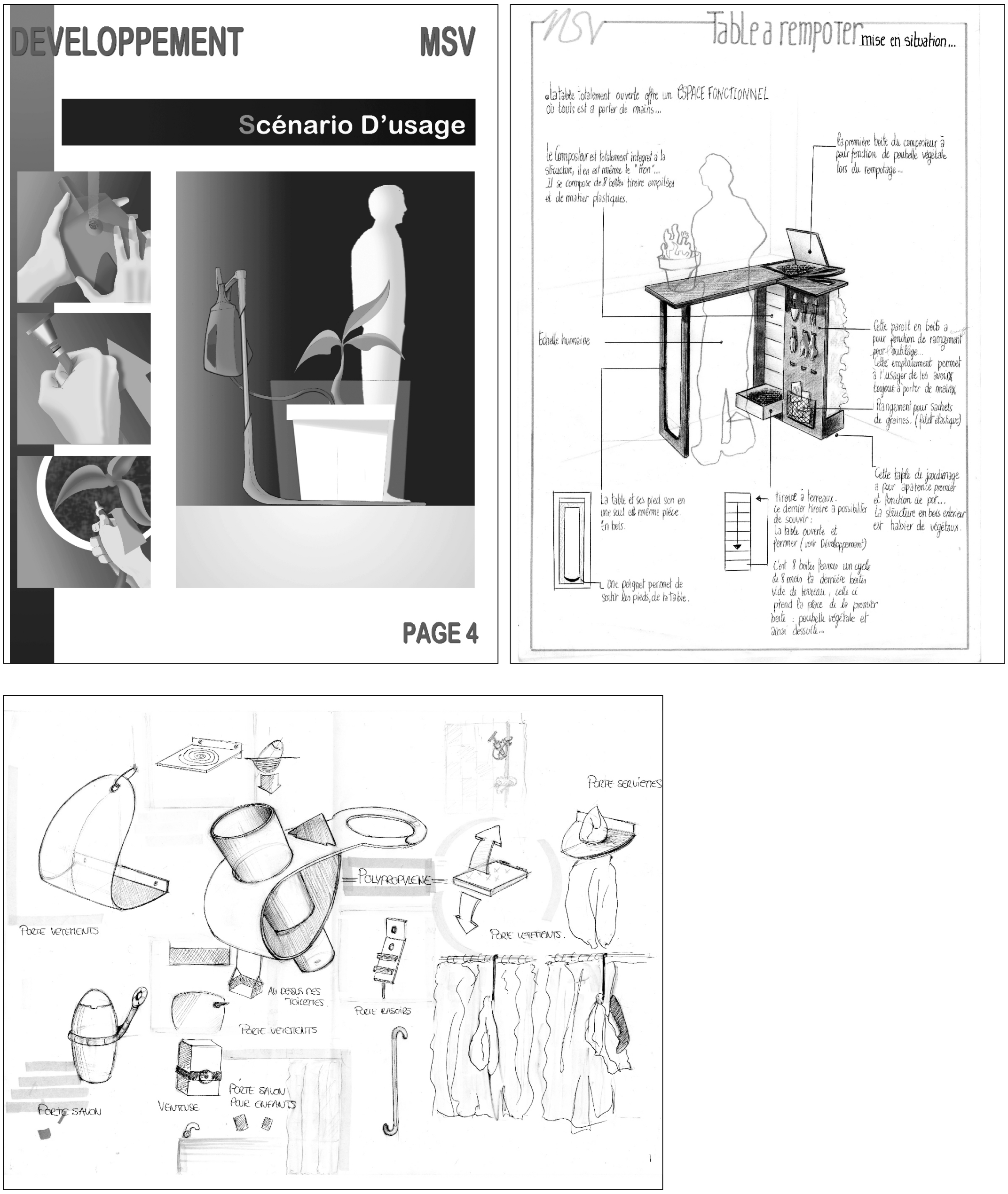

Figure 1. Pages extracted from students' notebooks (Situation B)

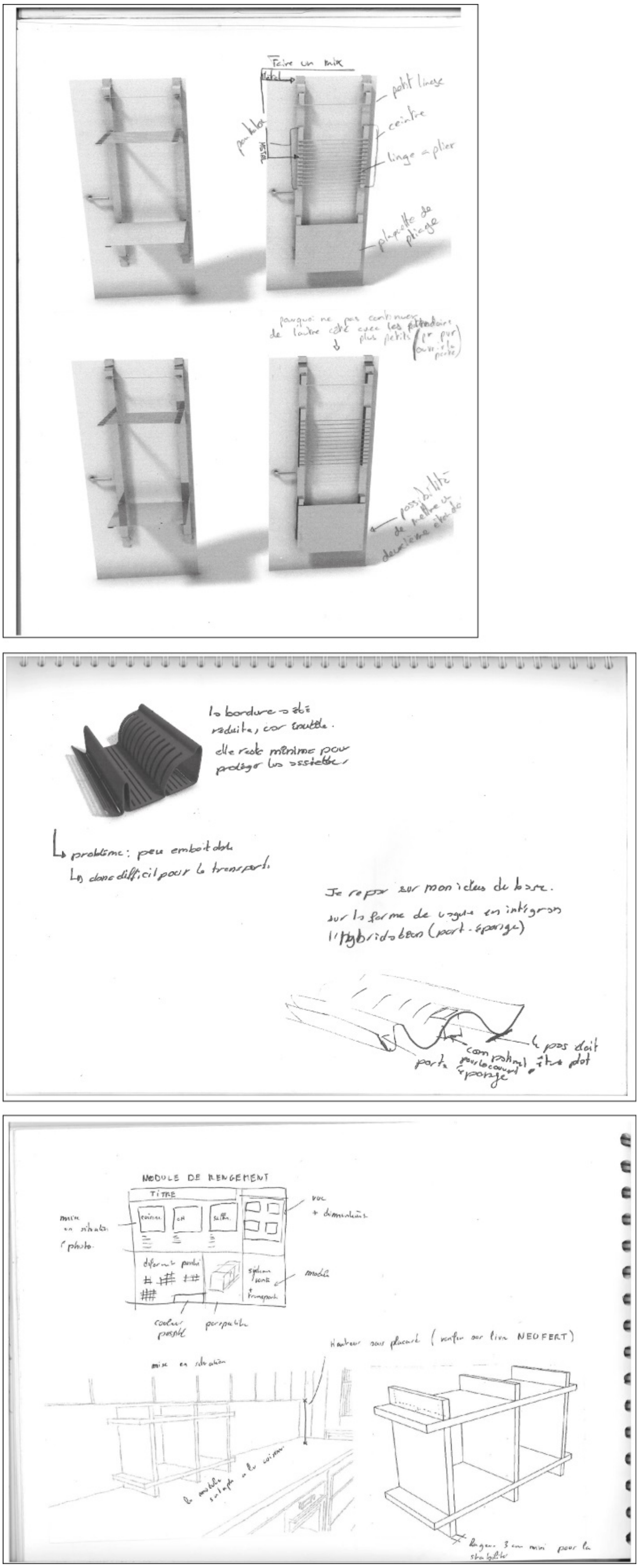

Figure 2. Pages extracted from students' notebooks (Situation A)

Findings

The results of the analysis of the students' statements are presented in table 1, classified into three categories. The first deals with the "components" of the profession: Knowledge, know-how, and values (Champy, 2011). The second deals with the question of the social identity of the profession: Its name, the "persona" of the designer and the relationship with other professions. The third is about the relationship they express between the exercise and their occupational goals. First of all, these results show that while four students do explicitly mention the designer's profession, it is only a very few times during the fifty-minute interview. So while the students frequently say that it was an operational situation ("working for a client", "that works", "achievable", "saleable") they don't say they worked as designers. However, their work and the feedback they give about it demonstrate the goals that define the profession.

Situation		**Situation A**							**Situation B**					
Students		**A1**		**A2**		**A3**			**B1**		**B2**		**B3**	
Stated / Used [1]		S	U	S	U	S	U		S	U	S	U	S	U
Components of the profession														
Skills	Design process	X		X		X			X		X		X	
	Others [2]	D+WS+E		D+WS+E		D+E+EE					WP		D	
Knowledge	Technical		X		X	X	X		X	X		X	X	X
	Design Work			X	X									
	Others [3]													
Values	Usage / Users	X	X	X		X			X	X	X	X	X	
	Sustain. Dev.	X		X		X								
Constraints	Usage / Users	X	X	X		X			X		X		X	
	Aesthetics			X	X							X	X	X
	Technical	X	X	X	X	X	X		X	X	X	X	X	X
	Marketing	X	X	X	X	X	X		X				X	
Tools	Drawing	X	X	X	X	X	X		X	X	X	X	X	X
	CAD (2D & 3D)	X	X	X	X	X	X		X	X	X		X	X
	Model	X		X		X	X		X	X	X		X	
Social identity of the profession		S		S		S			S		S		S	
Name [4]		DP+DA+DV		DP4+DA		DA2			DA		DP		DP3	
"Persona" of designer				X										
Design activity as a process		X				X			X		X		X	
Profession goals [5]		U S N T B I		U S - T B I		U - N T - -			U S - T B I		U - N T B-		U S - T - I	
Other professions [6]						M			A + I		E		E	
Occupational goals confirmed		X		X		X			?				X	

1. Stated: Students mention it. Used: students use this knowledge, skill or respect this value.
2: Other skills, generally stated <u>and</u> used: D = Diagnostic of "client" needs. WS = Work with other design Students. WP= Work with other Profession. E = Exchange with the enterprise. EE = Exchange with Experts.
3: Cultural, sociological, ethnological or philosophical knowledge.
4: DP = Says "designer ", "as designer", "designer's profession" or "design" to talk about the profession. DA = Uses design as Adjective. DV use "Design" as Verb. *Nota:* The number indicates the occurrence, if more than once.
5: U = make something Useful for users. S = make something Saleable, which make company earn money. N = make something New, innovative. B = Make something nice or Beautiful. T = something Technically realistic. I = Give the product or the company an Identity.
6: Professions that the students distinguish clearly from the profession of designer: M = Marketing. E = Engineering. A = Architecture. I = Illustration.

Table 1. Design students' professional representations

Design process

The six students precisely describe their process of design (research of a relevant need, idea generation, etc.) Students mention that this process has been taught before in previous pedagogic situations. Moreover, they specify that design is more than simply drawing a product: "It's a whole process". In order to produce a useful product, their first step was to generate ideas based on user's needs. The second step was to consider constraints (mostly technical and economic).

Skills and knowledge

Students mention skills or technical knowledge they needed to reach the goal of designing a real product, "a little bit like" a professional. In order to achieve this process, they rely on existing knowledge (mostly technical) and skills (mostly drawing and the design process), or develop new ones they considered helpful (CAD, for instance). Thus, they develop strategies in order to acquire these knowledge or skills (by self-training or collaborating with other students or external experts). This highlights the skills and knowledge which students consider inherent to the design activity, and consequently to the profession.

However, none of them used artistic or cultural works as a source of inspiration. Only one student mentions a product (a metal cupboard) that had influenced his design process ("working on the plate"). The aesthetic aspect of the product seemed relatively unimportant: only one student really describes it in depth and others just mention it once. The initial representation that five students had, of the design profession as artistic and creative (where they could use skills such as drawing) seemed to change during the exercise.

Values

All students refer to values ("that is meaningful", "that is serving people" "it looks alright...it's useful"…), to technical constraints ("that works", "achievable") and economic constraints ("saleable", "not too expensive", "make money for the company"). Three students (situation B) mentioned sustainable development, more as a way to generate ideas than as a real adherence to values. In both situations, values were considered as a part of the design methods taught in previous exercises. In the same way, sustainable development is mentioned as a constraint imposed by the teachers or as "a fashion".

Identity

Three students distinguish sub-categories of the design professions. A student says: "I do industrial" (i.e. industrial design) which is, from his point of view, a rather technical job. Two other says: "design is not style", (i.e. they are not primarily concerned with the aesthetics of the product). The exercise also allowed them to identify themselves with a cultural group with whom they share conceptual methods, tools (CAD, drawing) and knowledge (essentially technical) and mostly the capacity to achieve an entire design task. Four students clearly differentiate "their" knowledge and skills from those of other experts (e.g., marketing or materials resistance).

Before the exercise, a student had an idealistic representation of the profession of designer ("I thought that Designers had the freedom to do and to dream up whatever they wanted").

Profession goals / Pedagogic goals

Students distinguish this exercise from previous ones, it can even be said that they perceive them as "opposites". For all of them, at school the goal is to produce "something interesting", do a "nice drawing", to "meet the objective of the exercise" or "have a good mark". Whereas, "for a client", it's different: the goal is to design a "technically realistic", "saleable" product, which is "not ugly" and is "a little bit fashionable". They seem to have two concepts about the nature of design activity; an academic one, built on transmitted values and methodology, and a professional one, built on constraints and efficiency.

Occupational goals

Finally, all students considered the exercise as a challenge. We saw that the presence of a "client" allowed them to work on a live project, achieving a "real design activity". Four students say that getting good marks was not their goal; they "wanted to succeed", "it was hard to find an idea which works". But, in the end, all students were surprised by the results ("to see a product come out of my head", "I started with an idea in my head […] and now I've got the product in front of me", "when I try out the product I designed, I can see the point of what I do. It does me good"). They seem to be surprised to be able to go so far in the design process. So, four of them expressly say that the exercise confirmed their vocational choice.

Discussion

While students' perceptions of the competences they need to achieve the exercise were quite relevant, those of their future profession are rather stereotyped or inherited from their teachers ("coming here I understood that design is not about style"), Indeed, curricula of most design schools arise from the functionalist tradition. To make objects both beautiful and useful is a generally expressed goal of the design profession (Tortochot, 2007; Tortochot & Lebahar, 2008). However, despite the fact that they all state that they had an artistic background before they began design studies, students mention the creative process or aesthetic research very little or not at all. This raises the question of the importance they place on "creative practices" and aesthetics for their future profession.

The second point of discussion deals with matching students' occupational aspirations or career aims to their design activity in this exercise. Indeed, the exercise gave them the impression of practicing the whole design process: from the idea to the commercialised product. Thus, five of them say that this experience basically affirmed their career choice. This situation encourages them to acquire skills by themselves in order to achieve their career aims. But if they consider this particular situation as reference, it seems likely that the students could legitimise and favour acquisition of certain knowledge and skills more than others during the rest of their studies.

At last, this kind of exercise enhances their understanding of the pedagogic goals of previous exercises. Indeed, the students all said "they used methods, knowledge and skills previously learnt". Ultimately, it seems that working on entire design projects is important for maintaining their motivation and allowing them to project themselves on the representations they have of their future profession. University students (situation A) refer more to commercial constraints and goals of the design profession than the BTS students, perhaps because the former had direct contact with the "client". The question of values (ethics) remains critical. This "hybrid situation", seems to reveal a rather commercial representation of the industrial design profession: "If we want to work, we have to be able to design products which are going to be saleable" says one of the students without mentioning any ecological or ethical value.

Conclusion

In this exploratory study we analysed the students' activity in a "hybrid situation" (pedagogical/operational): their response to a real product design brief. We deduced from students' work and feedback some of the representations they have of the profession (activity) of industrial designer. We saw students strongly distinguish two design approaches: one, which is "academic", research-based and considers ethic values and aesthetics and another, which is "professional", based on efficiency and technical feasibility. Although the two approaches use almost the same design processes and similar tools, each context has different objectives. This means that the students don't need, use or acquire the same skills or knowledge in each situation. But the professional approach seems to be justified by its efficiency, despite its lack of explicit attention to values. For example, the students analysed users' needs only in order to generate ideas; thus, consideration of this value was not driven by ethics, but rather by the search for efficiency.

However, achieving an "entire" and "real" design task enhanced comprehension of the pedagogical program and also self-confidence and motivation. It allowed them to affirm their career choice and to develop skills, although many of these skills were outside the scope defined by the teachers for the exercise.

A survey and study on graduate students is presently being undertaken, in order to highlight the possible the evolution of these representations. This study will pay particular attention to the relationships between the representations of the product design profession, students' motivation and the acquisition of skills and knowledge.

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Visions for technology education in Malta
Brief history and current issues

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Abstract

This paper reports briefly about the evolution of visions for technology education at secondary school level in Malta during the last 20 years. Technology education is defined in its broadest terms to encompass technical vocational education. The work describes how technology education in Malta has started as purely utilitarian targeting primarily employment and the economy within the vocational framework commonly referred to as "trade schools" (Sultana, 1992). Later, technology education in Malta evolved to seek more of an academic rationalist and personal theoretical perspective especially with the inclusion of a design philosophy within the subject referred to as "Design and Technology (D&T)" (Ministry of Education, 1999). Currently, design and technology education in Malta has become a compulsory core for all students within the first two years of secondary schooling. It seems that the vocational scope of technology education is reconsidered useful to balance accreditation opportunities for diverse learning styles and a vision to introduce such vocational subjects at par with traditional academic subjects has been implemented (Ministry for Education and Employment, 2012). It also seems that technical vocational education is believed to help alleviate the problem of early school leavers (Ministry for Education and Employment). A chronological approach is taken to review the events and the documentation available on technology education in Malta. The paper concludes by presenting future visions for technology education in Malta as reported by the current Ministry for Education in Malta.

Introduction

With respect to other subjects in the Maltese curriculum, formal technology education in Malta is relatively in its infancy. Although technology education, understood in diverse forms, has been implemented in the Maltese curriculum within the last 20 years, reflection about the diverse understandings of technology education and the changes and rationale for these is not well documented. This work is meant to provide a summary of the most important events within formal technology education at secondary school level together with a brief reflection on these events. The relevance of this work is to provide awareness that within historical events in the Maltese curriculum, the diverse roles which different aspects of technology education can hold may not be well understood. This makes the situation in Malta interesting for research, although certainly not unique since similar curricular evolutionary situations may be found in other countries.

Evolution of the secondary school technology curriculum in Malta

1964 - 1979

When Malta gained Independence from Great Britain on the 21st of September 1964 the Nationalist Party was in Government. During the first legislative period (1964-1971) after gaining independence the Maltese Government in 1970 introduced "Secondary Education for all"(Zammit-Mangion, 1992; 2000). This was one of the milestones in the educational history of Malta. With the general election of 1971 the Malta Labour Party returned in Government with a vast and ambitious programme to reform the whole traditional education system. In 1972 "Comprehensive Secondary Education" was introduced (Zammit-Mangion, 1992; 2000) concurrently with the "Trade School System" (Sultana, 1992). At the time, the form of technology education at secondary school level was understood as being only trade related.

Trade schools were vocational schools which formed part of the secondary system specialising in the teaching or instruction of trades and crafts. With the introduction of Comprehensive Secondary Education, pupils could opt for vocational education in a Trade School when reaching the age of 14+ after three years general education in an Area Secondary School as illustrated in Figure 1.

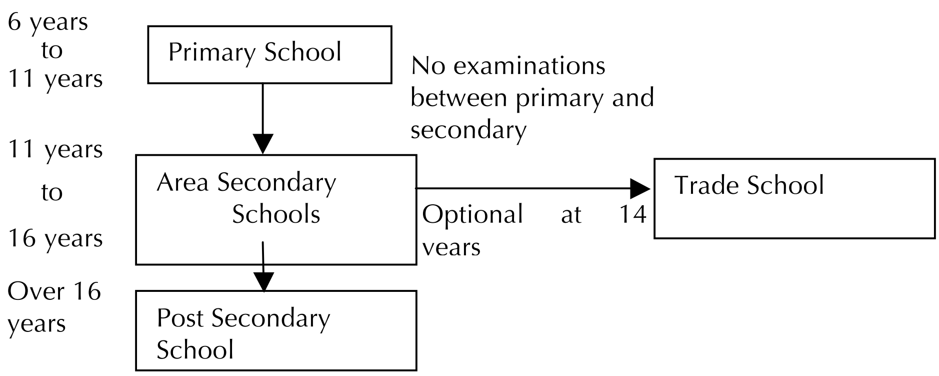

Figure 1. Comprehensive secondary education in the year 1972.

The trade curriculum was designed to have 75% practical skills in the workshop and 25% general education and theory related to the craft or trade (Zahra, 2002, p. 5). Initially the courses ran for two years up to the compulsory education of 16 years. The model of schooling was an assimilation of what goes on in industry or factories. Instructors having industrial experience and subject qualifications were recruited to teach specialized crafts and trades. However, they worked longer hours had less holidays and lower salary than qualified trained teachers in secondary schools (Sultana, 1992). The demand for Trade Schools increased in their popularity and by 1975 there were a total of 1,870 boys and 430 girls attending these vocational schools.

1979 - 1989

Educators, parents and the general opinion were unsatisfied with the Comprehensive Secondary Education system and in 1979 the Labour Party Government reverted back to a more segregated selective system that of a "Tiered Educational System" (Sultana, 1992) as illustrated in Figure 2

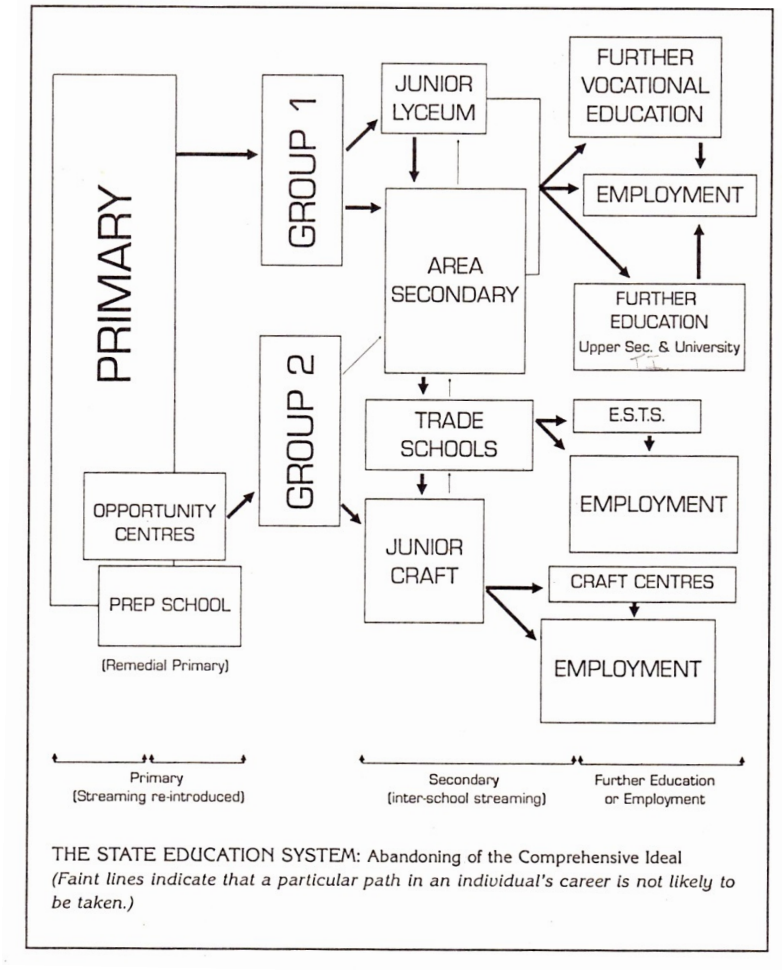

Figure 2. Tiered educational system 1979 (Sultana, 1992).

Pupils were streamed at primary and, a national competitive examination was introduced. Those who were successful in passing the exam entered ‘Junior Lyceums’ and were labelled as “high achievers”. Those who failed entered ‘Area Secondary School’ and were labelled as lower achievers. Both these secondary schools had the same academic curriculum, but achieved it within different timeframes. The system was very selective and had some serious repercussions on vocational education and the reputation of Trade Schools.

After completing the second year (Group 1 in Figure 2, referred to as Form 2) in the junior lyceum or the area secondary schools, students had the option to choose a vocational route in a Trade School. Academics, parents and the general public perceived vocational education in Trade Schools as a curriculum for ‘low-achievers’. Most students opting for vocational education in a trade school were not deemed capable of following an academic liberal curriculum as that in ‘Junior Lyceums’ and ‘Area Secondary Schools’, since they preferred manual work.

In the late seventies the trade school curriculum was equally divided between academic studies and workshop skills. Qualified teachers were transferred from area and junior lyceum secondary schools to teach general education, while instructors, who were experts in their trade, instructed various manual skills in specialised trades such as mechanical engineering, welding, plumbing, electrical installation work, wood working, construction work etc. Both the the Labour Government and later, the Nationalist Government tried to reform the trade schools to have the same status as the ‘Junior Lyceum’ and ‘Area Secondary Schools’, by increasing the level of general education. Nevertheless, there was no improvement, and behavioural problems, absenteeism and early school leaving increased (Sultana, 1992).

1989 – to date

Table 1 lists important milestones regarding the evolution of technology education in Malta. Technology Education was first introduced in Trade Schools in September 1995. The main objective was to foster creativity, problem solving and entrepreneurial skills through preparing students for future technological needs by adopting a design and make approach to develop artefacts. The National Minimum Curriculum was introduced in 1989 (Department of Information, 1989/1990 Legal Notice 73 & 103). The Trade School curriculum was revised giving more importance to general education while practical and theoretical lessons were reduced by 33% from the curriculum. During the nineties the vocational education programme in Trade Schools was being restructured by the Heads of Trade Schools together with an academic representative from the Faculty of Education, University of Malta (Sultana, 1992). Meanwhile, another group was working on the recommendations of the World Bank Policy Paper (1991), to postpone vocational specialization from compulsory schooling to post-secondary education (Zahra, 2002, p. 6). This group of educators recommended the introduction of a new subject called Technology Education (Purchase, 2005).

In 1994, Form 2 secondary students from area secondary and junior lyceum schools had an option to choose Technology Education instead of a trade school subject. This provision initiated the closure of trade schools. Technology Education was being offered in two different programmes: 'A' and 'B'. Technology 'A' curriculum was industry based (mechanical, electrical and woodwork) and aimed for male students. Technology 'B' oriented toward a caring service curriculum (food, textiles and interior designing) and was aimed for females (Zahra, 2002; Zerafa, 2003). At this stage, there was no formal, national examination on completion of the programme. Therefore, even though some students were following a technology course, this was not formally recognized by any national or international examining board. These programs were being taught by instructors in trade schools who were expert in their respective trades, but not formally qualified as professional teachers.

Since 1997 the Faculty of Education (Department of Mathematics, Science and Technical Education) of the University of Malta has been offering an Initial Teacher Training course named B.Ed. (Hons.) Technical Design and Technology with the intent of producing qualified professional teachers to teach technology in secondary schools. The programme's main domains of study are resistant materials, electronics and graphical communications. Students having the required entry requirements can follow a 4 year course leading to a qualified teacher status which enables them to teach D&T and Graphical Communication. This is still the course present today.

The National Minimum Curriculum (NMC) document (Ministry of Education, 1999) came into operation in September 2000 with the inclusion of Technology Education still as an optional subject in the secondary phase of education and integrated with science in the primary phase. The introduction of the NMC brought a major reform in "Vocational Education". Trade Schools and Technical Institutes were closed down and a new vocational college was established, namely the Malta College of Arts, Science and Technology, (MCAST) (MacDaniel, 1999). With the closure of trade schools, Technology Education was being offered as an optional subject in Area Secondary Schools for 4^{th} and 5^{th} formers, using the technology 'A' and 'B' syllabi.

In 2002, the Department of Technology in Education was established by the State Education Division. This department restructured the curriculum and opted for four new areas namely resistant materials, electronics, food and textiles. This also brought about change in the title, and from Technology Education it was now being called Design and Technology Education (Purchase 2005). The subject was optional from Form 1 or Form 3, in a number of Area Secondary Schools. Meanwhile a 'Technology Education Learning Centre' was established. This centre was aimed at supporting both novice and experienced teachers by offering continuous professional development courses specialized in D&T.

A milestone in the history of D&T was the introduction of the Secondary Education Certificate (SEC) examination ('O'-level) in May 2008. This exam acted to motivate and reassure both student and teacher that D&T had indeed gained status and became at par with other academic subjects at secondary level.

Almost 20 years have passed since the introduction of technology education in Trade Schools and D&T is now being offered in all State Secondary Schools and Colleges together with some Church Schools. Since the publication of the 'A National Curriculum Framework for All' (Ministry for Education and Employment, 2012), D&T achieved even more recognition in the curriculum, because it was made a compulsory subject for the first two years Form 1 and 2 and optional for Forms 3, 4, and 5. The domains of study are resistant materials (wood, plastic, metals and textiles) and electronics. Graphical communication was integrated across the mentioned D&T domains. Table 1 is a timeline showing important milestones and related documents regarding the evolution of the technology education curriculum in Malta.

Table 1. Milestones, Timeline of events and important documents regarding the evolution of the technology education curriculum in Malta.

	1993	1995	1997	1999	2000	2001	2002	2005	2008	2011	2014
Events	Recommendations made to the Minister of Education in the report 'A Curricular Framework for the Proposed First Cycle of Studies at the Trade Schools'	Technology Education offered in Trade Schools	Faculty of Education of the University of Malta offers an Initial Teacher Training course named B.Ed. (Hons.) Technical Design and Technology.	Set-up of Working Group 1.	Trade Schools closed. Technology Education introduced within general secondary schools as an optional subject. In primary, technology was coupled with science.	Technology curriculum as defined by Working Group 1 *.	Set-up of the department of Technology in Education from the Education Division, Working Group 2.	Technology Education offered in General Secondary Schools. Curriculum followed was that established by Working Group 2 *.	Introduction of SEC qualification for Design and Technology SEC 33	Re-introduction of vocational subjects in the general secondary schools, Engineering Technology SEC 36	The subject of Design and Technology became a compulsory core for Form 1, Form 2.
Important Documents		'Tomorrow's Schools' (Wain, 1995)		National Minimum Curriculum, 'Creating the Future Together' (Ministry of Education, 1999)	Trade Schools Review Report (Ministry of Education, 2000)				(MATSEC, 2008)		(Ministry for Education and Employment, 2012)

* Working Group 1 proposed that curriculum be based on the following topics: Production, Energy and Power, Communication, Control and Bio-technology. Working Group 2 proposed: Resistant materials, electronics, food and textiles (Purchase, 2005).

Reflections on evolution of the secondary school technology curriculum in Malta

Perceived curriculum orientations

Theorists such as Herschbach (1992) agree to the following basic curricular design patterns: a) academic rationalist/liberal; b) competencies: technical/utilitarian; c) intellectual processes; d) personal relevance and e) social reconstruction/adaption.

According to the authors of this work, the curriculum for technology education in Malta can be perceived to be related mainly to two of the above, namely the utilitarian/competencies pattern and the academic rationalist/liberal pattern. Figure 2 shows perceived proportions of bias toward utilitarian and liberal orientations on the y-axes of the graph. The evolution through time of the Maltese technology curriculum is perceived to have started as entirely utilitarian. With the introduction of technology education in general secondary schools and also with the inclusion of the "design" element in the content of the Design and Technology curriculum, the utilitarian pattern is perceived to have experienced a dip. Currently though, the utilitarian pattern is perceived to have re-gained strength with the introduction of technical vocational subjects such as Engineering Technology. Overall, therefore, the strong bias toward a utilitarian pattern has been maintained.

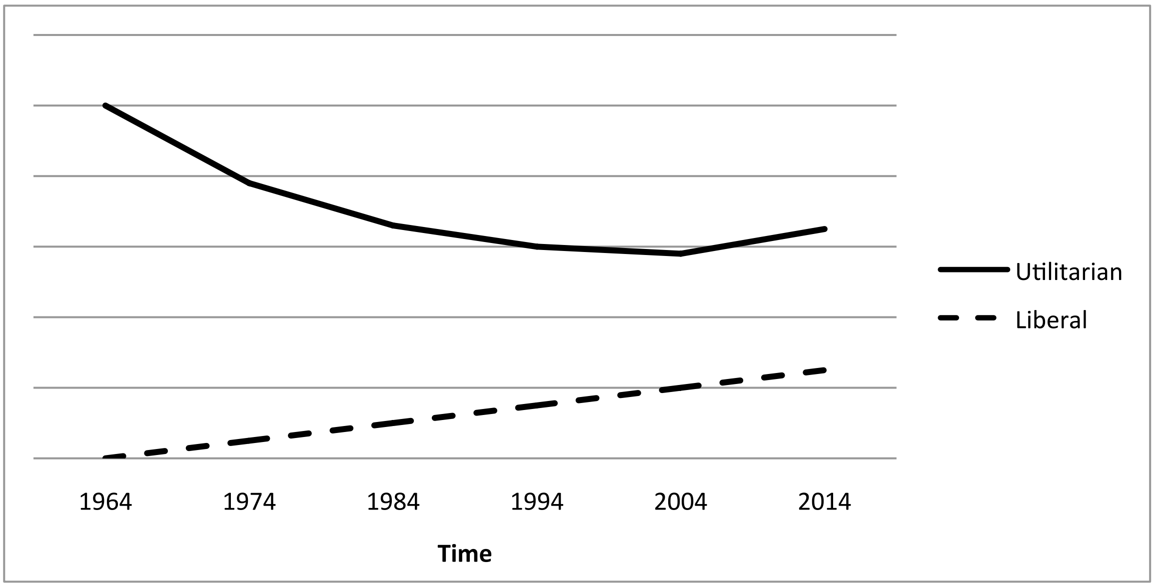

Figure 2: Perceived technology education curriculum orientations in Malta

Within the realm of secondary schools, the liberal pattern for a technology curriculum can be perceived to have grown steadily through time. Currently however, the authors' perception is that it still does not benefit from equal vigor as much as the utilitarian pattern.

Challenges incurred from the past

Technology education today, whether in the form of Design and Technology, or as vocational Engineering Technology, faces a number of challenges which have been incurred from how technology education has come into being in Maltese secondary schools. Many people claim that it "*started on the wrong foot*" for several reasons which include a) Lack of foresight and planning regarding the physical and human resources which were required to implement the subject, b) the belief that simply because there exists a relationship with vocational or trade subjects, the philosophical shift towards technological "*habits of mind*" (Lucas, Hanson, & Claxton, in press) would be easy enough for trade instructors to implement without adequate training, c) the notion that a technology curriculum is sufficiently related to a vocational or trade curriculum to base the former's structure on the latter's, d) the inheritance of negative perceptions and incentives of teachers, students and parents related to the status of the subject due to its initial introduction in trade schools.

While from the financial, physical and human resources point of view, the decision to introduce technology education in trade schools first was logical, this decision has acted to attach negative perceptions and misunderstandings related with the study of technology. From its introduction, twenty years back, the situation has slowly improved and recommendations from researched scholarly work have been or are in the phase of being implemented.

Technology education recommendations and works in progress

Although studies related to technical vocational education in Malta have been conducted in the nineties such as those by Sultana (1992, 1997), the nature of these studies explored more of the social dimension, rather than the detail of how a technology curriculum can be managed in terms of structure and content. Essentially, the authors have only found access to two major studies which tackle the technology curriculum in a certain amount of detail and give practical, direct recommendations as to how this can be managed. In their theses, Zahra (2002) and (Navarro, 2009) offer a number of recommendations giving explicit directions for the way ahead in technology education. Table 2 lists important recommendations and the current works in progress in relation to each recommendation.

Table 2. Zahra's and Navarro's recommendations and works in progress in relation to them.

	Theme	Quotation from Zahra's work	Current works in Progress
1	Curriculum development subject specialists.	*"The expansion of the curriculum is a delicate operation. The teachers are not well versed in curriculum development. They all should own the curriculum, but professional input is required. This is what we really lack in Malta since we have specialists in curriculum development but not specialists in the subject." (p. 78)*	The year 2014 has seen the graduation of one doctoral student and around six masters students in Design and Technology Education. One other doctoral student is expected to graduate by the year 2017.
2	Direction of funds.	*"Politicians must vote funds if they really believe in technology education's positive outcomes and want their policy NMC (1999) to be implemented." (p. 80)*	Considerable investment has been directed towards establishing structures and resources for secondary schools and the vocational institution MCAST. No funds have been directed towards establishing resources for the initial teacher education course at University (B.Ed. (Hons.) Technical Design and Technology). The current state of affairs is that facilities for teacher training are far inferior to those present in secondary schools.
3	Use of resources.	*"One of the strategies to temporarily compensate for the lack of suitable facilities within the Faculty of Education and to start offering Technology Education teacher training as soon as possible [is to] make use of laboratories within other Faculties, which may include Faculty of Engineering or make use of workshops within MCAST, as suggested in Trade Schools Review Working Group report 2000 (Ministry of Education, 2000)." (p. 82)*	In October 2014, Faculty of Engineering at the University of Malta was approached with a proposal and there is a spirit of openness for negotiation and support. It is not excluded that MCAST or secondary schools will also be called to contribute towards the use of resources.
4	Outreach and professional guidance	*"[Research] needs to deal with people working in industry." (p. 88)*	Research at doctoral level in progress.

5	Policy with all relevant stakeholders	*"We are in urgent need of producing, together with all stakeholders involved, a long term policy establishing a proper structure for Technology education teacher training." (p. 81)*	Authors not aware of any progress on this theme.
6	Major concerns	*"I would like to stress that my greatest preoccupation is the professional preparation of the teaching staff." (p. 83)*	Faculty of Education at the University of Malta currently re-structuring all courses, including that for Technical Design and Technology, to lead to a Professional Masters in teaching rather than just an undergraduate degree.

	Theme	Quotation from Navarro's work	Current works in Progress
7	Primary curriculum	*"D&T education should be included as a single subject in the primary curriculum … [since] the developmental process for D&T education in Malta does not exist." (p. 112)*	Currently, the D&T curriculum in the primary is still integrated with that of Science.
8	Revision of syllabus	*"the syllabus is too vast and without any consideration of time and depth". (p. 112)*	Currently, a national project is being conducted whereby the curricula and syllabi are being revised in terms of the desired learning outcomes for education.
9	Technology education for all	*"D&T should be compulsory at Form 1 and Form 2". (p. 113)*	Currently D&T has been made compulsory at Form 1 and Form 2.
10	Links with Graphical Communication skills	*"most pupils lack graphical communication skills … graphical communication should be a separate taught subject and not integrated within D&T … students opting for D&T should also opt for graphical communication." (p. 113)*	Until 2013, students opting for D&T were not allowed to study Graphical Communication. Currently, this rule has been revoked. Within the compulsory years of D&T at Form 1 and Form 2, D&T includes a Graphical Communication element together with the study of Resistant Materials and Electronics.
11	Gender differences	*"D&T is being offered in almost all boys schools … but only half of the girls' schools have this option. This preferential attitude could propagate the wrong impression that D&T is a subject more suitable for boys". (p. 114)*	In 1994 there were two programmes for technology education: Programme 'A' which was industry based (mechanical, electrical and woodwork) and aimed for male students, and Programme 'B' which was oriented toward a caring service curriculum (food, textiles and interior designing) and was aimed for females. With the launching of the NMC in 1999, there existed one technology programme which both genders could follow. Currently, with the introduction of the co-education (both genders in same classroom) in Malta for Forms 1 and 2, both genders experience technology education in the same way, at least for those years in which it is compulsory.

12	Further technology education	*"Now that D&T has a SEC qualification, it is imperative that other educational institutions recognize it as an entry qualification to further studies … MATSEC should seriously consider the introduction of D&T Intermediate and A-level matriculation at post-secondary education". (p. 115)*	Currently, only some courses at MCAST specify D&T as one of the SEC qualifications which make students eligible for entry into their courses. Intermediate and A-level D&T qualifications from MATSEC do not exist.
13	Minimum competencies within content and skills for teaching D&T and vocational Engineering Technology	*"most ex-instructors teaching D&T claim that graduate teachers [from the Faculty of education at University] do not have practical skills on using hand tools and machines … it is advisable that a working group will be set up to draw a set of minimum competencies for teachers to teach D&T in secondary schools. The Education Division should ensure that quality teaching with standard benchmarks is introduced." (p. 116)*	Currently, the Faculty of Education at the University of Malta is conducting an exercise to specify explicitly what teaching competencies are required of professional teachers. These will be general competencies and not necessarily subject related. The explicit specification of what knowledge and skills are required from a person in order to qualify him/her for teaching a technology programme still does not exist.

A vision for the future

As seen from Table 2, there have been a considerable number of positive accomplishments regarding technology education in Malta. Considering that some of the changes mentioned are substantial, within the time span of just 20 years, it can be said that Malta has really made an effort in the drive towards achieving better technology education within secondary schooling. This effort is not only due to governance, but also to newly graduate technology teachers who are passionate about the subject and who have recently taken the initiative to form an association, called DTEAM (2014), and sound their voice formally about technology education.

Within this work the vision for the future has been deduced only from documentation made available by government and the personal experiences of the authors. The following documents were considered of particular importance since they give a considerably clear vision of expectations for the future: a) The framework for Education Strategy (Ministry for Education and Employment), b) Malta's National Reform Programme under the Europe 2020 Strategy (Ministry for Finance, 2013) and Further and Higher Education Strategy (N.C.H.E., 2009).

All three documents concur regarding the following aims amongst others:

> Decrease the number of low achievers and raise the bar in literacy, numeracy, and science and technology competence. Reduce the relatively high incidence of early school leavers. Attract and retain more students to continue their studies after compulsory education into post-secondary and university studies. Raise levels of attainment in further, vocational, and tertiary education and training. Encourage students to undertake studies in areas relevant to Malta's economic, cultural and social development. Ensure fair and open access to all students willing to further their studies. Facilitate and promote student vertical and horizontal mobility across courses. Reduce the gaps in educational outcomes between boys and girls and between students attending different schools. Attract more women into the workforce. Make Malta a centre of excellence in education.

Within these aims, technology education is mentioned in a direct manner. However, within the documents mentioned, technology education at secondary school level is almost exclusively mentioned as vocational. In turn, technical vocational education is mentioned as being a possible solution for the reduction of early school leavers and low achievers. While this aspect of technology education might help alleviate such problems, both Zahra (2002) and the Ministry for Education and Employment (2014) stated that while aptitude tests have reported general progress made by students, early school leaving was also most common within technical vocational education. Also the majority of low achievers still did not qualify for apprenticeship and only managed to find employment in semi-skilled jobs. Thus the authors find it rather doubtful if the current perceived drive towards technical vocational education will indeed target the aims mentioned.

The mentioned documents also emphasize the fact that not only technical vocational education should be promoted as a credible alternative learning pathway but it should also be structured in such a way to respond more effectively to students' aspirations and learning needs. As pointed out before in this work, unfortunately technology education in the broad sense has already suffered from the inheritance of negative perceptions due to the way it was introduced. Both Zahra (2002) and Navarro (2009) clearly state that past reforms did not bring about change in the perception of parents and educators. Once again, the authors are unconvinced if current reforms will succeed where previous efforts have failed. Regarding investment, priority has been given to the vocational aspect of technology and this is already benefiting from structures which provide a vertical continuum. To date, the authors are unaware of parallel plans for the academic aspect of technology education and such plans do not seem to feature in the latest National Curriculum Framework (Ministry for Education and Employment, 2012). It is therefore questionable how much the "*parity of esteem in between academic and vocational pathways*" has been considered in Malta's National Reform Programme under the Europe 2020 Strategy (Ministry for Finance, 2013, p. 57).

The wish to make Malta a centre of excellence, is highlighted by the documents mentioned While the vocational institution of MCAST which hosts technical vocational courses has benefited from considerable investment, very little investment, at least in terms of physical resources, has been directed towards the initial teacher training course at the University of Malta. Once again the imbalance in the allocation of funds evidences bias toward the vocational aspect of technology education in Malta. Whilst appreciating that governance may have adopted a bottom-up approach towards solving this problem, such an approach has served to delay considerably the efficient use of the very good investment done in schools since graduate teachers are not proficient in the use of equipment and are simply cautious before attempting its normal use.

Limitations and recommendations

This study is limited because is it only based on a restricted amount of documentation and the experiences of the two authors. The authors draw their perceptions on a historical analysis of events regarding technology education, but also on their own personal experience of having lived through the mentioned twenty years of reforms as students, teachers and parents. As such, their perceptions may be subjective. This study is also limited because it only takes the educational view point and does not remark on political and economic forces which might have been behind important decisions taken about technology education. The work tackles the last 20 years because the authors believe that current perceptions toward technology education have their roots in events which took place since the subjects' inception. Such perceptions are very hard to modify. Also, the evolution and effects of a curriculum can be appreciated only if considered over a wide spectrum of changes.

The authors strongly feel that there is a need amongst students, teachers, parents, educational authorities, policy makers and researchers in Malta to be more informed about the different facets and levels of the nature of technological knowledge and the diverse roles these may be seen to serve. This should lead to the adoption of a less technocratic attitude towards the ownership of technological knowledge and a less instrumentalist/utilitarian view of technology. It should also aid in taking balanced approaches and evolutionary drives for the different facets of technology education such as Design and Technology and Engineering Technology, including the investment in teacher training for both these subjects, be it initial teacher training or continuous professional training.

Research is one vehicle which should help inform about the solution to problems or to identify deeply the roots of problems. The access of information such as government reviews is imperative. To date, the authors are aware of documents which have not been released for public access even though a considerable number of years have passed (Purchase, 2005). As a continuum to this work, further research should look into the evolutionary steps of technology education in other countries. Further detail and direct evidence into the effects of the Maltese curriculum could be obtained by conducting interviews with teachers and ex-instructors whose experience spans the 20 years mentioned in this study.

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An explorative study of the Swedish technology subject from the teacher's perspective

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Abstract

In this study Swedish teachers' views of the technology subject and technology teaching are examined. Investigations made the last few years show that there are deficiencies in the technology teaching in Swedish schools - e.g. lack of time in the timetable, low status, non-certified teachers and lack of materials. The subject is young, compared to other subjects, and the teachers have different backgrounds and different technological knowledge. Educational research in general tells us that the teacher has a great impact on the pupils and their learning situation. Therefore, the aim is to examine how Swedish Technology teachers experience and view the subject and its teaching.

The study is quantitative and based on a web based inquiry. 1153 teachers participated. The participants teach, or taught, technology in Swedish compulsory schools. The data was analysed with the Statistical Package for Social Science (SPSS) software. In order to examine the teacher's experience consisting of different underlying factors, an exploratory factor analysis was performed on 18 statements from the inquiry. The result of the analysis shows that there are four underlying factors; 1 Technology education is important, 2 Good conditions for technology education, 3 Syllabus is in focus for technology education and 4 Confidence, interest and technology education of the teacher. "Technology education is important" has the highest mean, which indicates that most of the teachers do find Technology important. The lowest mean is found in "Good conditions for technology education", it shows that the respondents were not satisfied with the circumstances in their school. The factors are a help for a wider understanding of the teachers

experience. Further investigations of the factors and the statistical material will follow, with ambitions to find out if there are some preconditions that explain why teachers have different views of the factors found in this first part.

Keywords

Technology education, technology teachers, teachers' attitude, factor analysis

Introduction

According to Hattie (2008); "Teachers are among the most powerful influence in learning" (p. 238). From educational research in general it is well known that the teacher has a great impact on the pupils and their learning situation (Hanushek, 2003; Hattie, 2008). It is therefore of importance to get close to the technology teachers and their perspectives, in order to understand how the Swedish Technology subject is presented to the pupils.

Previous Swedish research in Technology education indicates that the teachers' own education affects the pupils in different ways. Teachers with subject specific education have better confidence in their work as Technology teachers (Gumaelius, Hartell, & Svärdh, 2013; Mattsson, 2005). Teachers' own formal education in technology has a great impact on the interest in technology of the pupils, especially the girls (Mattsson, 2005). There seems to be three factors that affect to what extent pupils learn, one of them is the teachers' own education. Except for the teacher's education, the physical environment, like classroom and material, and the size of the class also seem to affect to what extent pupils learn (Bjurulf, 2008). Outside Sweden, for example, Rohaan, Taconis, and Jochems (2010) show that teachers' subject knowledge affect pupil learning and understanding. Hammond (2003) finds that pupil learning is a source of satisfaction, while school management is a source of dissatisfaction for teachers.

Theoretical framework

The Swedish School Inspectorate points out that one of the areas that needs to be taken care of in order to increase the pupils' interest in technology education is to "develop teachers' competence" (Skolinspektionen, 2014, p. 36). A lot of teachers in science, mathematics and Technology have deficiencies in their subject expertise, especially in Technology (SOU2010:28, 2010). Teachers feel insecure about the Technology subject and ask for continued professional development (Skolinspektionen, 2014). Technology does not have a particularly big significance as a subject, compared to other subjects in Swedish schools (Skolinspektionen, 2014) and a low status among teachers in general in Swedish schools (Nordlander, 2011). In Sweden, Technology has had a close connection to the natural science subjects since 1980, and sometimes the Technology subject has been overshadowed by those subjects. Some schools do not ensure that the pupils get the allotted time for the technology subject (Skolinspektionen, 2014). Another weakness is that there is a lack of study material and equipment in some schools. Teachers may feel frustrated for not having textbooks. In some schools, it is up to the teacher to bring material of their own to the lessons (Skolinspektionen, 2014). In New Zealand, as an international example of the same problem, one of the major challenges for implementing the previous technology curriculum was the difficulty of resourcing the needed equipment (Jones, Harlow, & Cowie, 2004).

According to de Vries (2011a) "technology teachers are in constant need to explain why their subject would have to be on the timetable" at all (De Vries, 2011a, p. 1). There are several possible reasons for this:

- **Technology is difficult to define:** Neither the concept of technology, technological literacy, nor the school subject is simple to define (Dakers, 2006; De Vries, 2011b). The concept technology has a deeper dimension than just being artefacts, but artefacts might just be the first thing school children would think of when they hear the word technology (De Vries, 2006). In fact, the meaning of technology is rather difficult to define and it is probably not possible to find one over all definition of the concept. The definition of technology also depends on the situation and time (Adiels, 2011), and can be associated to either positive or negative values, depending on the context (Hallström, Hultén, & Lövheim, 2014). De Vries explains why technology is difficult to define "The philosophy of technology is a fairly young discipline, compared to, for example the philosophy of science." *(2006, p. 17)* and that leads to the next point;

- **Technology is a young subject:** Internationally, Technology is a relatively new subject. The last 20-30 years technology has developed as a subject in several countries around the world. It has grown from crafts and skills to a wider subject with aspects of design and technological literacy (Jones, Buntting, & de Vries, 2013). In Sweden, Technology is a fairly young subject. The subject was introduced as a mandatory subject in Swedish compulsory schools (age 7-16) in 1980. Since then the subject has been reformed in the curricula of 1994 and of 2011. Around the world it can be observed as a "fuzzy subject" and has weaknesses like low status, and support needed for teacher education and in-service training (Jones et al., 2013).
- **Technology is taught by teachers with different backgrounds and different views:** There is not one unified view of technological knowledge among Technology teachers in Sweden. Norström (2014) illuminates this in his study of how Technology teachers understand technological knowledge. He suggests that the different opinions of technological knowledge among Technology teachers and the lack of a language that unites the teachers to understand technology will lead to different interpretations of the curricula. Bjurulf (2008) shows that teachers have different views on the Technology subject, depending on, for instance, how they were educated. The Swedish School Inspectorate establishes that Technology teachers have different educational backgrounds and the way they teach technology could vary between classrooms (Skolinspektionen, 2014).

Aim

By looking further and deeper at the teachers' experience of the technology subject and technology teaching, we could not only get a better understanding of the subject in Sweden as a whole but also gain more specific knowledge about what difficulties teachers perceive. An interesting area is how the teachers experience their own situation of being technology teachers; if they feel confident and comfortable in their roles as technology teachers, and if they consider that they have the right conditions (e.g. support and time for development, and material for teaching technology). In this paper, we therefore examine how Swedish Technology teachers experience and view the subject and its' teaching. This is formulated in the following research question:

What are the underlying aspects of technology teachers' experiences of their subject?

Method

Participants and data collection

The population for this study consisted of Swedish compulsory school teachers who teach Technology. 79.5% of the participating teachers were women and 20.5% were men. 234 of 290 Swedish municipalities were represented. Teachers of all grades, from preschool (6 years old) up to the ninth grade (16 years old) were represented. Most responding teachers worked in grades 4 to 6. Approximately, half of the participants, 51.3%, answered "yes" to the question "Are you, according to the new rules, certified to teach in technology?. The rules in this question are the certification of teachers that was introduced in 2011. Both then and now you can work as a technology teacher even without the certification, but you cannot grade the pupils (Skolverket, 2014).

The study is based on an inquiry that consisted of 21 closed questions and one open. Many of the questions consisted of one or more sub queries or statements. Eighteen of the questions were used in this study (see Figure 1), since they fitted the aim of the study. The questions are of a Likert-type scale (Pallant, 2013), in a "Semantic differential" style (Lovelace & Brickman, 2013), with a response range from 1 to 6. The scale represents opposites, for example "Doesn't agree at all" and "Totally agree". The respondents answer by choosing a number on the scale. In this enquiry, 1 represents a negative attitude and 6 represents a positive attitude. The questions were constructed by CETIS, Centre for School Technology Education, and "Teknikföretagen", a Swedish industrial employers' organization, to meet their interest areas. Except for the statements and background questions, there were also questions of the preconditions of the subject in their schools, like time in timetable, classroom, planning, and integration and so on.

The data collection was performed in April 2012 by the survey company Demoskop, which received a register of 4 000 teachers. Those teachers received a web-based inquiry, and 1 367 of them answered the questionnaire. 1 153 were picked out, because they were teaching technology or used to teach technology. The answers from these teachers (N=1153) form the basis for this study. When the inquiry was carried out, Swedish schools were at the end of the second year of the reform of the curriculum that was introduced in 2011, the reform was called Lgr 11. The inquiry has been compiled in a report by CETIS and "Teknikföretagen" (Teknikföretagen, 2012). In the report the answers are compiled, but not analysed further.

1. How satisfied are you overall with the way technology education is managed in your school?

Very dissatisfied 1 2 3 4 5 6 Very satisfied Don't know

Here are some statements about the subject of technology, how well does this agree with your opinion?

Doesn't agree at all 1 2 3 4 5 6 Completely agree Don't know

2. It is a good thing that technology is compulsory throughout school

3. Technology is an important subject

4. The management of my school wants to develop the technology subject

5. The technology subject will have increased importance in the future

6. The technology subject at my school is dependent on enthusiasts

7. Knowledge of technology is generally important for the students and their future

How important are the following factors on how you achieve technology education

No importance at all 1 2 3 4 5 6 Very important Don't know

8. My own interest/knowledge of various technology fields

9. The core content of the syllabus

10. At my school there are well-established work fields in technology

How well do the following statements agree with your opinion?

Doesn't agree at all 1 2 3 4 5 6 Completely agree Don't know

11. At my school, we have plenty of good teaching material for technology education

12. It can be difficult to have enough time to teach technology

13. I think the syllabus core content is a good starting point for teaching

14. The knowledge requirements are clear

15. I have the necessary training to conduct good technology education

16. I feel confident in teaching technology

17. I get the time for the development in the subject that I need

18. I am passionate about the technology subject

Figure 1. Statements from the inquiry

Factor analysis

In order to examine the underlying dimensions of the teachers' experience, a factor analysis was performed. There are both confirmatory and exploratory factor analyses. In this case an exploratory factor analysis (EFA) was the most appropriate, since the motive was to find the interrelationships among a set of variables (Pallant, 2013) and to generate a theory (Henson & Roberts, 2006). Tests indicated that factor analysis was appropriate for the data; Kaiser-Meyer-Olkin Measure of Sampling Adequacy (KMO) =0,83 (meritorious) (Beavers et al., 2013) and Barteltt's test of Sphericity = 0,000 ($p<0,05$) (Pallant, 2013). In a correlation matrix, correlation > 0.30 were found, which implies that factor analysis was considered (Tabachnick & Fidell, 1996).

A factor analysis was performed on the 18 statements. At first Principal Components analysis (PCA) was chosen since it is the most common when one want to reduce the number of objects (Beavers et al., 2013). It is recommended that for social science studies to employ an Oblique rotation method (Beavers et al., 2013), which allows correlations between constructs to be taken into account (Pallant, 2013). Direct Oblimin was selected for this study, since it is the most common Oblique rotation method (Pallant, 2013).

A four factor solution was found out to be the most appropriate. One construct; "It can be difficult to get enough time to teach technology", showed only weak loadings - less than 0,4 (Pett, 2003) and a low communality of 0,134 - less than 0,3 (Pallant, 2013). It was therefore removed, as Pett et al. (2003) recommend. The factor analysis was performed in the same way, one more time. A four factor solution was found to be the best this time too. Now, all constructs had high communalities, some of them were loading on two or more factors. One of them was dropped; "The technology subject at my school is dependent on enthusiasts" since it had loadings on more than one factor and it was difficult placing it conceptually. The remaining 16 constructs were decided to be kept, and the same analyses were performed one last time. It is a critical decision to set the correct number of factors, since the goal is to explain as much as possible of the variance, with the fewest possible factors. The decision directly affected the result (Henson & Roberts, 2006). Therefore, four methods (Eigenvalue, Screeplot, Parallel analysis and MAP) were used to find the correct number of factors; the result is presented in Table 1. In literature, Eigenvalues seems to be overestimating the number of factors (Henson & Roberts, 2006; O'connor, 2000; Pallant, 2013), while Parallel analysis and MAP seems to be the most correct methods (Henson & Roberts, 2006). In this case, after analyzing the results of the four methods and after reflecting on the concepts, four factors seemed to be the most reasonable solutions.

Method	Suggested number of factors
Eigenvalue (Pallant, 2013)	4
Screeplot (Pallant, 2013)	4
Parallel analysis, Monte Carlo PCA (Pallant, 2013)	4
MAP original (O'connor, 2000; W. Velicer, 1976)	4
MAP revised (O'connor, 2000; W. F. Velicer, Eaton, & Fava, 2000)	2

Table 1. Number of factors

The Component Correlation Matrix showed correlations between factor 1 and 3 (0,328), and 1 and 4 (-0,307), and therefore it was decided to keep on to the Oblique rotation with Oblimin solution (Pett, 2003) and that rotation was used to interpret the factors. The final result of the factor analysis is presented in the next section.

Results and discussion

Table 2 presents the results of the data analysis in the form of a Pattern matrix and a Structure matrix. The factors were given names to reflect the character of the items they included. The first factor was distinguished by the importance of technology and the technology subject and was called "Technology education is important". The second factor was characterized by positive statements about how the teachers feel about the terms and support of the subject in their school and was called "Good conditions for technology education". The three items in the third factor were all about the syllabus and the third factor was therefore named "Syllabus is in focus for technology education". The last factor was named "Confidence, interest and technology education of the teacher" since the items were about the teachers' own experience of, and comfort in, technology. Reliability was tested by Cronbach's Alpha, and all factors had a value greater than 0,70, which is recommended in the literature (Pallant, 2013). The four factor solution explains 63,9 % of the variance. The results are presented in Table 3. Overall, the best fitting model for this data (18 variables) was a four factor model, but with two items removed.

The mean of the first factor, "Technology education is important", is high, and the standard deviation shows that all participants are close in their answers. This means that most of the teachers do consider Technology to be important. Even though, Technology is considered as being a low status subject by headmasters and teachers in general (Nordlander, 2011; Skolinspektionen, 2014), more than 50% of the technology teachers in this study find it to be important (i.e. produced a value of 4 or more for the factor). The second factor "Good conditions for technology education" has a mean of about 3, with a standard deviation of almost 1. This means that the respondents were not very satisfied with the conditions in their school, which is in line with other literature (Jones et al., 2004; Skolinspektionen, 2014). When it comes to having the syllabus in focus, the teachers have a mean of 4.7 and a standard deviation close to one. The median is 5.0. A great part of the teachers have given high grades on the statements that this factor is constructed of. This probably means that they believe they are well aware of the syllabus and think that they follow it. According to Skolinspektionen (2014), teachers follow the syllabus, but often technology education is taught at a too low level, for example, primary level to pupils in lower secondary education. The fourth factor "Confidence, interest and technology education of the teacher", has the highest standard deviation, which means that this is the factor where the answers differ the most. The mean is close to 4. This factor is interesting to follow up to see what categories of teachers have answered high and low. Important aspects of this factor, also found in the literature, can be the youth of the subject, the different views of the subject and the different knowledge and education among the teachers (Bjurulf, 2008; Gumaelius et al., 2013; Mattsson, 2005; Norström, 2014; Rohaan et al., 2010; Skolinspektionen, 2014).

The 16 items identified in the study could be used together as a validated instrument for measuring the teachers' views of the subject and its teaching in terms of the four presented factors.

Conclusion and future research

The analysis shows that there are four underlying factors in this material. They indicate that there are different ways of viewing the subject and its teaching. The factors cover both internal and external areas of the teacher's experience, and by identifying those factors, a wider understanding of the teachers' experience of the subject and its teaching is created. The understanding of the teacher's perception will be even clearer with further investigations of the statistical material, which will be possible in future since this study is a part of a larger project. The next part will be to find out if there are preconditions that explain why teachers have different views along the dimensions identified in this first part. Those preconditions can also be found in the questionnaire. It could possibly be in the questions about the background of the teacher or in the questions about the practical conditions (e.g. time, integration, material). The next part will give an answer to what preconditions that matter for technology teachers' views of the technology subject and its teaching.

	Structure coefficients				Pattern coefficients				Commu-nalities
	Component 1	Component 2	Component 3	Component 4	Componment 1	Component 2	Component 3	Component 4	h²
Technology is an important subject	**0.89**	0.19	0.326	-0.354	**0.856**	0.013	0.018	-0.083	0.8
It is a good thing that technology is compulsory throughout school	**0.839**	0.189	0.33	-0.374	**0.789**	0.011	0.035	-0.119	0.72
Knowledge of technology is generally important for the students and their future	**0.839**	0.152	0.351	-0.342	**0.794**	-0.027	0.073	-0.084	0.716
The technology subject will have increased importance in the future	**0.811**	0.199	0.256	-0.189	**0.825**	0.072	-0.009	0.079	0.666
At my school, we have plenty of good teaching material for technology education	0.148	**0.78**	0.189	-0.225	-0.004	**0.77**	0.004	-0.04	0.61
How satisfied are you overall with the way technology education is managed in your school?	0.137	**0.734**	0.202	-0.284	-0.033	**0.707**	0.019	-0.119	0.552
At my school there are well-established work fields in technology	0.099	**0.73**	0.128	-0.115	-0.011	**0.75**	-0.023	0.055	0.537
I get the time for the development in the subject that I need	0.142	**0.616**	0.211	-0.464	-0.067	**0.541**	0.013	-0.352	0.49
The management of my school wants to develop the technology subject	0.375	**0.58**	0.248	-0.079	0.305	**0.549**	0.07	0.166	0.437
I think the syllabus core content is a good starting point for teaching	0.272	0.166	**0.902**	-0.239	-0.023	-0.038	**0.919**	0.002	0.816
The knowledge requirements are clear	0.257	0.212	**0.8**	-0.215	-0.007	0.037	**0.798**	0.015	0.641
The core content of the syllabus	0.267	0.149	**0.771**	-0.228	0.015	-0.032	**0.769**	-0.016	0.595
I feel confident in teaching technology	0.28	0.35	0.319	**-0.889**	-0.025	0.138	0.059	**-0.848**	0.814
I have the necessary training to conduct a good technology education	0.198	0.326	0.312	**-0.855**	-0.109	0.126	0.085	**-0.835**	0.76
I am passionate about the technology subject	0.525	0.235	0.316	**-0.793**	0.304	0.01	0.02	**-0.692**	0.717
My own interest/knowledge of various technology fields	0.369	0.03	0.188	**-0.537**	0.24	-0.131	0	**-0.495**	0.35

Major loading for each item is bolded. It also indicates were the items were placed. Double loadings are underlined (cut-off 0,4).

Table 2. Structure Matrix, Pattern Matrix and Communalities

Component/Factor	Item	% of variance explained	Reliability (Cronbach's alpha)	Mean (Range 1-6)	Standard deviation
1. Technology educat-ion is important	2, 3, 5, 7	33,1 %	0,88	5,21	0,88
2. Good conditions for technology education	1, 4, 10, 11, 17	12,7 %	0,72	3,00	0,97
3. Syllabus is in focus for technology educa-tion	9, 13, 14	9,4 %	0,76	4,72	0,95
4. Confidence, interest and technology educa-tion of the teacher	8, 15, 16, 18	8,8 %	0,80	4,07	1,15

Table 3. Names of the factors, variance explained, Reliability, Mean and Standard Deviation

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Technological experiments in technology education

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Abstract

In processes of engineering design and innovation, technological experiments are commonly conducted. The methods used are similar to those in the natural sciences, but the objectives are different. Technological experiments commonly deal with context-dependent problems related to function, rather than the uncovering or falsification of general laws. Furthermore, they often include value-laden concepts such as safety and ergonomics which are not part of the natural sciences. In school, experimentation is largely seen as part of the domain of the natural sciences, and the experimental parts of technological work gets little attention. This study is based on findings from a professional development course for teachers in years 7 to 9 in compulsory school in Sweden (pupils aged 13–16). In the course, the use of experiments in education was one of the major themes. The teachers who partook in the course generally found it difficult to formulate technological problems to be examined using experimental methods. During the course, they were to develop their own technology education experiments. These often turned out to be rather plain activities where the results, rather than the process were the important thing. In this paper, the results from the teachers' actual attempts to design technological experiments and reasons for why experimentation should get a more prominent position in school are discussed. Experimental work is an essential part of research in engineering design and the technological sciences and should therefore be included in technology education, but without turning it into only applied natural science.

Keywords

Experiment, engineering design, Technology education

Introduction

One of my strongest memories of experimental work from my own school days is from a physics lesson in upper secondary school. We were supposed to experimentally determine the gravitational acceleration. The procedure was described in the textbook: attach a weight to a long strip of paper; put the paper through a ticker tape timer placed on a pole; start the timer and let go of the weight. When it has reached the floor there is a long line of dots on the tape. Between each dot, 1/100 of a second has passed, and from the increasing distance between the dots it is possible to calculate the acceleration.

On our first attempt, the acceleration turned out to be 9.92 m/s^2, not the expected 9.81 m/s^2. Fortunately we could try again, and by picking the right dots to measure between, we reached 9.81 m/s^2, which we thought was correct as it said so in the textbook. Most of our classmates got the same result. From an experimental point of view, this is most peculiar for several reasons. If many groups conduct the same experiment, it is not common that they reach exactly the same result. Another, which is worse, is that gravitational acceleration varies with the latitude, and in Sweden where this experiment took place it is not 9.81 m/s^2 but 9.82 m/s^2 (never trust translated textbooks!). The error seems to be systematic, to say the least. The results were heavily biased because of the experimenters' prejudice.

So, what did we learn? Did we learn anything about gravitational acceleration? No, we knew that already. Did we learn anything about scientific method or scientific experiments? No. What we did learn was how to manipulate data to get the results that we wanted. This can be a very useful skill, but it is not one that should be taught in schools. The purpose of educational experiments generally is that pupils should learn about the object of study and/or about methods for experimentation, but the setup is often made so that this learning does not take place. To pupils, experiments seem like empty rituals with unclear purposes; far from how they are used in scientific and engineering work.

This article argues that learning about experimental work is important, and the educational experiments should therefore be real experiments, where there are no shortcuts to 'the correct answer' to be had.

Experiments in technology, engineering, and design

Experiments are carried out in (but not exclusively in) the natural sciences, the behavioural sciences, the social sciences, and in technology and engineering. In this article, the concept of experiment is used in a wide way, from systematic trial and error work to full-fledged large scale scientific experiments. An experiment is characterised primarily by the experimenter's being able to manipulate one or more parameters that are believed to affect the result.

Experiments in technology and engineering have a long tradition, longer than natural sciences. Documentation of experiments exists at least from the middle ages. When building gothic cathedrals, each building site was used like a kind of experimental setup, where the shape of beams and arcs were based on previous experience, but modified to gain new experience (Hansson, 2007; Turnbull 1993). There are plenty of examples from more recent times, such as the well-known experimental apparatuses used in the 17th century by Smeaton (Channel, 2009) and Polhem (Berner, 1999) to determine the efficiency of waterwheels. As the physics of the day could not be used to show the differences between overshot and undershot wheels, it had to be proven experimentally. No general laws about energy were created, but knowledge about the usefulness of waterwheels was gained. Similar methods are used today in the form of 'systematic parameter variation' (Vincenti, 1990) where the relations between design characteristics and function-related outcomes are examined.

Technological experiments deal with questions about usefulness in a wider sense, about effectiveness and efficiency. If a new alloy is tested in a climate chamber to determine its ductility after being immersed in sea water for ten years to determine whether it is suitable to use on an oil rig, it is a technological experiment. If attempts are made to generalise the findings, and draw conclusions about for example corrosion in general or how the mechanical characteristics depend on the crystal structure of the alloy, it borders on the natural sciences. It is not the necessarily the object of study that determines whether it is a technological experiment or not, but the questions asked. Technological experiments also often deal with context dependent value-laden characteristics (such as safety and ergonomics), which is uncommon in the sciences (Hansson, 2007). To a large extent the same methods can be used in scientific and technological experiments; we must use calibrated instruments, sound statistical methods, control groups, etc. if the results are to be trustworthy.

Technological experiments can be performed as part of a design process (to evaluate a suggested solution), but also in a more exploratory way (typically in technological research or long-term development projects).

Experiments in science and technology education

The term 'experiment' is seldom used in the literature on technology education. Experimental work is implicitly mentioned in textbooks as well as research articles, hidden behind wording like 'testing and retesting possible ideas for solutions' (Skolverket 2011a, p. 261) or 'test, evaluate and refine their ideas' (Department for Education 2013, p. 2).

It is the same in many teachers' handbooks. Bjurulf (2011) tries to cover all aspects of technology education in Swedish compulsory school. She mentions that problem solving is part of the product development process (p. 39 ff.), but not how to teach it. Banks & Barlex (2014) describes technology education in a STEM context. They provide examples of technological experiments (e.g. p. 85 ff.) that all have in common that the correct answer to the questions posed (about gear ratios in this case) can be found in the textbook. The problems can be solved using school science.

In ITEEA's (2007) *Standards for Technological Literacy*, technological experiments are described as a part of the design process and when examining everyday objects. Pupils compare the sturdiness of different types of grocery bags experimentally (p. 70) and test buttons (p. 75). The role of experiments in technology and engineering is described: 'The process of experimentation, which is common in science, can also be used to solve technological problems. Typically, experimentation includes testing something under controlled conditions in order to improve or change it.' (p. 108).

Two aspects are common to the examples above: Neither training in how to conduct technological experiments nor how general ideas about experimental method can be learnt from technological experiments is discussed. This is in stark contrast to for example the *National Science Education Standards* (1996), where various aspects of using experiments in education (safety, learning methods, knowledge gain, criticising, etc.) turn up several times in the chapters dealing with 'science as inquiry'.

Technological experiments in teachers' professional development

A module about educational experiments in technology was included in a professional development course for teachers in years 7 to 9 in compulsory school (pupils aged 13 to 16) in the spring of 2014. The reasons for this were the weak traditions of experimentation in technology education, and the supposed value of including experimentation in product development processes and also of self-contained experiments to practice the ability to 'identify and analyse technological solutions based on their appropriateness and function' which is demanded by the curriculum (Skolverket, 2011a, p. 254).

The students were all teachers with a degree in education, but without proper education in the technology subject. Most of them were originally trained as science teachers, but had been forced to teach technology due to a lack of properly educated personnel. One of the students' tasks in the course consisted of creating an experiment that would train their pupils in experimental work and also provide valuable knowledge of facts and/or help them to choose a design solution in a product development process. The experiment was tried out three times, and improved in between the attempts. First, each student acted as a teacher, presenting his/her experiment for group of co-students. Second, each experiment was conducted with another student acting as a teacher and a group of co-students as pupils with the creator of the experiment as a non-participating observer. Third, the revised experiment was conducted by its creator with his or her own pupils. The experiment was documented with instructions that would allow somebody else to carry it out, and a report where the contents, methods, and results were commented on using theories and literature from the educational sciences.

Eleven students fulfilled the task. An overview of the themes chosen is given in table 1. The students' names have been changed for integrity purposes.

Table 1. Participating students and overviews of their experiment projects

Name	Experiment	Method	Object
Agatha	How does rotational speed vary when gears of different sizes are combined? The pupils first use pictures of gears to form hypotheses and then examine them experimentally by using Lego gears.		√
Bertram	What happens with the speed of data transmission to and from a wireless router when more and more client units are added? The actual transmission rate was measured as more and more units were connected. Graphs of the capacity were drawn.	√	√
Claude	How does the will to share pictures via social media vary with the motive of the image? Pupils uploaded 'cute' and 'funny' pictures to their Facebook accounts, and the number of times it has been 'shared' were recorded. The figures varied with the type of image, and also depended on the sharer.	√	
Dahlia	Exploration of how mechanical impulses affect the object being hit. The experiment was conducted using the two-dimensional physics simulator Algodoo where a small vehicle hit a block with a small ball placed on top. The speed and weight of the vehicle, as well as the height where it hit the block were varied in a systematic manner.	√	√
Eustace	How is the load-bearing capacity of concrete beams changed when they are reinforced with iron? Slender concrete beams with square shaped intersection (approximately 50 mm side) were exposed to a bending load until they broke off. The beams were reinforced with varying numbers of thin steel wires.		√
Florence	How does rotational speed vary when gears of different sizes are combined? This is examined using a simulation program.		√
Gwladys	How does wheel size, friction, and voltage affect the acceleration of a model car? This was examined using systematic parameter variation.	√	√
Hildebrand	How does corrugation of paper affect its ability to withstand mechanical force?		√
Madeline	How does friction and engine power affect a model car's ability to go up a steep slope? This was examined using the two-dimensional physics simulator Algodoo and systematic parameter variation.	√	√
Roderick	How can paper be folded to create the sturdiest possible beams?		√
Stephanie	What are the advantages and drawbacks of different methods to join pieces of wood? Pupils joined wooden pieces using screws, glue, nails, etc. The strength was determined by measuring the force necessary to pull them apart. The joint's ability to withstand heat and acids, as well as its being possible to take apart and join again were also compared.	√	√

A ticked 'method' column indicates that learning methods for successful experiments are stressed in the pupils' activities. A ticked 'object' column indicates that the experimental results (that corrugated paper is stronger than

Notable is that all eleven students chose to create a self-contained experiment, not part of a product development process. Four did variants of canonical experiments from Swedish technology education. Hildebrand's and Roderick's solid mechanic exercises using folded papers, and Agatha's and Florence's examination of gear ratios could all have been picked from a teachers' handbook. Five others did standard tasks, but with a twist. To determine load bearing capacity of beams is a standard exercise, but generally done with wooden sticks or spaghetti and hot melt adhesive. This makes Eustace's concrete bending exercise and Stephanie's wood-joining task somewhat original. Exercises with model cars are also common, but Dahlia, Gwladys and Madeline introduced the concept of systematic parameter variation to give a clearer structure to the task and also for the pupils to learn about techno-scientific method.

Two of the proposed experiments are unlike anything that is commonly done in Swedish technology classrooms, but could be motivated using the current curriculum: Bertram's data transmission capacity measurement and Claude's socio-technical experiment where pupils should try to find out what made people share some images but not other. These turned out to be the most interesting ones. As there were no predefined methods, the experimental setup had to be designed by teacher and pupils in collaboration. They had to discuss concepts of uncertainty, ethics (Is it all right to involve your Facebook friends in a technological experiment without their consent?), validity and reliability. The teacher did not know the answer beforehand and there was no correct answer to be found in the textbook. The result of the wireless router experiment was surprising to the pupils as well as the teacher. The transmission capacity for each device connected to the wireless router was more or less constant up to a certain number of units, after which it dropped rapidly. This information can be valuable everyday knowledge, and also prompted the pupils to try to find out why this was the case.

According to their creators, both the genuine experiments were successful when conducted by pupils. Bertram's experiment with the transmission capacity of the router was surprising to teacher and pupils alike, as it suddenly dropped when a certain number of clients were connected but was practically unaffected if there were fewer. The results varied with different types of routers, which made some pupils trying to find out more about how the information was really transmitted. Claude's experiment with sharing images on social media was more difficult to do in a controlled way, but led to qualified discussions about problems about validity and reliability and also about ethical concerns about using friends as non-consenting guinea pigs in experiments. Both the students (teachers) found using experiments for genuine search for new knowledge in education interesting and rewarding.

Results and discussion

The Swedish technology subject in compulsory school is multi-disciplinary and includes knowledge about mechanical and electrical components, the design process, the history and sociology of technology, and more. Craft skills are practiced in a separate subject, called Crafts.

The task of designing technological experiments was considered very difficult by many of the students. Florence even remarked at an early stage that 'we should not do experiments in technology, if we do it will turn into science studies'. To convince the students that experiments are part of engineering work and technical science research and therefore should be included in technology education was hard work. The idea of the product development process as the core of technology education is strong among Swedish teachers, but it does not have a particularly prominent position in the curriculum or the comments to the curriculum (Skolverket 2011a, 2011b, 2012). The product development process is one of the themes that should be included in technology in compulsory school, but there is no need to organise all or even a majority of the teaching activities around it.

For a majority of the students, the pupils' learning objectives were based mainly on the object of study, not upon methods for experimentation as such. If experimental method is practiced in the natural sciences, it will in most cases be practiced in situations that pupils do not fully understand. In technology, they can experience the difficulties concerning experimental design and the unavoidable uncertainty of the result in relation to graspable and observable phenomena. How the rotational speed of a DC motor varies with the voltage, or that the data transmission rate drops when too many devices uses the same wireless router is tangible to the pupils. They can understand what the results can be used for and also test their plausibility. That a red precipitate is formed when Fehling's solution is dropped into a solution of monosaccharides can be observed and learn by heart, but hardly understood by a teenage pupil. Even the concept of monosaccharides is complicated, and the molecules that the experiment is about cannot be observed directly.

School science experiments are unlikely to lead to any genuinely new knowledge; the magnitude of the gravitational acceleration and that glucose is a monosaccharide has been known for a very long time. School technology experiments can lead to genuinely new knowledge, for example by combining materials or components in a special way in a special context. This forces the pupils to take experimentation seriously; it is not just a ritual you have to do before copying '9.81 m/s^2' from the textbook onto an experiment sheet, but a genuine search for new knowledge.

Implications for the future

Using experiments in technology education should be examined further. Experiments of many different kinds are common in engineering practice and in techno-scientific research. This means that pupils should learn about it as part of their general skills in engineering and technology. Properly conducting an experiment is difficult and should be practiced. By practicing it in a technology context rather than in a natural science context, we can let pupils learn about experimentation in a setting where they have a greater chance to actually understand the results. That a cute image is shared more than a funny one and that the difference is emphasized when the sharer is female, and a that a certain beam breaks while another does not for the same load are results that pupils can understand and see the importance of.

In Swedish technology education, there are no curricular reasons to keep the 'design and make' strait-jacket. In a report by the Swedish school inspectorate (2014, p. 7), it is stated that technology education is commonly dominated by 'non-reflective tinkering' (my translation). A more systematic use of experiments, self-contained ones as well as those that are part of the evaluation process in a design project, could be one method to improve what is done in the classroom: to make pupils reflect. For this to take place, we need to give technological experiments and their pedagogical opportunities a more prominent position in our teacher training programmes.

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Creating links between the design & technology curriculum and global perspectives – an investigation of trainee teachers' perceptions

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Abstract

The revised National Curriculum for England became statutory from September 2014. An overarching aim is to:
'Develop the creative, technical and practical expertise needed to perform everyday tasks confidently and to participate successfully in an increasingly technological world' (DfE 2013, pg 1).
Using the implementation of the revised National Curriculum as a starting point, the purpose of this study is to investigate how initial teacher training (ITT) trainees respond to the cross-curricular opportunities offered by the global education agenda, design and technology and the subsequent impact these planned projects have on student learning and professional practice.
The five learning perspectives of global education are underpinned by sustainable futures and extend beyond subject specific boundaries, but have close allegiance with design and technology as identified in the National Curriculum in statements such as:
'Developments in design and technology, its impact on individuals, society and the environment, and the responsibilities of designers, engineers and technologists' (DfE 2013 pg 2)
Research for Development Education Association (DEA) identified that 64% of teachers worry that young peoples' horizons are not broad enough to operate in a globalised and multi- cultural economy and society (DEA, 2013). An earlier DEA poll in 2009 identified that 93% of young people think it is important to learn about issues affecting other peoples' lives in other parts of the world.
A key feature of the research will therefore be to determine the extent to which a design and technology project results in 'attitudinal change' in the trainees concerned.
The data collection method comprised of an online questionnaire and an attitudinal scale. Trainees were given a taught session relating to global perspectives and took part in practical projects. A Likert Scale was used to collect data on attitudes from the ITT trainees both before and after they had experienced the taught session.

Keywords

Global education, key concepts, National Curriculum, initial teacher training

Introduction

Design and Technology (D&T) has been part of the ITT curriculum since the introduction of the subject to the National Curriculum (DfE 1989). Over the last 25 years National Curriculum content has evolved to include a greater emphasis on global issues

> 'Through the evaluation of past and present design and technology, they develop a criticalunderstanding of its impact on daily life and the wider world' (DfE 2013, Pg 1)

Global Education is also an area that may be focused upon during ITT inspections by OfSTED when judgements are made concerning:

> 'How prepared trainees are to teach pupils/learners in schools/colleges or other settings in different circumstances, and for the age range, and/or subject(s)/specialisms for which they are being trained?' (OfSTED 2014, pg 28)

Additionally, core graduate skills are identified as part of the teaching and learning policy of the Higher Education Institution (HEI) concerned as this project specifically addresses the provision of a learning experience that ensures all graduates by the end of their programmes of study exhibit the core graduate attributes of scholarship, *global citizenship* and lifelong learning.(Quality Handbook AQH-A10: Research Active Curriculum Version 2.0 November 2013)

So, given the internal and external drivers impacting on the curriculum design of the D&T curriculum used within the HEI it was clear that Global Education should be addressed across all phases of ITT provision.

Global Education may be sub-divided by the means of five interconnecting perspectives or 'lenses' which focus upon interdependence and globalisation, identity and cultural diversity, social justice and human rights, peace building and conflict resolution all underpinned by sustainable futures. These extend beyond subject specific boundaries, but are also a key area to address with the D&T curriculum particularly when addressing issues of 'designer responsibility' and 'design impact'.

Within the HEI where the study took place, D&T is taught as a specialist subject to secondary phase trainee teachers and as part of the wider 'foundation studies' programme for primary trainees. It can therefore be concluded that whilst the secondary trainees should enter their programme with specific expertise in the subject area the same could not be said for the primary group; as the latter group are recruited to a generic, as opposed to subject specific, programme. All trainees were studying at postgraduate level. The key question was the extent to which their subject knowledge extended to the global education agenda.

Two inputs were planned for each group of trainees. The global learning activity for the primary involved 29 trainees and took the form of a 'themed day' where they focused on global issues embedded within the D&T curriculum as a whole. For secondary, 13 trainees took part in a session that focused specifically on global issues as they were already confident with the contents of the D&T curriculum.

Prior to the day, the primary trainees had completed a subject knowledge self-audit, the results of which indicated low levels of confidence and expertise across the group surrounding Global Education and also Design and Technology. They began the session by completing a questionnaire relating to their understanding and attitudes surrounding Global Education. The day was therefore planned to facilitate learning via a workshop based approach to encompass the two areas, thereby emphasizing the cross-curricular nature of the issues raised. 'Interconnectedness' or 'interdependence' was a key concept discussed by the trainees after they had engaged with several short activities e.g 'A country I feel connected to', the other activity required them to guess the number of countries that are involved with the manufacture of a popular food item, planned as 'starter' activities to focus the debate.

The main activity aimed to raise awareness of the term 'critical literacy' in relation to higher order thinking skills, dialogic methods (Alexander 2004) and the use of talk in the classroom when linked to a design and technology activity. This took the form of an evaluative 'product analysis' exercise, which included an emphasis on sustainability.

A series of artefacts were analysed by the group and trainees began by identifying low order questions that could be asked initially before moving onto higher order questions, the aim being to demonstrate a progressive series of questions that could be planned for implementation in a hypothetical primary classroom situation. The aim was to carry out a dual investigation that encouraged discussion about the critical design decisions made by the designer in terms of the product's manufacture, intended use and eventual disposal and also how these reflect the themes contained within the five Global

Education perspectives. This information enabled them to refer back to the products with a greater sense of criticality allowing them to 'read the hidden story' or the 'hidden ugliness' behind each product (Datschefski 2001 pg 16)

Trainees considered the concept of 'interconnectedness' and planned possible alternative activities to those they had undertaken that they could use in the classroom, for example, finding out where all the players in their favourite football team originate from or interviewing the school cook to find out where the origins of the component parts of the children's lunch and whether these had been fairly traded.

Secondary trainees also completed the questionnaire relating to their understanding and attitudes towards global education and global education within D&T. They completed an evaluative product analysis exercise using the same artefacts and activities as the primary trainees and with the same focus to the activities. 'Interconnectedness' and 'interdependence' were again key concepts discussed throughout the day.

A workshop based approach followed with trainees working in 3 groups and focusing on the following:

a. Researching global issues surrounding Smart phones, including a product lifestyle analysis.
b. 'Behind the Brands' – issues surrounding sugar production and land grabs.
c. Be a 'Secret Global Shopper' – using a swing-tag from a garment, they researched the global impact/issues surrounding the product/company. A product lifestyle analysis was used.

'Critical literacy as a way of learning' was introduced to the group with a discussion about how this could be embedded within the D&T curriculum and the tasks detailed above were used to draw conclusions, but also raise further issues.

Methodology

An online questionnaire using 'survey monkey' was sent to trainees from the previous years' cohort to determine the extent of Global Education in cross phase partnership schools. The results from this survey led to the realisation by the researchers that training in Global Education was necessary for all ITT trainees.

A Likert-Scale type questionnaire was given to both primary and secondary PGCE ITT trainees at the start of the year to determine their understanding and perception of Global Education. Both researchers have responsibility for the training needs of the groups.

The rationale behind the two phase approach to conducting the research, as described above, was to allow for initial understanding and knowledge to be determined followed by the opportunity for the trainees to reflect and carry out further investigations in the area. The study aims to determine the extent to which 'attitudinal change' was observed.

It should be emphasised that only initial findings are contained within this paper and the second part of the research will consider the views of the trainees at the end of their programme in June and will be the focus of the next stage in this study.

Findings

In order to gain knowledge of student perceptions of Global Education before teaching the sessions the question in table 1 indicates student misconceptions.

Table 1. What do you think is meant by Global Education?
The table is divided into secondary and primary student responses.

Response	Secondary	Primary
Learning about different cultures and religions	1	1
The education of trainees worldwide comparing standards, curriculum and results	10	5
Educating children about global issues, the impact they have on the global environment, knowledge about different cultures and how they are different to their own.		1
No response		1
Education that involves learning about other cultures, societies and political structures across the world		4

Educating children on global issues avoiding not just geography but history, religion, culture and politics		1
Same standards of education across the world and the culture surrounding different education systems		4
Looking at issues nationally and worldwide which come into daily life	1	1
Education which teaches children about the world, different cultures and world issues		2
Education around the world, how cultures differ regarding education issues. understanding culture and countries	1	1
I have little knowledge of this. I think it means teaching children about topics around the world, it looks at teaching around the world and issues which affect us all		1
Education that teaches children about global issues and different countries.		2
Life in other countries, politics, history, global warming and the environment		1
Teaching of other cultures, aspects which influence the world around us could include areas not seen as necessary in the curriculum that provides skills for employment later in life		1
Educating children about the world and the issues surrounding cultures, differences, environment and any areas with impact on individuals or groups globally. How our decisions impact upon others nationally and internationally		1
Teaching about other cultures around the world issues that affect people across the globe including environmental areas such as global warming, food supply and destruction of habitats		1
Structure of education systems across the globe. Gaining understanding of the wider world and some of the main issues present, becoming a global citizen		1

The high percentage of trainees across both phases believed that Global Education referred to education worldwide. It is interesting to note that 10 secondary trainees and 5 primary trainees included information related to standards, curriculum and results being the same in education worldwide. Many trainees listed some areas related to the learning perspectives of global education but the breadth of knowledge is very limited.

Table 2 shows responses relating to the link between Global Education and D&T.

Table 2. Is Global Education taught in D&T?

	secondary	primary
Yes	3	3
Not sure	8	24
No	2	

As the secondary trainees all had design related degrees it is surprising to find that 8 were not sure if Global Education is taught within D&T and 2 trainees even said 'no, it was not taught within the subject!' Of the 27 primary trainees only one trainee had a design related degree so it is not surprising that they were unaware of Global Education within the D&T curriculum.

When asked which subjects were responsible for teaching Global Education a variety of responses from the trainees were recorded.

Table 3. Which subjects in the curriculum are responsible for teaching about global education?

Response	**Secondary**	**Primary**
Citizenship , geography		1
PHSE, citizenship, geography		2
History, geography, science, **D and T**		**3**
Geography, Health and social citizenship		4
All lessons	**7**	**7**
Don't know	3	3
Not sure		2
PHSE, RE, History, Geography		1

Citizenship, PE, history, Geography, PHSE, Science		2
History, PHSE, science, citizenship		1
PHSE, English, Geography		1
PHSE, citizenship, history, RE, Science		1
Science, PHSE, History		1
Geography, citizenship, RE		1
PHSE, Geography, RE		1
RE, **D and T**, geography, history, many subjects		1
English, History, Geography		1
English, History, Geography, **D and T (Food)**	**1**	
English, PHSE, geography and **D and T**	**1**	
PHSE, Health and Social Care, History,	**1**	

3 secondary and 3 primary trainees did not know, however 6 secondary and 6 primary were aware that all subjects in the curriculum are responsible. Only 4 trainees in total from both phases identified that D&T was responsible with food technology being specifically identified.

The results from Table 3 justify the need for Global Education to be taught to both primary and secondary ITT trainees early in their training so that they may gain an understanding in the importance of global education across the curriculum.

When asked which issues global education may include some surprising statements were given relating to education standards, policies, and the impact of league tables internationally and attainment grades. It is quite concerning that education across the world is described as being a competition. 1 secondary and 1 primary trainee responded thus:

> **'Attainment grades, teaching standards, cultural issues, development in technology, curriculum, subject range. Countries competing against one another'.**

Some of the respondents, did however, identify some of the areas within the perspectives of global education, but as above in Table 1 the breadth of knowledge is limited providing further justification of the need for appropriate subject knowledge development.

Table 4. What issues may global education include?

Response	Secondary	Primary
Economy pollution, (global warming), poverty, religion, recycling.	1	1
Attainment grades, teaching standards, cultural issues, development in technology, curriculum, subject range. Countries competing against one another	**1**	**1**
Language barriers, cultural barriers that could be difficult in education	1	
Environmental issues, living issues, lifestyle	1	
Strengths and weakness in subject areas and how to improve them so standards are the same worldwide	**3**	
Levels and assessment, school structure, the school day	**1**	
Language barriers, travelling distance to schools	1	
Economy of the country	1	
No response	**1**	**2**
Subjects to be taught	1	
Current affairs, news, politics, human rights	1	
Impact of league tables internationally, how this affects education policies in different countries. How everyone can have a fair education		**2**
Environment, culture, global problems, social awareness, human rights, globalisation		1
Environmental geography, global citizenship, global mitigation		1
Environment, country relations and conflicts, travel		1
Equality, inclusion, poverty		1
Environment, social background, religion, government funding		1

Diversity, exclusion, /inclusion, SEN, culture		1
Education in other countries/comparisons, recycling, living standards, poverty, politics		1
Lack of equality in children's education in third world countries, it is getting better though		1
Inclusion, assessment, standards		1
Global warming, poverty, politics		1
Ebola, famine, global warming, war, politics, Scottish referendum		1
War, politics, disease, political issues, national disasters		2
War, politics, different cultures		1
Global warming, nature preservation, conservation, politics, history, recycling		1
Technology, nutrition, history, politics, economies, geography, industry, citizenship, languages, journalism		1
Government, health, human rights, economy, cultures		1
Conflicting religions		1
Health and disease, cultural and religious practices, availability of resources including food and energy		1

Summary

The interim findings of this study clearly confirm the DEA (2013) poll relating to teacher's concerns over their students understanding of global issues, if the trainee teachers themselves are insecure in their personal knowledge base.

The Global Education Network (GLEN) describe Global Education as being an active learning process based on the universal values of tolerance, solidarity, equality, justice, inclusion, co-operation and non-violence. Findings from this research show that it is essential to give ITT trainees a breadth of understanding about global education issues so that they incorporate this into their development as a teacher in school. It is essential that they are given this initial understanding so that they will constantly 'be open' to develop this throughout their life and career in education, and realise that in order to be relevant, up to date and effective it needs to be an active learning process.

Eraut (2001 p 11) believes that professional learning does not take place in bite-size chunks at 'off the job' Continuing Professional Development Events (CPD) events but is an ongoing process where individuals incorporate new learning through a significant period of practical experience.

'Global education is a creative approach of bringing about change in our society', this statement by GLEN reinforces the need to include Global Education into the curriculum and resonates with the National Curriculum Programmes of study for Design and Technology. 'It is important that using creativity and imagination, pupils design and make products that solve real and relevant problems within a variety of contexts, considering their own and others' needs' (DfE, 2013 pg 1).

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The experiential domain: enhancing traditional practice in design & technology education

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Abstract

This paper reports on an exploratory, single-case study that looked at the effects of integrating ubiquitous interaction (UI) on traditional classroom practice in Design and Technology (D&T) education. As is typical practice within D&T, the methodology encompassed a design task requiring pupils to construct and capture an evidence-based learning process. Additionally, the integration of UI provides D&T with an infrastructure to support communication and promote cogitation of the learning process. UI presents synchronous and asynchronous opportunities for teaching and learning to occur both within, and outside of, regular scheduled class time. This approach demonstrates the potential for a ubiquitous learning environment (ULE) made possible by seamlessly embedding virtual online presence into the physical traditional classroom. The integration of UI advocates a process of learning from experience. This research classifies this as the *'experiential domain'* of ubiquitous learning, and begins to hypothesise a conceptual framework.

The observational monitoring of pupils online activity suggests that the strength of UI lies in its capacity to stimulate the creation of more qualitative and quantitative knowledge, as well as reducing any discrepancies or misconceptions in pupil understanding. This practice is contingent on the capturing of multiple operations of judgement about when and how to comprehensibly evidence patterns of thinking. This process also provides a means of representing problems logically, not just the accumulation of knowledge. This paper maintains that by integrating UI and the experiential domain we can begin to trace the complex and fundamentally non-linear nature of activity-based learning. In this model the traditional boundaries of classroom practice become blurred and new configurations for learning become possible. These findings and the proposed framework serve to advance pedagogical methods to beyond the state of the art, enabling new modes of interaction between teachers, pupils and other resources in ways that were previously unavailable.

Keywords

Activity based learning, learning environments, interaction, pedagogy

Background

The dynamic nature of technology has resulted in an educational system that is spurred by innovation. Innovation which, as Laurillard (2002) maintains is subject to the changes that technology affords. What technology affords is an array of platforms for pupils and teachers to access people, content, and resources to support innovative ways for curriculum to be implemented and to promote interactions as part of a knowledge rich learning experience (Redmond & Lock, 2006). This allows the integration of technology in education to focus on creating "real world environments that employ the context in which learning is relevant, and to focus on realistic approaches to solving real-world problems" (Chen, Benton, Cicatelli, & Yee, 2004, p. 47). However, creating the *'space'* for schools to advocate a new balance between knowledge and innovation, while safeguarding the quality of pupil learning and efficacy of teacher pedagogy is contingent on the availability of adequate resources to achieve real change. The need to address this expansion of knowledge and innovation has led this research to consider recent advancements in cloud-based technologies towards finding new ways of working together. The idea is to give pupils the opportunity to interact around their learning both during (synchronous) and outside of (asynchronous) school time, and to support pupils by integrating online platforms into traditional classroom practice.

The challenge of traditional classroom practice

There have been increased expectations put on schools and teachers to make use of online platforms to enhance traditional practice. Physical impediments to their successful integration into the classroom are swiftly disappearing as more schools are installing wireless broadband systems and access to technology becomes increasingly ubiquitous (Kimbell, 2008). Ubiquitous learning or u-learning is based on ubiquitous computing (Weiser, 1991). This is a vision of computing power invisibly embedded in the world around us and accessed through intelligent interfaces. Its role is to make computing so embedded, so fitting, so natural, that we use it without even thinking about it. This shift is about human-centred computing where technology is no longer a barrier, but works for us, adapting to our needs and preferences and remaining in the background until required (Ley, 2007).

The challenge for schools is to fluently integrate ubiquitous computing into traditional classroom practice and to design a framework to support pupils and teachers in the effective use of these tools and services. However, integration of such technologies must go beyond the simple transmission of knowledge to transactional learning in support of the active construction of knowledge. John Dewey's (1938) transactional conception of activity-based education views an educational experience as a "transaction taking place between an individual and what, at the time, constitutes his environment" (p. 43). Dewey's description not only fits neatly with the complex shifting of time and place that defines ubiquitous computing but also emphasises the importance of interaction with the various people, content, and resources that constitute their learning environment. For Dewey interaction is the defining component of an educational process that occurs when pupils transform information passed on from another and actively constructs it into knowledge with personal meaning and value.

The potential of ubiquitous interaction

Interaction is a key component of the formal curriculum in many disciplines, as pupil's capacity to demonstrate social and communication skills is critical to both vocational and personal success. Interaction builds a strong foundation for articulating ideas (Reznitskaya, Anderson, & Kuo, 2007), plays a vital role in increasing pupils ability to test their ideas, synthesise the ideas of others, and develops higher-order understanding of what they are learning and why (Corden, 2001; Nystrand, 1996; Weber, Maher, Powell, & Lee, 2008).

Interaction has been defined in a variety of ways based upon pupil's level of involvement in specific learning opportunities, the objects of interaction such as other pupils or content, and the settings in which interaction occurs, i.e. traditional or online (Woo & Reeves, 2007). Muirhead and Juwah (2004) provide us with a description of interaction in a computer-mediated context as being a dialogue between two or more participants and objects which occurs a/synchronously, mediated by response or feedback and interfaced by technology. Interaction in the context of ubiquitous computing is characterised by multiple dialogues distributed on various technological artefacts with dynamic interfaces (Klokmose, 2006). Hence, interaction should be supported not only in the classroom, but fluently between being stationary and being mobile, and not rely on a single encapsulating personal computer.

The capability of extending learning beyond the classroom allows pupils to actively construct knowledge through their social environment, at their individual learning rate (Brown, 2004). This enables the development of a ubiquitous learning environment whose borders are only limited by the imagination of those who participate within them, blurring the traditional institutional, spatial and temporal boundaries of education (Cope & Kalantzis, 2008).

The role of design & technology

This research recognises the unique opportunities afforded by the collaborative problem solving context of D&T activity (Hennessy & Murphy, 1999) for ubiquitous interaction between teachers and pupils, supported by online design studios. Broadfoot and Bennett (2003) refer to online design studios as networked workshops distributed across time and space, such that pupils maybe in different locations handling design communications (i.e. collaborating). Design is a dialectic process between hand and mind (Kimbell & Stables, 2007) where the designer constantly interacts with oneself in pursuing a design solution. In collaborative design this procedure is increased and diversified as pupils or small groups of pupils that emerge as a result of the interactive design process consult with the teacher and other small groups of pupils throughout the collaborative learning process (Karakaya & Senyapili, 2006). As suggested by Achten (2002) collaborative design emerges from the process of working together in a manner to enhance each pupil's contribution to the design solution, where individuals are responsible for their actions and respect the abilities and contributions of others. This approach though difficult to provide evidence of, necessitates an iterative process that values the pupils' own voice as evidence of both collaborative problem solving and interdependency in performance assessment, while maintaining a focus on the overall design solution. Accordingly, this research acknowledges that the automatically recorded and machine-readable timeline of both pupil activity and the interactions that occur between pupils generated by online platforms can offer an accountable source of data. In turn, this data set could be used to provide feedback regarding aspects of performance and understanding, or as progress monitoring through criterion referenced interpretation.

Ubiquitous interaction compels us to be explicit in the design of our educational pedagogy so that pupils can make informed choices that meet their individual needs and desires for interaction. Therefore, if we bring UI into our classroom practice we should ensure that our instructional design promotes interactions that are pedagogically grounded. Anderson (2003) argues that we need instruments and techniques that allow pupils to reliably assess their own preference and capacity to engage in both collaborative and independent learning. Likewise, we need frameworks and practical theories that allow teachers to determine the appropriate mix of both collaborative and independent learning activities based on a complex set of factors, including learning styles, pedagogical approaches, educational goals, and practical implications. Hence, this research sought to investigate the effects of integrating ubiquitous interaction on traditional classroom practice in design and technology education.

Methodology

This study is proposed as a preliminary step in a relatively new field of investigation in which research questions are still unclear and the data required for a hypothetical formulation has not yet been obtained. Therefore, this research conducted an exploratory, single-case study (Yin, 2014). The advantage of exploratory case study research in D&T education allows the researcher to investigate the effects of UI in two ways: (1) during the learning process (e.g., the effects on learning development and/or growth during the learning transactions); (2) the pupils' products (e.g., the effects on pupils' performance at the conclusion of the learning transactions). The study was carried out over a two week period conducted during regular scheduled class time and consisted of two single 40 minute periods and one double 80 minute period per week. The participants for the study consisted of 24 pupils (8 Female, 16 Male) ranging in age from 13-14 and their class teacher. As stated in Yin (2014), small sample size (as in this case) is not a barrier to external validity provided that the study is detailed and analysis of the data reveals elements of practice relevant to the study at hand.

Approach

As the research is concerned with how UI around pupil learning (process, or product) can be used to provide evidence to pupils about their learning, the approach taken was formative. The methodology encompassed a design task requiring pupils to design an artefact to be personal to the user and relative to the environment in which it would be placed. The approach integrated a commercially viable online platform provided by the development division of Sherston Software Ltd. (award-winning publisher and supplier of best-of breed creative educational software tools), and was supported on both stationary computers and mobile technologies (e.g. pupils smartphones, tablets, etc.). This allowed the pupils to:

- Construct theoretical knowledge and practical skill as is common practice in D&T
- Capture both the learning process and evidence of learning in real time
- Communicate a/synchronously with all participating group members
- Cogitate their learning process collaboratively and/or individually

This facilitated multimodal opportunities to analyse a wide range of design choices, and revealed understanding of social, technological, cultural, functional and personal concepts.

Data Collection

This study focuses on the quality of pupil learning and efficacy of teacher pedagogy, therefore it was important that the essence of data analysed be qualitative. As Denzin and Lincoln (1994) write; qualitative research enables the studying of people and things in their natural settings, attempting to make sense of, or interpret, phenomena in terms of the meanings individuals bring to them. To gather 'live' data from UI this study exercises an observer-as-participant approach (Cohen, Manion, & Morrison, 2011). The observer-as-participant is not a member of the group but may participate a little or peripherally in the group's activities and whose role as a researcher is clear, overt and unobtrusive as possible. This enables the following categories of information to be analysed to better understand UI: settings; participants; goals; acts; events; time; meanings; relationships; and behaviour.

An in-class survey was used to provide statistical analysis of the findings and filter out any external factors. This would allow for a comprehensive answer to be reached and the results to be legitimately discussed. Responses to the survey were provided by means of a five-point Likert type scale ranging from 1: ''strongly disagree" to 5 ''strongly agree". Of the 24 participants, 5 pupils (2 female, 3 male) were randomly selected to participate in a semi-structured study focus group. Questions were designed to collect a qualitative insight into pupils own interpretation of what happened when they were learning. The study focus group was recorded, transcribed and emergent categories analysed. The findings would ensure the data collected would be explanatory in its description of the validity of the approach and would be effective when considering intangible factors to interpret and better understand the complex reality of UI and the implications of the quantitative data. A post-study interview was conducted to query the teacher's perception of the pupil's response to the integration of UI. Additionally, questions were designed to assess the impact of UI in regulating educational pedagogy and/or leading to an increased difficulty in measurability and assessment.

Findings

For the purpose of the findings section it must be noted that interactions are referred to as "comments", and the process of composing a comment as "posting". A total of 161 comments were posted throughout the duration of the study. Table 1 depicts the magnitude of UI (i.e. who was posting comments and when). Approximately 52% of all comments (n=83) occurred synchronously - online during regular scheduled class time. No teacher comments occurred synchronously. The remaining 48% of comments posted (n=78) occurred asynchronously - online before and/or after regular scheduled class time.

Table 1. Magnitude of comments posted to online design studios

Interaction	Male	Female	Teacher
Synchronous	50	33	0
Asynchronous	25	14	39

Although this resulted in a multitude of processes being addressed in any one class at any one time, it is evident that as a result of the comments posted pupils felt encouraged and supported. The following extract is taken from the in-class survey, study participant 7:

> "I began to talk to people in the class that I normally wouldn't have talked to and I found that the more people who can look at your work the better it will turn out to be."

The practices observed by monitoring pupils' online activity reveals that posting comments to the design studio influenced pupils' capacity to define capability and derive educational values appropriate to inform the quality of their learning. In an effort to solve the design brief pupils articulated their learning process by working iteratively, posting annotative comments, engaging in collaborative dialogue with their teacher and peers, and uploading subsequent data files (evidence) to their design studios. This process begins to suggest that the strength of posting comments lies in its capacity to stimulate the creation of more qualitative and quantitative knowledge and reducing any inconsistencies in pupil understanding. Figure 1illustrates how posting comments advanced the dissemination of pupils learning process.

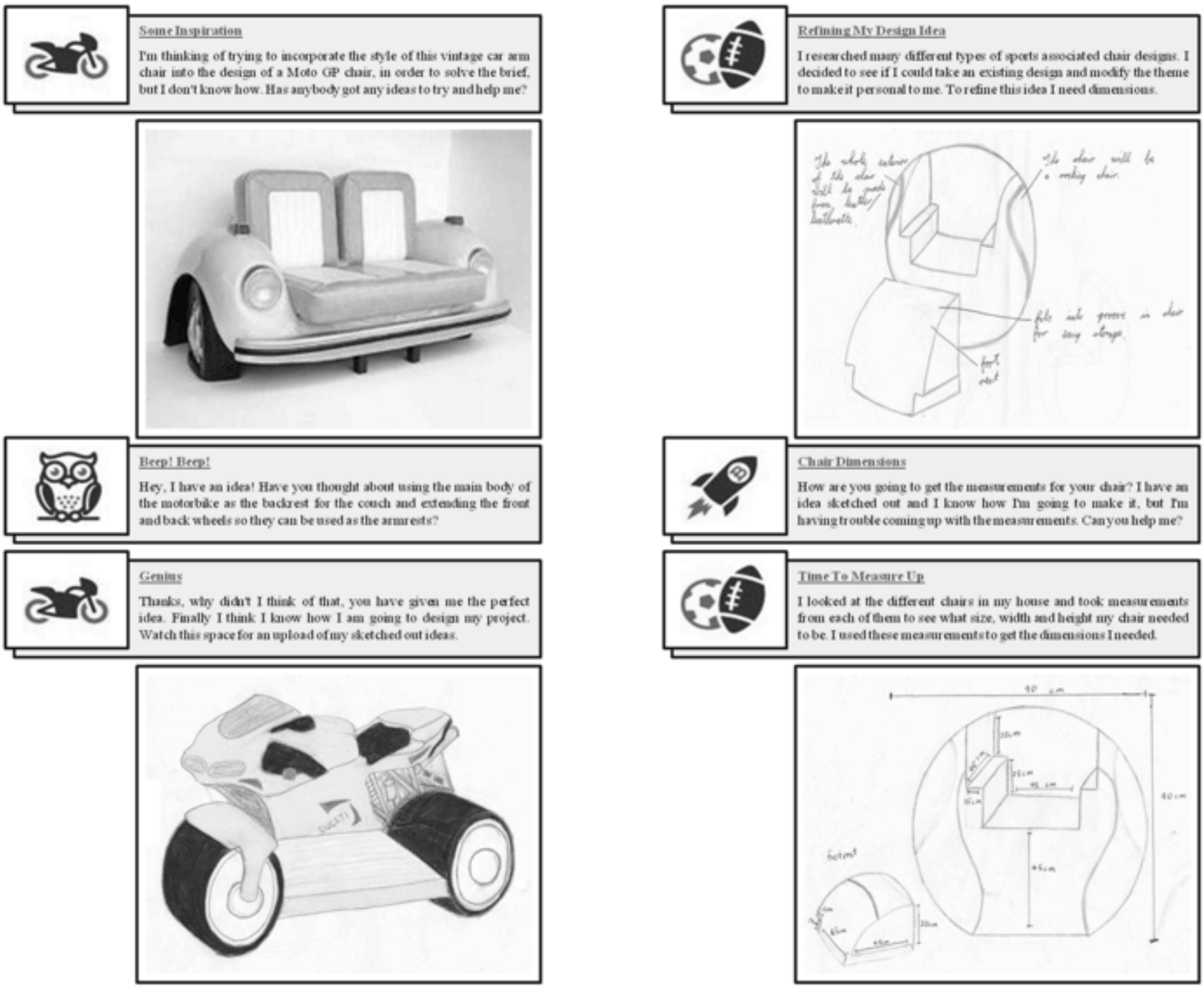

Figure 1. Example of comments posted to online design studios

The following extract (transcribed from the post-study interview) reveals the class teacher's response to the integration of UI on traditional classroom practice and D&T education:

> "The quality of learning was greatly increased as pupils interacted in a larger community, and the ability to moderate and review interactions was an excellent tool in the assessment of pupil learning. Interactions forced pupils to expand their thinking while gaining constant feedback and affirmation from their peers. This facilitated a greater level of idea generation which ultimately led to more robust design solutions."

This process of creating such rich evidence of activity-based learning is contingent on the capturing of multiple operations of judgement about when and how to comprehensibly evidence patterns of thinking and representing problems logically, not just the accumulation of knowledge. The connection between this evidence and the pupil's activity forcefully points to the authenticity of UI as being an actual record of pupil learning. The following account taken from the in-class survey, study participant 23 provides a basis for this reasoning:

"Posting comments makes you create more ideas, redesign them and not just stick with your first idea, like I normally would have. Your posts tell a story of your project."

Interestingly the pupils' choice of language suggests that they see the design process as a product in itself which challenges traditional classroom practice and contemporary models of educational pedagogy where a made artefact is often the main outcome of learning. It is important to note that the theoretical knowledge and practical skill central to the quality of pupil learning and efficacy of teacher pedagogy was not undermined. Figure 2 presents the pupil's response to the level of time engaged in each of the four processes outlined by the methodology (construct, capture, communicate, cogitate) and posting comments. To ensure that all survey items were interpreted correctly pupils were typically asked to rate activities such as 'reflecting on design ideas'. In terms of this study, this was categorised as the process 'to cogitate'. The data indicates that all categories are positively disposed and that pupils were doing more thinking than anything else. The indication is that as a result of the anytime, anywhere opportunities for interaction pupils can take advantage of more think-time. As suggested by study participant 18 (quotation transcribed from study focus group):

"You think about the work you are doing even when you're not in class."

According to Swan and Shih (2005) asynchronous interaction affords pupils the opportunity to reflect on their classmates' contributions while creating their own, and to reflect on their own writing before posting it to articulate coherent and logical responses. That is, pupils have the choice of private reflection equitably balanced with interaction in the public sphere.

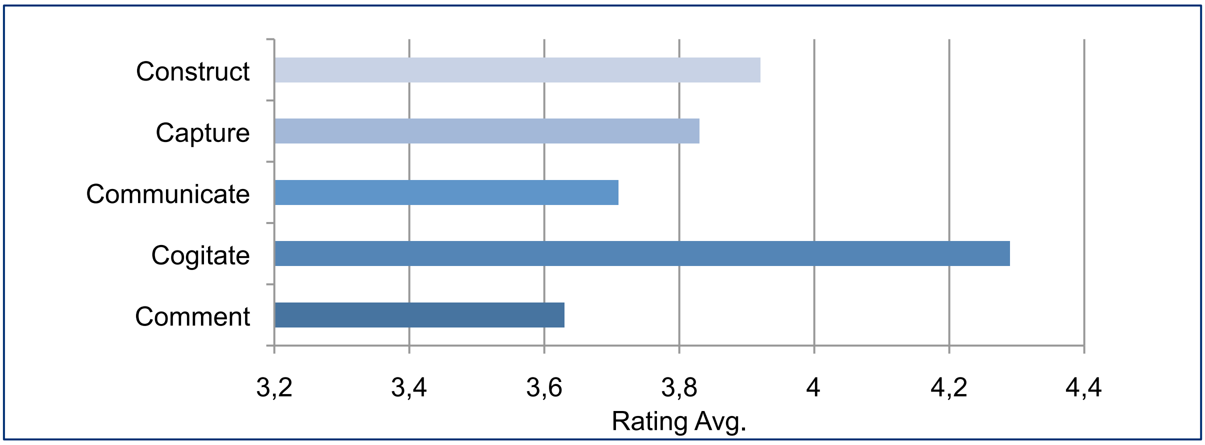

Figure 2. Average pupil engagement ratings in activity based processes

Although the context of this research is set within D&T the processes outlined by the methodology are more about doing, thinking, feeling and watching, i.e. features of experiential learning (Kolb, 1984). The suggestion is that UI represents a process of "learning from experience". Accordingly, this research proposes the *'experiential'* domain. It is posited that this domain which has at its core an adaptive educational transaction and requires pupils to construct, capture, communicate, and cogitate evidence of learning, begins to hypothesise a model for the conceptual genesis of UI in a ubiquitous environment.

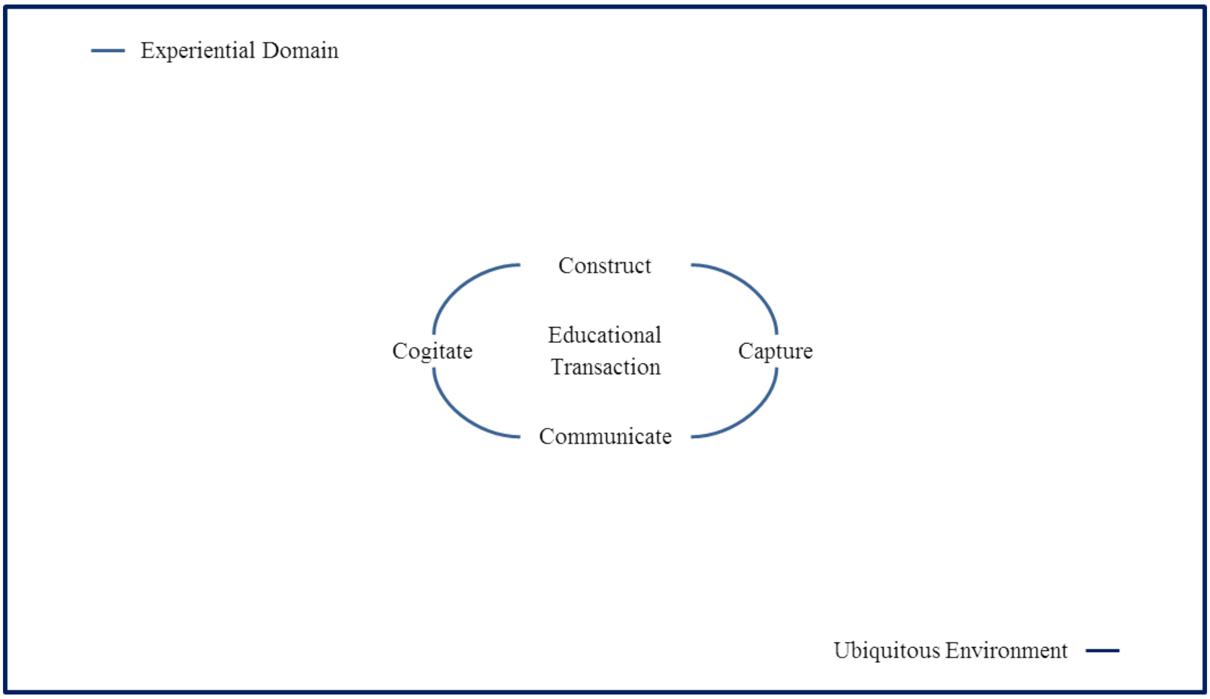

Figure 3. The experiential domain of ubiquitous learning

Discussion

The integration of UI in traditional classroom practice stimulated the creation of qualitative and quantitative knowledge and promoted increased periods of reflection while operating within the proposed experiential domain. It is suggested that UI can begin to describe and map learning as evidence-based progress through each stage within the domain (construct, capture, communicate, cogitate) in the direction of knowledge and understanding. This study demonstrates that UI through each stage reflects new knowledge, linked to existing knowledge, and deeper understandings are developed from, and take the place of, earlier understandings. The aim of this approach is to move pupil understanding along a path of increasingly complex knowledge, by focusing on pupil's readiness to learn, and building upon their current stage of understanding. This paper suggests that by integrating UI and the experiential domain we can begin to trace the complex and fundamentally non-linear nature of activity-based learning such as the educational transactions from initial conceptualisation, to the moment when knowledge becomes the learner's intellectual property. In this model the traditional boundaries of education become blurred and new configurations for learning become possible. UI gives pupils the opportunity to think about their learning before, during, and after regular scheduled class time, establishing a ubiquitous learning environment. Finally, the following extract transcribed from the study focus group, study participant 20 begins to suggest why the interactions that occurred can in fact be deemed as ubiquitous:

> "It's a new way of connecting with friends. You could post updates and people could comment on your work just like Facebook. I feel that it made people more interested because it was something they were familiar with, and they were comfortable with it."

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Opportunities to grow and sustain technology and engineering education in the US

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Abstract

The field known today in the U.S. as technology and engineering education has been in decline for more than four decades. The purpose of this paper, presented from an American perspective, is to introduce the reader to the profession, briefly discuss reasons for its decline and then present a discussion on opportunities to grow the profession into a sustaining well-known and well-respected discipline.

Keywords

Technology and engineering education, decline of technology and engineering education, growth opportunities for technology and engineering education

Introduction

Today in the United States of America (U.S.) the discipline known as "Technology and Engineering Education" is focused on teaching and learning in a variety of topics, concepts, principles, and practices in areas related to technology and engineering. The discipline has a long history and can trace its roots back to the late 1800s and educational movements in the areas of vocational and industrial education. Early names associated with discipline included "manual training" and "manual arts" (Foster, 1997).

In the early 1900s the discipline evolved into "industrial arts" which was intended to provide the general population with an expansive education covering the industrial world (Putnam, 1992). In the U.S., industrial arts programs, that often focused on industrial skill development and career awareness, flourished into the 1970s and mid-1980s.

In the 1970s a U.S. society based on information and technology began to emerge and the profession saw a need to change the curriculum to better reflect the times. This change was reflected in the publication of the Jackson Mill Industrial Arts Curriculum Theory document that emphasized teaching in the areas of manufacturing, communication, transportation, and construction (Snyder & Hales, 1981). This new philosophy led to the field changing from industrial arts to technology education in the mid-1980s.

With the change to technology education, the major professional association dedicated to technology education (i.e., known today as the International Technology and Engineering Educators Association – ITEEA) began to create a rationale and structure, standards, curriculum, and assessments for the teaching of technology. In 2000, the profession released the *Standards for Technological Literacy: Content for the Study of Technology* (ITEEA, 2000/2002/2007) that defined what students should know, understand, and be able to do in order to be technologically literate in grades K-12.

In the U.S. today there is a push at all levels of education to improve student learning in the areas of science, technology, engineering, and math (STEM). This push is being driven by the U.S.'s desire to stay globally competitive by building a solid STEM-educated workforce. It is a national agenda item that can be seen in President Obama's "Educate to Innovate" initiative that aims to provide students at every level with the skills they need to excel in the high-paid, highly-rewarding fields of STEM and to help move American students from the middle to the top of the pack in science and math achievement (White House, 2009).

The "push" for STEM education led the profession to again examine its mission, and in 2010 it changed its name to the International Technology and Engineering Educators Association's (ITEEA). The name changed for the ITEEA's desire to better position itself to deal with the 'T' & 'E' of a strong science, technology, engineering, and mathematics (STEM) education movement, and the need for a STEM educated workforce (ITEA, 2010).

Today, STEM education continues to grow in importance in the U.S. and the profession of technology and engineering education may be best positioned to prepare the K-12 teachers to teach the "T & E" of STEM. However, technology and engineering teacher education programs in the U.S. continue to decline, thus producing fewer teachers. As Litowitz (2014) notes, "technology and engineering teacher preparation programs across the United States have been in a state of decline for more than four decades. There are currently only 24 undergraduate technology & engineering teacher preparation programs in the U.S. with an enrollment of 20 students or more" (p. 80). This is not a good situation for the discipline and there are many possible factors as to why this is occurring.

The decline of technology and engineering education

There are many factors associated with the decline of technology and engineering education in the U.S., and this section will briefly review some of these "key" factors. These factors have been identified by the author who has more than 35 years in the profession and include the following:

- *Decline of Teacher Education Preparation Programs.* Litowitz (2014) notes of continual decline of programs in the U.S. supports the previous findings of Volk (1993; 1997). A lack of qualified teacher educators impacts many areas of the field, including those related to leadership, research, curriculum development and teaching innovations.
- *Inconsistent Teacher Education Preparation Programs.* As Litowitz notes, that among the programs reviewed, "there exists much diversity about what constitutes a required sequence of courses or curriculum to complete a bachelor's degree and earn teacher licensure" (p. 80). An inconsistency in teacher education programs hindered building an identity of the profession.
- *Lack of Qualified Teachers*. Few teacher preparation programs have created a shortage of qualified K-12 teachers and without qualified teachers, programs may be forced to close. However, there still exists a strong need for these teachers, especially those interested in teaching in some area related to pre-engineering.
- *Student Enrollment.* Lack of students enrolling in K-12 technology and engineering education courses can force administrators to make hard decisions as to the viability of a program. Lower student enrollment could be caused by many factors, including the push for students to take more academic courses, leaving little room in the schedule for elective courses, and by student and parent perceptions as to the importance of the course.
- *Cost.* At all levels of education, technology and engineering education programs are often more expensive than other school programs. Because of budget cuts, schools often look to eliminate or downsize expensive programs, especially those with low enrollment.
- *Curriculum:* The U.S. has no national curriculum. There is no consistency in technology and engineering course offerings among states and local school districts, and most will have a "mixture" of elective technology and engineering type courses available for students to take. The wide diversity of courses offered and curricula used hampered building an identity of the profession.
- *Leadership – State & Local:* At the state and local levels, there was often an individual employed as a "technology and engineering specialist or supervisor" who helped to guide, supervise and promote the programs. However, today it is often hard to find these professionals and they often wear "many hats" and furthermore may not have a strong background in the discipline (Moye, Dugger, & Starkweather, 2012).
- *Leadership – National:* The ITEEA and its affiliated councils are tasked to provide consistent leadership to the profession, even in challenging times. With fewer professionals, good leaders become harder to find and association and established council activities may suffer. In 2008, Wright, Washer, Watkins, and Scott completed a study that examined stakeholder's perceptions of technology education in public secondary education in the U. S. and found that national leadership had struggled for decades to define technology education as a "new basic."

- *Identity*. The term technology has so many different meanings and interpretations and this may have hurt the discipline in establishing itself an identity that is easily recognizable and understood. Compounding the identity crisis has been the lack of standardized technology and engineering curriculum and course offerings. Also, there are many other education organizations involved in promoting some aspect of technology (e.g., The International Society for Technology in Education).

Opportunities to grow and sustain technology and engineering education in the US

The above discussion identified many of the factors that may have caused the decline of technology and engineering education programs in the U.S. However, today as the world continues to change, there exist many opportunities that may help the profession grow into a sustaining well-known and respected field of study. The following provides a discussion on these opportunities.

STEM Education

STEM education is a national agenda, however, when discussing STEM education, it often refers to either science or mathematics or both, and seldom does the reference mean technology and almost never does it include engineering (Bybee, 2011). While math and science are clearly identified, defined, required, and supported subject areas in U.S., technology and engineering education are not. As Bybee (2011) notes, "while the nation is concerned about STEM education, the "T" is only slightly visible, and "E" is invisible" (p. 26).

To help grow the profession, it must clearly identify and show its value, relationships and significance in STEM education. This can happen by closely working with others involved in STEM education, for example on efforts related to joint curriculum and professional development efforts, as well as research efforts focused on best learning practice in STEM education. Connecting with STEM education can help build the profession's identity. It may also help to invigorate and grow established teacher education programs, and it may also contribute to establishing new programs.

The next generation science standards

Education standards most often identify the content and objectives or benchmarks of what students need to know and be able to do in the subject area, they are not a curriculum. In the area of K-12 STEM education, science, technology, and math have national standards, none have been written for engineering.

A recent development that may have great promise for the field of technology and engineering education is the release of the *Next Generation Science Standards* (*NGSS*). Released in 2013, the NGSS state a "commitment to integrate engineering design into the structure of science education by raising engineering design to the same level as scientific inquiry when teaching science disciplines at all levels, from kindergarten to grade 12" (NGSS, 2013, p. 1). This commitment to teach engineering design is admirable; however, the teaching of engineering design and its related content and practices has been a major tenet in the field of study technology for many years.

For those in the profession, the *NGSS* may represent an opportunity to help those in science education in developing curricula and professional development in the area of engineering design. In a recent study by Ames (2014) that looked at Utah's science teacher's preparedness to teach engineering design, it was found that secondary education science teachers in the State of Utah did not feel as prepared as they would like to be to teach the engineering design process in their science classrooms. Furthermore, getting involved with the science education community provides the profession with the opportunity to better convey the profession's identity, and it may serve as an avenue of attracting new teachers into the field which may contribute to program growth.

Professional involvement and leadership

To grow the profession and its programs will require that individuals involved in the field become actively involved in the discipline. Actively becoming involved means working with the local community as this can help to promote the profession. Active involvement also means getting involved in state and national professional associations that provide opportunities to present best practices and opportunities to get involved in leadership roles.

Those involved in leadership roles can best work to move the profession forward, for example by building strong relationships with the STEM community, including schools and advocacy groups. For example, in trying to build the national association, the ITEEA recently implemented a PreK-12 STEM membership program for elementary and middle/high schools and is involved with the Triangle Coalition for STEM Education that advocates for better STEM education across the U.S.

At the national level, professionals involved in the Council on Technology and Engineering Teacher Education (CTETE) and the Council for Supervision and Leadership (CSL) must "step-up" their efforts (e.g., in research and publications, curriculum development, and in recruiting members to the profession) to help the profession grow. Efforts such as the Foundation for Technology and Engineering Education (FTEE)/ ITEEA/CTETE 21st Century Leadership Academy that began in 2006 to develop emerging leaders in the field must be supported and expanded as these efforts can help the field grow.

At the state and local levels, qualified state supervisors and supervisors at the district level who have a deep understanding of the profession must be hired as they can help promote the field, and "fight" for its status in the schools. At the local level, technology and engineering instructors can help the field grow by developing "strong programs" that attract students by encouraging their "best" students to consider becoming technology and engineering teachers.

Identity

To grow the profession it must have a clear identity about what it is and what it does. Over the years the profession has changed its name to reflect current thinking and practice in society. Adding the name "technology" may have caused more confusion than helping the profession establish a clear identity. Recently adding the name "engineering" to the profession may help to better identify the profession, but more efforts will be needed as little was done to identify what should be taught or studied in the area of engineering. Opportunities to grow the field will require developing a clear identity that the public understands and by developing and promoting quality programs and standards that offer students similar experiences across the nation.

National student assessment in technology and engineering literacy

As part of the "*Nation's Report Card*" a national computer-based test began assessing students in the area of *Technology and Engineering Literacy (TEL)* in 2014. The *TEL* assessment was designed to measure three interconnected areas of technology and engineering literacy that included: (1) Technology and Society, (2) Design and Systems, and (3) Information and Communication Technology (NAEP, 2014). This national assessment helps to show the public the importance of technology and engineering literacy.

The new *TEL* assessment may prove to be very beneficial to the profession because the content assessed in the exam can best be taught by those from the profession. As a required assessment, more qualified technology and engineering teachers may be needed to develop and deliver curricula that address the major assessment areas in the *TEL*. Furthermore, the need for new teachers may help to spur new technology and engineering teacher education programs and help grow existing programs.

Partnering with STEM-Minded professionals

To help the profession grow and sustain, it must reach out to others involved in promoting STEM education (e.g., Engineer Girl, Expanding Your Horizons Network, the 4-H Youth Organization, MESA, and the Science Olympiad) to show them how the profession "adds value" to the "T & E" of STEM education. Reaching out to others can help add visibility, understanding, and interest to the profession. It may also help to grow student enrollments in technology and engineering education programs and attract new teachers to the profession. The following briefly presents examples of national organizations that the profession should view as opportunities to collaborate and develop sustaining partnerships.

Professional Education Organizations. In addition to the science and math professional education associations (i.e., the National Science Teachers Association [NSTA], and the National Council of Teachers of Mathematics, [NCTM]) those involved in the profession should look to other academic areas involved in STEM related activities education (e.g., agricultural and family and consumer science education). Furthermore, the Association for Career and Technical Education (ACTE) promotes career preparation and has divisions related to STEM education.

Professional Engineering Organizations. Engineering is an important component in STEM and those involved in the engineering profession have begun to reach out to those involved in K-12 education to help promote the discipline and provide assistance (e.g., curriculum materials) as needed. For example, the American Society of Engineering Education (ASEE) has a "K12 and Precollege Engineering Division" with more than 700 members who focus on the development and delivering of innovative K-12 engineering education curricula (ASEE, 2014). The IEEE is another professional association dedicated to advancing innovation and technological excellence and is the world's largest technical professional society and promotes K-20 STEM Education, for example, through its Integrated STEM Education Conference.

Advocates of STEM Education. As the importance of STEM education grows in the U.S., the profession should consider partnering with organizations involved in advocating STEM education. Today, around the country there are a variety of state and national organizations dedicated to advocating for STEM education. For example, many states promote and provide funding for STEM education in their State (e.g., see Utah's STEM Action Center, stem.utah.gov). At the national level, organizations such as the *Triangle Coalition for STEM Education* (www.trianglecoalition.org), the *STEM Education Coalition* (www.stemedcoalition.org) promote and advocate for STEM education, and the National Aeronautics and Space Administration's (NASA) education programs (www.nasa.gov/offices/education/about).

National curriculum efforts in STEM Education

To grow the profession, there are a number of national curriculum efforts in the area of STEM education that may offer opportunities for collaborations that can lead to strengthening the entire discipline, including building consistency in curricula and course offerings. In addition to ITEEA's *Engineering by Design (EbD)* (www.iteea.org/EbD/ebd.htm) curricula, two noteworthy national curriculum efforts in the area of STEM education include *Project Lead the Way (PTLW)* (www.pltw.org) and the *Engineering the Future* and *Engineering is Elementary* (www.mos.org/engineering-curriculum) that have been developed by the Boston Museum of Science.

Student organizations/national competitions

To help grow the profession, including attracting students to consider a career as a technology and engineering teacher, professionals in the field need to better collaborate with successful state and national student organizations involved in promoting STEM education. These student organizations, along with other organizations, are involved in developing and hosting national STEM competitive events. These collaborations could include attending state and national conferences and competitive events, becoming an advisor to the group, developing activities for the group, or becoming involved as a judge or advisor in student competitive events. Examples of major national organizations/national competitions involved in promoting STEM education would include:

- Technology Student Association (TSA) – (www.tsaweb.org)
- Skills USA (skillsusa.org)
- FIRST (For Inspiration and Recognition of Science and Technology) Robotic Competitions (www.usfirst.org)
- VEX Robotics Competitions (www.vexrobotics.com)
- Sea Perch (www.seaperch.org/index)
- Real World Design Challenge (www.realworlddesignchallenge.org)

A do-it-yourself culture

Today, there are many opportunities for the public to engage in hands-on activities. From craft projects, to cooking, to remodeling, to woodworking, people often engage in hands-on activities for a variety of reasons (e.g., for enjoyment or to learn new things) and this "Do-It-Yourself" culture is growing in the U.S.

As people's desire for hands-on activities continue to grow, especially in areas related to technology and engineering education, there may exist opportunities for the profession to reach out to this culture. Reaching out to this culture can help to inform the public about what the profession does and it may help to recruit new students into the profession. A very good example of a movement in the U.S. promoting a do it yourself culture is known as the "Maker Movement" where people come together at "Maker Faires" around the country to show what they have made and to share what they have learned (Maker Faire, n.d.).

Conclusion

From an American perspective, the purpose of this paper was to introduce the reader to the profession of technology and engineering education as practiced in the U.S. and to briefly discuss possible reasons for its decline. The paper then presented a discussion on opportunities to grow and sustain the profession. Professionals involved at all levels in the field are encouraged to investigate these opportunities as they may help grow the field into a well-known and well-respected field of study.

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Food technology education: preparation for life and work?

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Abstract

Food technology has been on the school curriculum in England for 25 years, but its purpose and value continues to be debated. Some argue that it should focus on developing pupils' practical cooking skills and, with increasing concerns over child obesity and health, contribute to them developing healthy lifestyles. However, with the food industry as a major employer in the UK, others argue that alongside cooking skills food technology should focus on developing pupils' knowledge and understanding of all aspects of food, including food science and social, political and economic food issues (Lawson, 2013; Rutland & Owen Jackson, 2013, 2014). This research considers the value of food technology from the pupils' perspective, asking if they think it provides preparation for future careers or more general life preparation.
This paper presents findings from part one of the study, based on the views of pupils and teachers in five secondary schools in England. The schools were selected on the basis of being known to the researchers and as teaching food technology GCSE examination courses for pupils aged 14 years and A Level courses for pupils aged 16 years. The results indicate teacher concerns regarding pupil numbers and, in some cases, the lower academic ability range of pupils choosing to study food technology. The views of the pupils indicate that they believe the food technology course will provide them with life skills for their future lives. However, there is a lack of understanding of the content, aims and breadth of food technology and its potential contribution as preparation for work. It is recommended that the nature of food technology is clarified and consideration given to the development of food-related courses in schools that focus clearly on addressing the needs and aspirations of all pupils.

Keywords

Food technology, life skills, food industry, school pupils, general education, careers

Introduction

Food studies have been on the school curriculum in England since the mid-nineteenth century, when it was taught to prepare girls for domestic work or housewifery. Despite many changes the subject has found it difficult to shake off this low status, utilitarian, view (Attar, 1990; Cockburn, 1991; Riggs, 1992; Lawson, 1993). In 1990 it was merged with other craft areas in 'design and technology' and renamed food technology (DES, 1990). However, there continues to be 'confusion about food technology's basic aims (Ofsted, 2006, p.5) and 'a lack of clarity about the relationship between the teaching of food as a life skill and the use of food as a medium for teaching D&T' (ibid, p.2). It was recommended that the nature of food technology should be clarified (2006) and recently that learning concerned with food technology should be more intellectually challenging and include 'designing, product development, empirical testing and applying mathematics and science' (Ofsted, 2008, p.5).

In England, the 2014 National Curriculum retained food within design and technology for pupils aged 5-14 years (DfE, 2013), but also introduced 'cooking and nutrition' for pupils in primary and lower secondary school. The requirements of cooking and nutrition can be met through the teaching of food technology but this requirement adds to the lack of clarity about the purpose of food on the school curriculum. Whilst pupils are expected to design and make with food ingredients, working in home and industrial contexts, they are also required to 'learn how to cook'. Learning how to cook is described as a 'crucial life skill' but the curriculum document does not make clear how this requirement aligns with the nature of design and technology as a whole. Nor is it clear how learning to cook, without an understanding of ingredients, food science, and modern food technologies will prepare pupils for their future lives or employment in the twenty-first century.

The teaching of food technology has been influenced by its inclusion in the design and technology curriculum, with pupils being asked to 'design and make' food products but often with limited underpinning knowledge and skills (Rutland & Owen-Jackson 2012a, 2012b). Many pupils enjoy the practical aspects of food technology but there is little evidence that the subject is contributing to their general education or preparing those interested for employment. However, with the revision of the design and technology curriculum and proposals for change to the examination courses for pupils aged 16 and 18 years (DfE, 2014) it is timely to review the contribution that food technology makes to pupils' education.

This research aims to consider the appropriateness of the food technology school curriculum as a contributor to pupils' general education and as preparation for employment. Previous research explored the content and views of teachers and pupils of food technology courses for pupils aged 11-16 years (Rutland & Owen-Jackson 2012a , 2012b, 2013) and the content of school and university food-technology courses and how appropriate they are as preparation for pupils' future life and employment within the food industry (Rutland, & Owen-Jackson, 2014).

The research investigates:

- Pupil motivation at age 14 and age 16 for selecting food technology as an examination subject
- The value of studying food technology to pupils' general education or as preparation for a career.
- Food technology teachers' views regarding General Certificate for Secondary Education (GCSE) and A Level General Certificate of Education (GCE) Food Technology.

Methodology

A mixed methods approach was used with quantitative questionnaires and qualitative semi-structured interviews. Pupils and teachers in five schools in across the UK (London, West of England and Sheffield) were selected on the basis of being known to the researchers and as teaching food technology examination courses for pupils aged 14 years and 16 years. The schools were located in suburban, inner city and rural areas in England.

Interviews were conducted by the researchers with one food technology teacher in each school. The interviews provided background and contextual information about the schools and the examination courses available to pupils. These results are shown in Table 1 below.

Questionnaires were given, either by the researcher or the class teacher, to Year 10 GCSE and Year 12 A-Level food technology pupils at the beginning of their two year examination courses. In total 113 GCSE and 37 A level questionnaires were completed, this was a 100% response rate. The questionnaires were analyzed quantitatively, with results shown in Table 2 and Table 3 below.

Findings

Table 1 shows the background and context within each school and the number of pupils surveyed as well as total numbers of pupils studying the subject.

School	GCSE courses available	No. GCSE pupils (14 yrs) surveyed	A level courses available	No. A-level pupils (16 yrs) surveyed	Teacher/department information
A	Food technology	13	Food technology	6	Head of Department (HoD) is a food specialist, has been at the school since April 2014. Plans to increase the number of pupils studying food technology. Good support from Senior Management Team (SMT).
B	Food technology	16	Food technology	0	Class teacher experienced food specialist. HoD experienced textiles specialist, supports practical food work but not industry-based work. First year that there has been no A-level course. SMT generally supportive.
C	Food technology. Two FT classes taught (38 pupils). Have previously offered Catering, this did not attract high ability pupils and has been discontinued.	19		0	HoD, food specialist. Thinks GCSE course now attracting pupils of lower ability. Tries to balance practical work with teaching wider food related issues. First year there has been no A-level course, previously numbers have been good.
D	Home economics: food and nutrition Three classes taught (60 pupils).	22	Food technology Offered each year but only taught when numbers are viable	12	Class teacher, experienced food specialist. SMT supportive, but likely because they are part of D&T; with curriculum revisions they are becoming more separate.
E	Food technology Two classes taught (43 pupils). Taught Home economics for one year but returned to FT. Offered Catering for one year but now discontinued.	15 28	Food technology	19	Class teacher, experienced food specialist. SMT supportive.

Table 2 shows, for each group of pupils surveyed their reasons for studying GCSE food technology or home economics. For questions one and two, pupils were given a list of responses and asked to tick as many as applied. Questions three to six were free responses.

The pupils were all studying English, mathematics and science together with a range of optional subjects, including food technology/home economics. We asked what other optional subjects were being studied and responses were so varied that there was no relationship between other subjects studied and interests in food technology.

School:	A	B	C	D	Ea	Eb	% of all pupils
Why did you choose to study GCSE Food Technology/Home economics?							
Just interested in food	6	11	15	16	12	25	75%
Want to study food technology at university	0	1	0	6	1	3	8%
Want to work in catering	2	0	2	3	4	4	13%
Want to work in food science	5	0	1	0	1	0	6%
Want to work in nutrition/dietetics	5	2	0	0	1	0	7%
Other ………………	Open a bakery. Enjoy cooking	Enjoy cooking		Loved cooking 4	Enjoyed it	Loved cooking 2	
What do you hope to learn from studying GCSE Food Technology/Home Economics?							
Learn more about food	3	4	4	10	6	19	41%
Learn more about nutrition	8	4	1	8	8	4	29%
Learn more about food science	1	1	0	3	2	2	8%
Learn practical cookery skills	8	14	14	20	12	24	81%
Other ………		Making food healthy	About food safety	Cooking a variety of foods			
What are you most looking forward to over the next two years?							
Learning about healthy foods	0	2	0	6	2	0	9%
Developing practical cooking skills	6	11	13	10	6	4	44%
Learning about the functions of food	0	0	3	0	0	0	3%
Learning about food science and how to combine flavours	0	0	0	1	1	2	4%
Cooking new and creative things	1	3	1	6	0	0	10%
Making new recipes	1	0	1	0	1	1	4%
Presenting dishes attractively	1	0	0	0	0	0	1%
Learning about nutrition	0	1	0	1	1	0	3%
Evaluating foods	1	0	0	1	0	0	1%
The most useful part of food technology/home economics is:							
Learning about food	2	2	0	0	0	0	4%
Developing our own ideas	0	0	1	1	0	0	2%
Practical work to develop cooking skills/different techniques	8	4	4	11	6	11	40%
Understanding the science behind and functions of food	2	0	3	0	1	0	5%
Understanding of nutrients and healthy eating	4	1	0	6	2	3	14%
Being more independent	0	0	1	2	2	0	5%
Organizing our time	1	0	0	0	0	0	1%
Health and safety/storing food hygienically	2	1	1	3	2	1	9%

Many pupils, 44%, were most looking forward to developing practical cooking skills, whilst 3% looked forward to learning the functions of food and only 1% evaluating foods. The most useful parts of the subject were considered to be developing practical cooking skills (40%), understanding about nutrients and healthy eating (14%) with only 5% thinking that an understanding the science behind and functions of foods was useful.

Question six asked pupils if they thought food technology/home economics would help them in their career. Thirty four percent of pupils said that they would not help them, for those who did, the emphasis was on working as a cook/chef (11 pupils, 10%), with others referring to careers in:

- working with children (6)
- doctor (5)
- dietician or nutritionist (4)
- ‘carer’ (2)
- an interest in science (2)
- midwife (1)
- nurse (1)
- developing products for a bakery (1)
- sports nutritionist (1) or sports physiotherapist (1)
- pharmacist (1).

Question seven asked if they thought the subject would help in their adult life and all responses (100%) were positive. The main reasons they gave related to cooking for themselves and their families, with 10 pupils mentioning cooking healthy food and 11 developing higher level cooking skills.

Table 3 shows, for each group of pupils surveyed their reasons for studying A-level food technology. As with the GCSE questionnaires, for questions one and two pupils were given a list of responses and asked to tick as many as applied. Questions three to six were free responses.

School:	A	D	E	% of pupils
Why did you choose to study A Level Food Technology?				
Just interested in food	6	10	16	87%
Want to study food technology at university	2	0	1	8%
Want to work in catering	0	0	0	0%
Want to work in food science	1	0	0	0%
Want to work in nutrition/dietetics	0	6	2	2%
Other ………………			Be a food technology teacher Work in food & sport	
What do you hope to learn from studying A Level Food Technology				
Learn more about food	2	7	9	68%
Learn more about nutrition	5	10	10	95%
Learn more about food science	2	3	4	32%
Learn practical cookery skills	5	6	10	73%
Other ………				
What are you most looking forward to over the next two years?				
Going into the science of food in more depth	1	0	0	3%
Studying food and nutrition later at university	1	1	2	11%
Learning to cook different foods	1	4	2	19%
Developing more skills	1	4	2	19%
Learning about nutrition	1	1	1	8%
Taking part in a local cooking challenge activity	1	0	0	3%
The most useful part of food technology is:				
Learning about food and food science	2	0	1	6%
The functions of food and nutrients and how they work in the body	3	4	10	46%
Cooking different things	1	2	4	19%
Practical skills of cooking	3	8	8	51%

The A Level pupils were most looking forward to learning to cooking different foods (19%) and developing more skills (19%). There was limited interest in, or a lack of understanding of, the importance of going into the science of food in more depth (3%). The most useful parts were considered to be the practical skills of cooking (51%) and the functions of foods and how they work in the body (46%), with only 6% thinking that learning about food and food science was useful.

When asked if they thought A-level food technology would help with their career, 10 thought that it would not, 11 were unsure as they had not yet decided on a career path and 17 thought that it would be helpful. Those that thought it would help referred to possible careers in:

- being a nutritionist (5)
- psychology looking at people's eating habits and how this affects their life (3)
- being a personal trainer (1)
- being a primary teacher (2)
- studying food at university (1)
- being a pharmacist (1)
- teaching food technology teacher (1)
- running a business (2)
- being a chef (1).

All the pupils thought that the subject would help them in their adult life, mainly due to being able to cook for themselves and their families. Six pupils also referred to cooking healthy or nutritious meals and seven that cooking was great skill to have. A small number of responses mentioned that it may provide job opportunities (1) with only one mentioning the possibility of opportunities within the food industry.

Discussion

We acknowledge the limitations of this study as the numbers surveyed were small. However, these findings are likely to resonate with other teachers and pupils as, anecdotally, similar views are expressed elsewhere.

The interviews with the teachers showed that the context within which food technology is being taught in schools is changing. In School D, when food technology was no longer compulsory (2004) the number of pupils choosing to study it reduced; they now have more pupils choosing Food & Nutrition than chose Food Technology. The teachers also believe that this GCSE provides pupils with a 'better match' to the A-level course which follows. School C and School E had also offered alternatives to food technology in order to attract more pupils but had reverted to food technology. In School C this was because alternative courses did not attract the academically-able pupils and in School E a course in 'catering' was not popular with parents as it was not considered sufficiently academic. The teacher thought that the GCSE course does not have sufficient nutrition content, lacks clarity on how to design with food and contains too much emphasis on industrial practices but it has proved popular with pupils and parents. In the past, some pupils from School E have progressed to food-related degree courses at university, especially nutrition.

The teachers expressed concerns about pupil numbers in recent years and related this to changes at national level making food technology an 'entitlement' rather than compulsory (DfES & QCA, 2004). Also there has been a government drive, fuelled by the 'obesity' crisis, to make it compulsory for all pupils to learn to cook. This has put pressure on teachers who not only value that pupils learn to cook in food technology but also value the teaching of scientific, technical and technological understanding within a wider context. This includes learning about the underpinning science of food, cooking and nutrition, existing and new technologies, sustainable development of local, national and global food supplies, together with an appreciation of the impact of consumers, food industry and government agencies in monitoring, regulating and developing the foods we eat (Rutland, 2010).

The findings of this research are important because the government is proposing to remove all current food-related GCSE examinations and replace them with GCSE Cooking and Nutrition (DfE, 2014). The proposal takes aspects from current examinations in food technology, home economics, food and nutrition and hospitality and catering and attempts to combine them in one examination. The findings of this research suggest that this would be considered academically unsuitable for some pupils. It would have breadth but lack depth in crucial areas such as related science and technology, would attract pupils of lower academic ability and would not prepare pupils for work in the food industry, other than catering.

The pupil responses show that they chose food technology mainly because they are interested in food, 75% at GCSE and 87% at A Level. This is also reflected in the finding that they hoped to learn practical skills, 81% at GCSE and 73% at A Level. Whilst practical work is of value, pupils, especially at

GCSE level, do not appear to appreciate that food technology also includes nutrition (GCSE 29%, A level 95%) and food science (GCSE 8%, A level 32%).

There seems to be limited interest in studying food technology as preparation for a career; at GCSE level 7% want to work in nutrition/dietetics, 6% in catering and 6% in science. At A-level, it is surprising that only 2% refer to work in nutrition/dietetics as pupils study only three or four subjects at this higher level and there is usually a correlation between the subjects studied and career or higher education aspirations. The food and drink industry in the UK is one of the largest manufacturing sectors, yet the pupils seemed unaware of the possibilities of careers within the food industry. Those pupils who expressed an interest in a food-related career referred mainly to catering work, and the lack of science subjects studied by pupils at A-level would limit their opportunities within the food industry. These findings are complemented by Turner (2012) who comments that many schools in Australia struggle to identify the differences between food technology as science based and food hospitality as a vocational focus. This would suggest that food technology courses need to be reviewed and their content clarified in relation to the pathways pupils might follow later in careers and higher education (Rutland & Owen-Jackson, 2014). It also highlights the need for more information for pupils about the range of potential careers available in the food industry.

There is little further recent research that we are aware of which focuses on food technology within design and technology. It would appear that there is still confusion about food technology's basic aims (Ofsted, 2006) and a lack of clarity about the relationship between the teaching of food as a life skill and the use of food as a medium for teaching design and technology. Bielby (2005) noted that there has been limited research into the food curriculum and that it had been significantly influenced by examination requirements emphasising 'designing' rather than the development of food preparation knowledge and skills. She highlighted gaps in the take-up of examination school courses and food-related courses in higher education and concluded that food technology has retained many important aspects of food education; including the origins of food and the scientific principles related to food preparation. Though, there has been an overemphasis on industrial food production rather than a critical overview of the food industry.

Overall, in England there seems to be a lack of understanding of the nature of food technology, its potential contribution to pupils' general education and preparation for employment. This research indicates that pupils' expectations are that food technology will teach them to cook and prepare them for a career in catering but they seem unaware of the wider possibilities of a broader understanding of food and its related issues.

Summary

This research has highlighted the continuing lack of clarity around the nature of food technology and its purpose in the school curriculum. We believe that, as it currently stands, the subject contributes little to pupils' education and that the broadening of the food technology curriculum would make the subject more appropriate for pupils' general education, better prepare them for citizenship in the twenty-first century and would open up career opportunities in the food and drink industry. There is a need for the clarification of course content and for examination courses to be more intellectually challenging and designed to meet the needs of three distinct groups of pupils: those intending to go onto higher education in food studies, those wanting careers in hospitality and catering and those wanting careers in nutrition and dietetics. The views of students and admissions tutors in higher education should be gathered to consider the relevance and appropriateness of the current food technology school based courses as entry requirements to food related courses at university. Pupils wanting to learn to cook and develop 'life skills' could be offered courses which sit outside of the school examination curriculum. Food education has an important remit in the twenty first century and courses should be available in schools to meet all pupils' needs and aspirations.

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Swedish teachers' views of assessing technological systems in compulsory school

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Abstract

Technology education is regarded as a new school subject in comparison with other subjects within the compulsory school system – both nationally and internationally. As such, the practice of teaching and assessment in technology lacks the long-term experiences that other teachers within other subjects can use in their own practices. This becomes especially apparent when technology teachers assess students' knowledge in and about technological systems. Studies have shown that technology teachers lack experience of and support for assessment. Consequently, technology teachers' (implicit) experiences constitute a crucial factor in the making of the course design and shaping students paths to knowledge about technological systems.

This paper describes the assessment views of five technology teachers and their elaborated thoughts on valuing systems knowledge for students aged 13 to 16 in the Swedish compulsory school through the use of semi-structured qualitative interviews. The research aim is to describe the teachers' assessment views in terms of types of knowledge, spanning from basic to higher understanding of technological systems. Six focused areas of interest when the teachers assess knowledge about systems are presented. The teachers experienced three levels of understanding - basic, intermediate and advanced. In conclusion, the gap between basic and higher levels of understanding can be defined as a linear, uni-dimensional understanding of systems on a basic level, but a non-linear, multi-dimensional understanding on both an intermediate and advanced level.

Keywords

Technological systems, assessment, teachers' views, compulsory school

Introduction

The process of determining what students on different levels understand and do not understand at a particular moment of teaching is overall a difficult teacher task, but even more so for technology teachers. With the emergence of a technology subject with its own syllabus within the Swedish school curriculum in the mid-1990s (Skolverket, 2006), a new practice of assessing knowledge about technology presented itself. Earlier perspectives on and about technology attributed different and more established contexts – technology as a vocational elective subject within the upper secondary school in 1960s – 1970s, and technology as a compulsory subject related to natural science subjects in the 1980's (Hultén, 2013). As a newly formed subject with its own curriculum, the technology subject both lacks identity and a tradition (Blomdahl, 2007), something that heavily affects the assessment practice (Kimbell, 1997). This consequently strains the technology teachers' abilities to design and evaluate his or her formative and summative teaching approaches to accommodate the students' specific levels of understanding (Kimbell, 2007).

Adding to the complexity of assessment in technology education, the overall school curriculum tends to divide the teaching and learning practice within subjects into a theoretical and practical part, where theoretical knowledge is tested by written examinations and practical (procedural) knowledge by examining skills of craftsmanship together with organizational abilities (Bjurulf, 2013). Recent research in Sweden by Klasander (2010) and Svensson (2011) has shown that this is particularly has a negative impact on the compulsory school subject of technology as the absence of a "holistic perspective" weakens the teaching and learning about technological systems as knowledge about these require conceptual understanding in terms of historical context, man-machine relationship and principal complexity of the systems internal and external interactions.

Too further problematize the complexity of the teaching of technological systems, there are different aspects and definitions of what "technological systems" are, for example Soft System Methodology (SSM) that illuminates the human and social contributions to a technological system (Checkland & Poulter, 2010) and System Dynamics that focuses on complex systems over time where feedback loops and time delays alter the behavior of a technological system (Karnopp, Margolis, & Rosenberg, 2012). Although both examples illustrate different system thinking about technological systems, they do not explicitly include perspectives suitable for the teaching about system where the students are trained and prepared to be skilled users and technologically conscious members of society, capable of critically evaluating technology and its social implications (Feenberg, 2006; Hagberg & Hultén, 2005; Keirl, 2006; Michael, 2006; Peters, 2006). The gap between the understanding about technological systems on a professional level and suitable level for teaching within the compulsory school system still exists. In addition, there is also an artifact-driven perspective (Bjurulf, 2013) on technological systems that still lingers within the latest school curriculum (Skolverket, 2011b), consequently leading to what can be called a lost systems perspective within the compulsory school (Klasander, 2010).

The late introduction of technological systems as educational content has therefore led to a situation where these have not yet received an adequate stronghold within the compulsory school technology subject. In regard to the assessment practice, it becomes even more evident that the value-based views on knowledge that teachers use in their assessment practice (Kimbell, 2007) needs to be further explored. The following descriptive and explorative research questions were therefore created to provide insight into compulsory schools technology teachers' assessment practice:

1. What types of knowledge do Swedish technology teachers within the compulsory school say they focus on in their assessment about technological systems?
2. How do the technology teachers value the students' understanding of technological systems in regard to their own defined levels of basic, intermediate and advanced understanding?

Method

Assessment practices derive information about students' different degrees of understanding from the combined systematical use of formative and summative validation (Karlsson & Grönlund, 2011). This information and its highly value-based nature forces teachers to reconcile how they value knowledge (Kimbell, 2009), using their implicit understanding about technology and overall assessment practice to construct teaching within the technology subject (Dow, 2006).

Consequently, in accordance with the presented explorative and descriptive research questions, qualitative interviews were chosen as the preferred method for data collection. As different interview techniques present either more open (un-structured) or closed answers (fully structured), semi-structured interviews allows the informants to elaborate their answers within a structured discussion framework with adjusted delimitations (the interviewer has the option to present follow-up questions within the discussion framework to allow more elaborated answers). Follow up questions form an opportunity where a smaller selection of informants can contribute to larger amounts of qualitative data about their teaching practices (Bryman, 2002; Denscombe, 2000; Kvale, 1994).

The study

In the spring of 2014 (March-April), nine (9) technology teachers from three regions in Sweden (Småland, Östergötland and Södermanland) were asked to participate in a pilot study regarding knowledge assessment within compulsory school technology education (for the ages of 13 to 16). Out of these nine teachers, six chose to participate and five interviews were later fully transcribed in their entirety. The five completed interviews varied between 50 and 90 minutes each in length, and each interview began with orally presented information about the pilot study. Written information was also presented before the interviews through an e-mail describing the purpose of the interview and the contexts in which the interview responses would be used.

Of the interviewed teachers all had formal teacher education, but only two had a teacher's certificate for teaching technology in the compulsory school (the rest had a certificate for teaching natural science). For this paper, the teachers' identities were anonymized and received the following fictitious names:

- Anna, certified technology teacher
- Bertil, uncertified technology teacher
- Carl, certified technology teacher
- Daniel, uncertified technology teacher
- Erik, uncertified technology teacher

The collected data from the interviews formed well over 5 hours of audio data (recorded via a digital video camera), and the word-by-word transcriptions reached approximately 44.000 words including interview questions and informants' responses, using the software InqScribe (for audio transcriptions). From the transcriptions, a dataset of approximately 4.500 words was constructed using the software MAXQDA (a qualitative analysis software) containing the valued views of knowledge in regard to the teachers' experienced levels of basic, intermediate and advanced levels of technological systems understanding, which was used to structure and code the data. The dataset, containing quotes from the interviewed technology teachers, was later used for a thematic analysis according to the step-by-step method described by Braun and Clarke (2006).

Findings

The informants gave a span of general and detailed information regarding their views on assessment and what knowledge was assessed in their teaching. Using the interview guide, it was possible to directly ask the informants what types of knowledge was relevant for their teaching as they all had experience from grading students within the later years of the Swedish compulsory school. Later, in an effort to derive explicit information on how they valued different aspects of knowledge about technological systems, the interview focused directly on what they perceived of as appropriate knowledge for grades E, C and A in the Swedish grade system (Skolverket, 2011a; Swedish National Agency for Education, 2014). Because the informants related relatively freely to the grading criteria, we here refer to their statements about grading levels as basic (grade E), intermediate (grade C), and advanced (grade A) levels of understanding about technological systems.

Teachers' views of a basic level of understanding technological systems

Anna recollected that in the past school year, she and her colleagues focused on larger socio-technological systems in their teaching about technological systems, and that they used a local context - the local water treatment plant in their home municipality - as the primary learning object. Anna and her colleagues sought to teach the students the consequences that might occur when the wastewater reaches the fresh water and that the wastewater must be clean and treated or the fish could die from the exposed contamination caused by the unclean water. However, she emphasized that the students did not need to fully understand the contamination process from untreated waste water to the killing of water life in the municipal lake. She explained that on a basic level, only the effects not the causality should be understood.

Bertil had a similar point of view regarding simple causality and the effects of technological systems. According to him it is more important for the students to know the consequences and social impacts of systems rather than understanding a system's internal structure or how a system relates to other systems. Carl took it to a slightly higher level when he mentioned in his interview that the system consequences should be highlighted and discussed with the pupils, that is, whether a system and its implications are beneficial or counter-beneficial to individuals, society, and the environment.

When asked about the technological system's internal structure, Anna told us in her interview that a certain amount of central components within a technological system could be required on a basic level of understanding, but not necessarily how they interact with each other. Carl had a similar point of view regarding component interaction as knowledge on an advanced level.

Teachers Bertil and Erik stated in their interviews similar views regarding components and their overall functionality. Erik also saw a possibility for the students to express their understanding about rudimentary key concepts about technological systems - consequences, components, impact on individuals, society and the environment - through the use of graphical non-verbal communication (drawings). The reason Erik uses drawings as a central assessment tool is that sketches and illustrations mediate more information from certain students, especially recent immigrants, who do not have Swedish as their mother tongue.

In the interviews, only one teacher diverted from the other teachers' statements. Daniel had a different view on basic knowledge about technological systems, and he explained in detail that knowledge about mechanics, inclined planes, levers et cetera are key concepts that his students must learn in the discourse of technological systems. He exemplifies with how the bottle opener works, and how air pressure and different types of forces can be used. This was the only direct misconception about technological systems presented in the interviews.

Teachers' views of an intermediate level of understanding technological systems

Where Carl sees the ability to value the consequences and impacts of technological systems on individuals, society, and the environment as basic knowledge, Bertil values such discourses on a higher, intermediate level. The only difference, explains Bertil, between an intermediate and an advanced level of understanding is the way that the student discusses the upside and downside of technological systems in regard to consequences. He also adds in the interview that the student should be able to determine, or at least be able to see, the internal flows that run through a system from input to its output, on an intermediate level. When a student turns on a faucet, he explains, he or she should understand the different stages that flow of water takes – from a lake, through a water plant, through a filtration process, and later on out of the water tap.

In contrast to the basic level, on an intermediate level Anna and her co-teachers in technology education explicitly use construction of physical models to visualize real technological systems as the basis for students' learning about systems. Factual knowledge about a technological system is enough on a basic level, but on an intermediate level the students are required to discuss a real technological system in relation to their own constructed model. From the own model, the student is expected to show key elements, such as flows and components, and relate the model to the original real world technological system, most often the local municipal water plant.

Daniel had some difficulties determining a suitable intermediate level for students' understanding of technological systems. Carl expressed in his interview a clearer connection between natural science and technological systems as regards the consequences that a technological system might cause. In the interview he emphasized that on an intermediate level of understanding the students should be able to discuss the impacts of carbon dioxide on society and nature as well as on the individual.

Teachers' views of an advanced level of understanding technological systems

To reach an advanced level of understanding, Anna explained that she required the students to present a holistic view on a technological system, setting the system both in a local and global context together with a more profound understanding of how a system interacts with individuals, society and different aspects of the environment. As Anna and her colleagues center their teaching about technological systems around physical models of real world systems, she explains that students with an advanced understanding are able to discuss beyond the model, and that they can also see a technological system as both a complete system and as a subsystem to an even larger technological system. Daniel presented a similar view; students with an advanced understanding must be able to move between different systems using common interaction points.

Erik, on the other hand, values the vocabulary of technological systems the highest, and a student that can use specific concepts about systems on an abstract level are considered as advanced. He concluded his views on knowledge and assessment with saying that he has great difficulties in grading students on higher levels of understanding beyond the basic and intermediate levels.

Of the interviewed teachers, only Carl spoke explicitly about using conceptual system models as tools to understand a technological system as well as the relationships between one system and other systems. This perspective differs somewhat from Anna's teaching about technological systems where she focuses on one system and its local to global consequences, while Carl searches for the students' ability to understand the common denominators of technological systems so that the students also can understand other systems than the ones the classroom setting brings up.

In contrast to the other teachers, Erik also values historical context as important for an advanced understanding about systems. The student should be able to see the technological system from a historical, present, and future perspective, as well as being aware of the driving forces, needs and wants behind the development of a technological system.

Conclusion

The interviews showed that the teachers focused on several areas in their assessment of students' skills and knowledge about technological systems. The most prominent areas are: (a) the systems structure in regard to components and flows, and (b) the systems implications and consequences on the individual, society and environment. Anna exemplified clearest in her teaching when she and her co-teachers made the students study a socio-technological system (water plant) within the local municipality and later on construct a physical model (replica) of the water plant, consistent with the perspective of Carl Mitcham (1994) and his view on technology as man-made objects – and also as mediating artifacts (Säljö, 2014). In relation to implications and consequences, Daniel exemplified a clear connection between technology and natural science when he claimed to assess the students' understanding of a technological system's biological and chemical implications for the environment. Visualizing systems thinking through the use of (c) physical constructed models was something that Anna and Erik had in common in their own teaching. Anna had the students make replicas of socio-technological systems, and Erik used drawings of systems to allow the students to mediate their system understanding. These activities correspond with the viewpoint of technology as an activity (Mitcham, 1994) . Utilizing (d) a vocabulary of systems terms was something that Anna, Carl, and Erik explicitly focused on in assessing students' knowledge about systems. This concerned being able to discuss technological systems with a set of correct terms as "input", "output" and "flow", and enabled the student to also see (e) similarities between one system and another, two areas that share the perspective of technology as knowledge (Mitcham, 1994), as well as also the aspect of a "control engineering" language (Klasander, 2010). Carl spoke mostly about this in his interview, the ability to see similarities between systems through the use of a systems model, an ability that both Svensson (2011) and Ingelstam (2002) see as a key factor in developing an understanding for technological systems. The final focused area of systems, (f) historical context and technological change, was something that only Erik brought up in the interview, an area that corresponds with the aspect of technology as volition, i.e. historical context and development tells us about (the human) will behind the technology.

Regarding the valuing of skills and knowledge about technological systems, the derived six focus areas from the interviews had different weighing when the informants were asked to explicitly explain their assessment process (see table 1).

	Linear	Non-linear	
Focused areas	**Basic** *(related to grade E)*	**Intermediate** *(related to grade C)*	**Advanced** *(related to grade A)*
The systems structure in regard to components and flows	Mostly input and output	Focus on component interaction and flows	Able to see subsystems
The systems implications and consequences for the individual, society and environment	More local perspective	Discourse through natural science	Local and global impacts
Physical constructed models	In regards of input/output	Focuses on the accuracy of the model	Able to speak "beyond the model"
Vocabulary of systems terms	Few system terms	Some system terms	More system words
Similarities between one system and another			Through the use of physical constructed models
Historical context and technological change			Yes

Table 1. Levels of understanding technological systems

The basic understanding (in relation to grade E) of technological systems consisted of having a rudimentary (one dimensional) linear perception of the systems functionality: an input, a specific flow and an output. Anna spoke of the students' understanding of a water plant, from a lake's freshwater, through the water plants filtering process and out through the household taps as potable water. Erik used a similar analogy (local water distribution) of a technological system and on a basic level the students should be able to depict a water distribution system using at least linear (one-dimensional) explanation. On a basic level, the students should also know of the implications and consequences that a system has on individuals, society and environment, something that both Bertil and Carl focused on in their teaching.

Intermediate and advanced (grade C and A) level of understanding shared the similarity of the students' ability to discuss and present his or her knowledge about technological systems in a non-linear, multidimensional way – consistent with the "control engineering" language use of "system significants" (Klasander, 2010). Carl focused on this in his assessment, especially on how his students discuss differences and similarities of technological systems using a vocabulary of system terms – but also to be able to understand internal components' relations to each other.

All informants shared the experience of having difficulties in grading students' intermediate and advanced levels of understanding. Even if the focused areas were a part of their teaching, in practice their main assessment evaluated knowledge consistent with a basic (grade E) level of understanding.

In conclusion, the six focused areas could be regarded as explicit abilities that technology teachers can use for assessing students' knowledge about technological systems.

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Cognitive load as a key element of instructional design and its implications for initial technology teacher education

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Abstract

One of the core aims of contemporary technology education is the development of advanced and flexible problem solving skills. These skills are highly desirable given the rapidly evolving societal context in which pupils live. The capacity to engage with ill-defined problems where multiple solutions are possible, necessitates the development of robust mental models of problem solving (Jonassen & Strobel, 2006).
Given this context, the nature of instructional design is of paramount importance. This is especially true in the context of technology teacher education where it is expected that student teachers develop effective technological problem solving aptitudes and as a result develop associated pedagogical content knowledge.
How students conceive problems and assign cognitive resources is dependent on the propositioned learning task. The work of Sweller, vanMerrienboer, and Paas (1998) discuss cognitive load as a further consideration which is often overlooked that may impede learning performance. This study explores the impact of task design (considering cognitive load) on problem solving efficacy using the abstraction of theoretical principles. Two separate experiments were carried out with a group of year three Initial Technology Teacher Education (ITTE) students (n=118). The method employed a positivist style comparative study where task designs were manipulated under formulated hypotheses to observe any differences in cognitive load and the associated performance.
The findings illustrate that, in general, students displayed a low-level of efficiency in solving the specific tasks in the experiment, which were directly related to their course of study. Low efficiency is indicative of high mental effort in addition to low levels of performance. This research highlights the importance of balancing the requirements of extraneous load while facilitating an increase in germane and intrinsic load, which supports effective learning. The design of tasks for the purpose of effective learning must take cognisance of the implication for cognitive resources. This research presents empirical evidence that can be used to inform a scientific approach to learning task design.

Introduction

The development of robust problem solving skills among students is one of the most important focuses of contemporary education. Problem solving competency is a necessity in contemporary society especially given the broad and rapidly evolving nature of knowledge and its application (OECD, 2014). Technology education offers an ideal forum for the development of problem solving capabilities (Williams, Iglesias, & Barak, 2008). One of the unique characteristics of technology education is the use of design based activities for the purpose of learning (Kimbell & Stables, 2008). When placed on a continuum of development, design activities lie at the higher end where tasks become permeable and multiple solutions are possible. The work of Lane and Seery (2011) demonstrated the critical supportive role freehand sketching plays in building mental libraries, which are necessary for successful engagement in these higher-level problem-solving tasks. In order for students to perform at this high level, it is first necessary to ensure the appropriateness of the task, before considering the development of these skills within the defined problem solving competencies.

Developing problem solving knowledge

One of the primary requirements for advancing students capacity to engage with higher-level problem solving activities is the development of robust mental models of problem solving (Bogard, Liu, & Chiang, 2013). These mental models refer to the various knowledge and beliefs of use within the problem solving process such as *"structural"* and *"performance/procedural"* knowledge among others (Bogard et al., 2013; Eysenck & Keane, 2010). The optimal manner in which students' mental models of problem solving can be developed and strengthened is to engage them in the solving of various types of problems (Jonassen & Strobel, 2006). Aligning with constructivist educational theory it is necessary to consider the appropriate scaffolding of problem solving activities to facilitate this development. Kimbell (1994) discusses the development of core knowledge through the movement from closed to permeable tasks. Focusing specifically on developing problem solving skill, this can involve progression from convergent (well-defined) to divergent (ill-defined) style problems (Delahunty, 2014).

Potential deficiencies in student problem solving capabilities

Within the pertinent literature, there exist a number of studies citing potential areas of concern in students' ability to solve problems. This spans both second and tertiary level contexts. McCormick (2004) discusses the overemphasis certain teachers place on specific problem solving procedures during their pedagogical practice. This has the negative effect of promoting *"ritualistic"* approaches to solving problems on the part of the students (Ibid). This type of practice can often occur in the face of external pressure such as terminal examination requirements (Entwistle, 2000). Adopting procedural approaches to solving problems can lead to rigid conceptualisation of problem solving situations and subsequently ineffective performance (Delahunty, 2014).

In a tertiary level context, Delahunty, Seery, Lynch, and Lane (2013) investigated ITTE students' approaches to solving applied problems following the explicit study of underlying principles. Overall, it was found that student teachers displayed an inability to effectively apply previously learned theoretical principles to a directly related applied task. The study highlighted procedural approaches to solving problems on the part of the student teachers and this raised a number of concerns about the nature of the learning activity. Research has discussed the importance of the relationship between learning experience of undergraduate educators and their future practice (Williams, Iglesias, & Barak, 2008).

There are a number of empirical frameworks, which focus on the development of problem solving aptitudes. These include among others the *"Theory of Inventive Problem Solving Technique"* (Akay, Demiray, & Kurt, 2008) and *"Systematic Inventive Thinking"* (Barak & Goffer, 2002). Both of these frameworks have been successful in fostering the development of creative problem solving skills in large organisations (Barak & Goffer, 2002) and have potential within an educational context. However, rather than focusing on the impact of problem solving frameworks and pedagogical approach, this paper is primarily concerned with the efficacy of task design in supporting the development of fundamental knowledge and skills. With the emphasis on task design for learning, the application of the students' mental resources must align with the objective of the learning activity in order to maximise learning gain. Consideration must be given to ensure that the appropriate balance of cognitive load optimises the mental resources that can be devoted to learning and ultimately the development of effective transfer skills.

Cognitive load theory

It has been well established that the human cognitive architecture has a limited processing capacity (Baddeley, 2003). Taking cognisance of this, Sweller et al. (1998) discuss cognitive load theory as a crucial element of instructional design to optimise cognitive resources for learning purposes. Sweller, Ayres, and Kalyuga (2011) present three types of cognitive load as follows:

1. **Intrinsic**: Imposed by the nature of the information (simple/complex, concrete/abstract) contained within the problem

2. **Extraneous:** Effected by the design of the learning material and occurs where information irrelevant or unnecessary to the task is present
3. **Germane:** A third category of cognitive load that is directly related to intrinsic cognitive load. It occurs when attention and resources are focused on the intrinsic nature of the learning material

The magnitude and relationship of these loads will affect an individual's capacity to assign cognitive resources during a task thus determining the quality of learning which may occur. The measurement of cognitive loads has been of substantial interest to researchers and as a result, a number of approaches have been adopted within the literature. Physiological techniques have been used on the assumption that cognitive functioning can be reflected in physiological variables. These tests have measured physical elements such as heart rates and pupillary responses (Paas, Tuovinen, Tabbers, & VanGerven, 2003). Task based activities such as secondary task analysis have been implemented with the assumption that the quantity of errors made in a secondary measuring task are indicative of cognitive load imposed by the primary task (Sweller et al., 1998).

The focus of this paper is centred on the impact of cognitive load on instructional designs for developing problem solving capabilities.

Method

For the purposes of this research study, a comparative experimental approach was adopted where a series of analytical graphical problems were prescribed with the goal of manipulating elements of cognitive load. The tasks were based on the use of visuospatial reasoning and the application of geometric principles to achieve a solution. As the focus of the study was to explore the effect of altering cognitive load within typical educational tasks on problem solving performance the participant group was critically important. It was decided to use year three graphical education students who were enrolled on an initial technology teacher education (ITTE) course. The rationale for this choice was based on the students' level of knowledge in graphics, which at this stage in their studies was quite advanced given their progression to this stage of the degree programme. This ensured that task difficulty was not a factor in engagement with the analytical problems and instead the focus was on flexible problem solving approaches. Kalyuga and Hanham (2011) describe flexible problem solving as being associated with the skill of applying one's knowledge structures in novel situations. They further consider the need to take into account the processing limitations of the human cognitive system when designing instructional tasks to develop these flexible aptitudes (Ibid). This is where the current study sets its focus.

Two separate experiments were undertaken where different types of cognitive load were manipulated to explore the effect on flexible problem solving performance as defined by (Kalyuga & Hanham, 2011). The tasks were administered to the students (n=118) during their weekly lecture in their graphical education module and this spanned two weeks.

Experiment 1

The selection of the tasks is premised on students having completed the material in previous prerequisite graphical education modules. In the first experiment, intrinsic load was manipulated by altering the nature of the subject content (Sweller et al., 2011). The tasks are shown in Figures 1 and 2 and take the form of orthographic projection problems. It was hypothesised that by manipulating the intrinsic nature of the task through presenting it to the second group in third angle, problem-solving efficiency would be negatively impacted.

The tasks required students to construct, using a sketch, a pictorial representation of an object given the principal orthographic views. The activity sheets (Figures 2 and 3) were structured to minimise the impact of sketching skills on the results by providing an isometric grid for students to create their solution. A nine-point symmetrical likert scale was used to capture a self-report measure of cognitive load and is located in the bottom left corner of the worksheet (Figures 2 and 3). This is in line with previous studies, which have validated the use of self-report measures as an accurate means of capturing cognitive load (Hoffman & Schraw, 2010). The intrinsic nature of the task was manipulated by altering the projection system used to third angle for the second task (Figure 1).

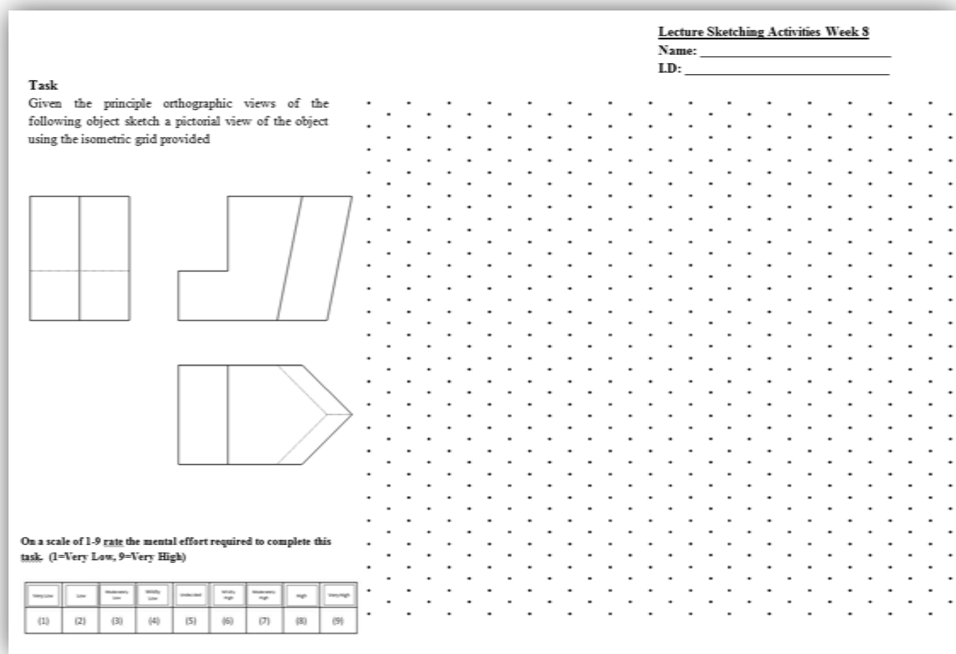

Figure 1. First angle orthographic projection task

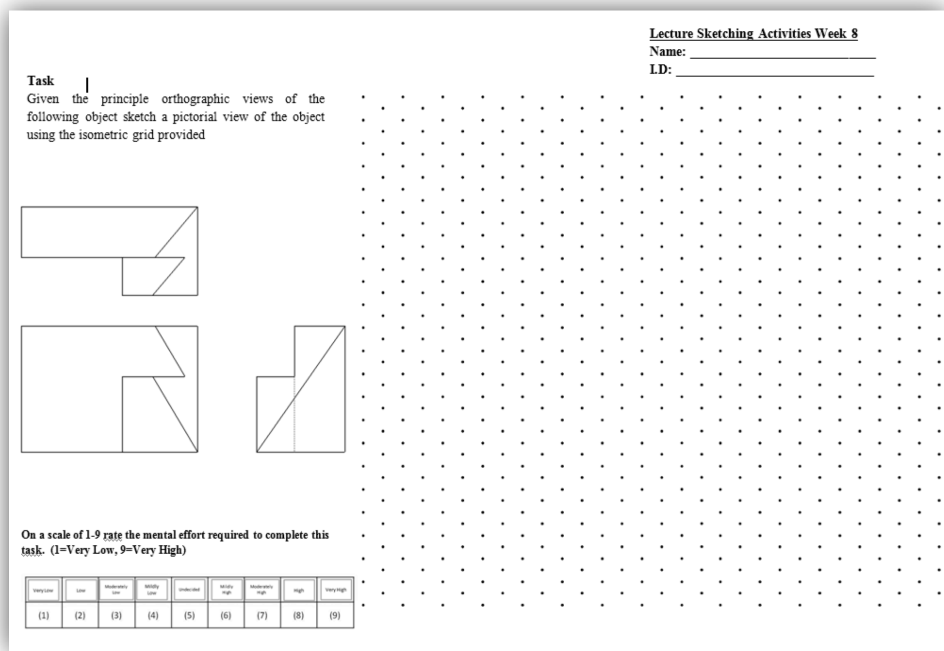

Figure 2. Third angle orthographic projection task

Experiment 2

In the second task, extraneous load was manipulated by altering the format information was presented in within the task (Sweller et al., 2011). The tasks (Figures 3 and 4) required the students to complete given orthographic views by identifying the traces of an oblique plane inclined at 70^{o} to the Horizontal plane which contained a given point P and was tangential to a given sphere. In the first task (Figure 3), instructional information was provided textually while the extraneous load was altered in the second through the provision of a pictorial solution to the problem (Figure 4). It was hypothesised that using a graphical medium for the second group would reduce the extraneous load on the task and result in increased problem solving efficiency.

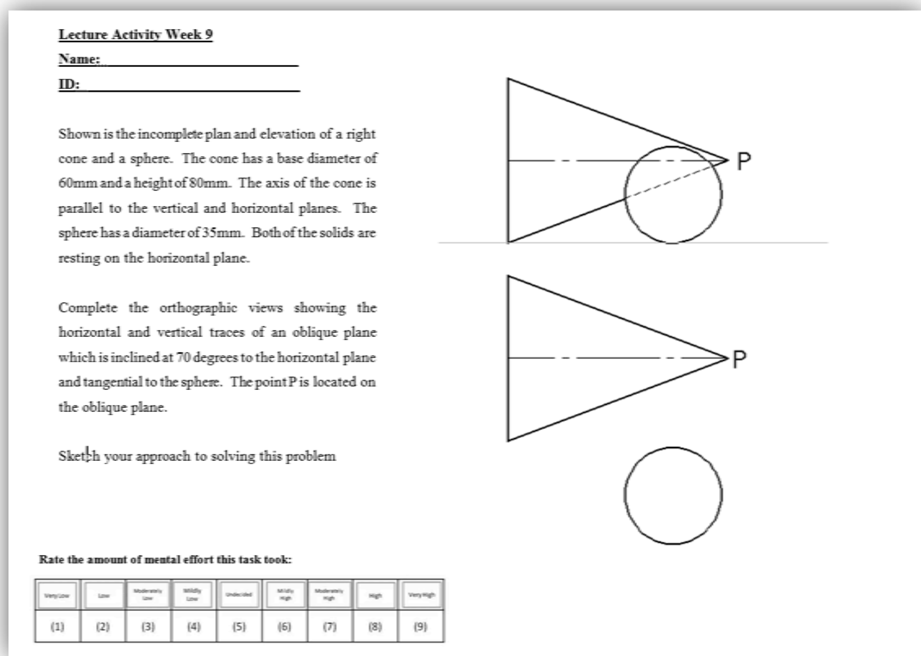

Figure 3. Text condition task

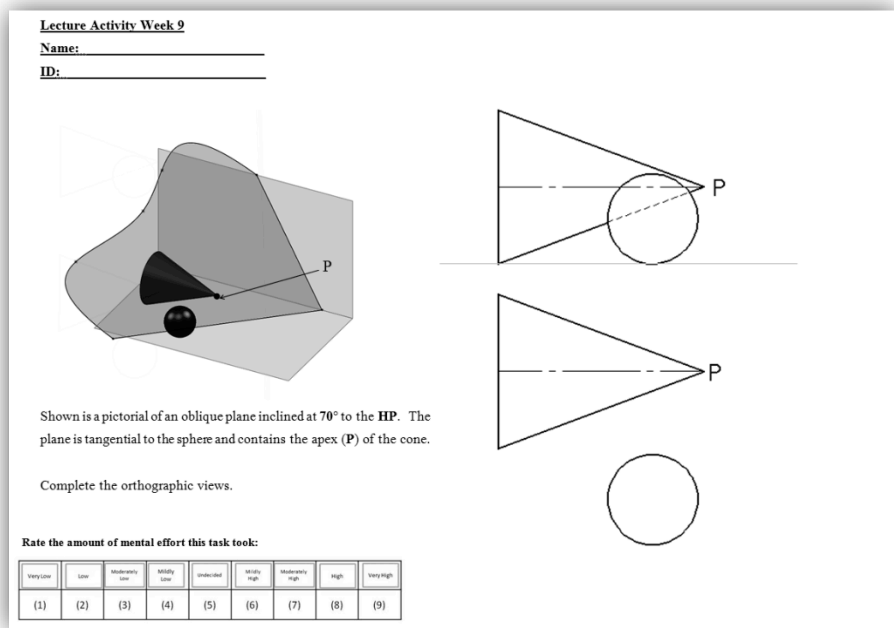

Figure 4. Graphic condition task

Administration of the tasks

The tasks were administered during the students' weekly lecture. Given the format of the lecture hall, students were divided into two groups for comparative purposes and asked to maintain these same groupings across both weeks of the study. Once the groups were formed the handouts were presented to the students and they were given ten minutes to complete the tasks. Students were clearly instructed to rate the mental effort they required to complete the problem once they had provided a solution.

Findings

This section of the paper will present the findings from the two experiments. The primary goal of this study was to investigate the impact of task design on problem solving efficacy while controlling for students' level of expertise. It is firstly important to consider overall performance. Performance was initially rated out of 10 using a sliding scale of professional judgement as has been used in previous research by Delahunty (2014). The breakdown of marks is shown in Table 1.

Table 1. Breakdown of Marks for Scale of Professional Judgement

Sliding Assessment Scale Marks Awarded	Assigned for
8-10	Effective approach and correct solution
5-8	Reasonable approach (likely to lead to a solution)
4-5	Ineffective approach (unlikely to yield solution)
1-3	Incorrect approach (marks for attempt)

As the focus of the study was on the effectiveness of problem solving approach, performance scores were categorised into successful and unsuccessful performances. An unsuccessful performance was one where the score was categorised as unlikely to yield a solution so therefore any mark of 5 or less fell in this category. The full set of performance data is shown in Figure 5.

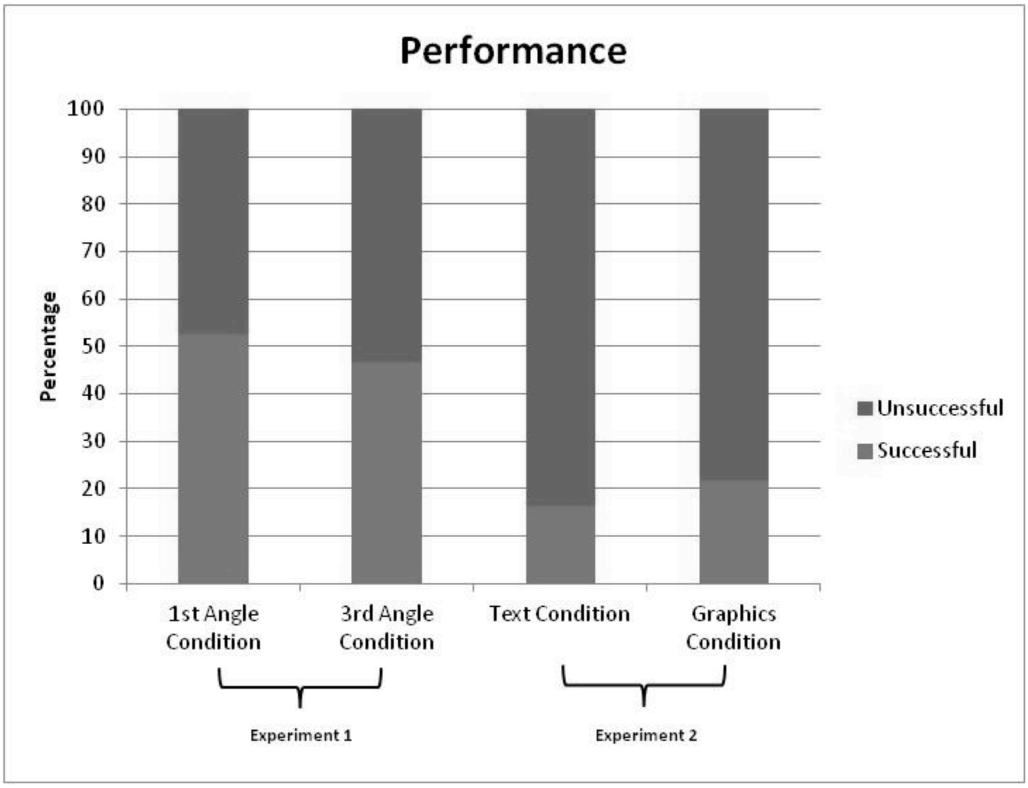

Figure 5. Performance statistics

In addition to capturing a measure of performance, mental effort was also collected by means of a self-report measure as was discussed in the method. Table 2 illustrates the descriptive statistics for mental effort ratings that students reported while engaging with the analytical tasks.

Table 2: Descriptive statistics for mental effort

Mental Effort Ratings	1st Angle Condition	3rd Angle Condition	Text Condition	Graphics Condition
Median	8	8	8	8
Mode	8	8	8	8

As can be seen in Table 2, all tasks display a median mental effort rating of 8 and a mode of 8. This indicates that overall students had to exert a high level of mental effort during these analytical problems. Given that the performance was poor for this particular participant group, taking their background as graphical education students in to account, it is clear that the approaches were overly inefficient. To further investigate the relationship between performance and mental effort a series of Chi-square tests were conducted with categorical variables of performance (successful/unsuccessful) and mental effort (rated from 1-9).

For the first experiment, the first angle condition a Chi-square test for independence revealed a significant association between performance and mental effort, $\chi^2(5, n=40) = 12.3$, $p<.05$, Cramer's V = .55. The large effect size indicates a strong relationship between performance and mental effort. Students had to exert high levels of mental effort to perform well and also to perform poorly. The third angle condition revealed no significant association between performance and mental effort, $\chi^2(5, n=45) = 8.6$, $p=.13$. However, the data do indicate that the majority of students who were successful had to exert high levels of mental effort. This was also the case for students who were unsuccessful where the majority of students rated mental effort as either high or very high.

For the second experiment, where extraneous cognitive load was manipulated, the text condition revealed a significant association between performance and mental effort $\chi^2(6, n=43) = 12.8$, $p<.05$, Cramer's V =.55. The large effect size once again indicates a very strong relationship. Interestingly, the association here refers to very high levels of mental effort and unsuccessful performances. For the graphics condition a strong significant relationship was found, $\chi^2(5, n=46) = 30.3$, $p<.001$, Cramer's V =.81. This very strong association refers to the relationship between unsuccessful performance and high mental effort.

Discussion

This research employed 'typical' graphical tasks to explore the capacity to manipulate cognitive load. The assumption was that previously acquired content knowledge was a controlled variable and enabled experimentation with task design. Experiment 1 focused on manipulating the nature of the subject content (Intrinsic Cognitive Load). The results recorded a high level of effort exerted by students in each group. What is interesting is the generally poor performance despite the high level of mental effort. The significant association between effort and performance recorded in the control group indicated that to perform well on the task the student had to devote a large amount of cognitive resources to think about the problem, while the thesis expected to see evidence of optimum efficiency (low effort and high performance). When compared to the students' performance in the experimental task (Third angle) the high level of mental effort was not rewarded in higher performance scores. The high level of effort was impeded by the additional load introduced by the task design. For both groups, although the principles of the task were previously acquired (and assessed), the ability to apply the knowledge was problematic and suggests a rigid approach to framing this type of problem. Therefore, if the intent was to use these problems to develop visuospatial skills and mental libraries (Lane & Seery, 2011), associated with robust problem solving skills the misalignment in task design could have impeded the intent.

With respect to Experiment 2, the manipulation of the task focused on altering the extraneous cognitive load by changing the way that information was presented to the student. The thesis focused on presenting the task graphically to reduce the amount of extraneous load, reduce split-attention effect (Sweller et al., 1998) and ultimately optimise problem solving efficiency. The assumption was that the data would demonstrate lower mental effort and higher performance in the experimental task by comparison. The results however illustrate that both groups exercised high mental effort and in general had poor performance, despite having previously studied the content. Interestingly, students in the control group outperformed the experimental group, which suggests that the text format of the control task (including extraneous load and splitting attention) did not by comparison adversely impact on problem solving performance. As text format is the conventional way of presenting this type of question, this performance variance could be explained by familiarity and operant conditioning, further evidence of rigid cognitive processes. Although cognitive efficiency was low in this experiment, this cannot be fully attributable to the manipulation of cognitive load and the resulting application of cognitive resources. The generally poor performance by both comparative groups may be indicative of a tangential problem. It may instead suggest inflexibility in conception. Concerns have been highlighted in research by Delahunty et al. (2013), where deficiencies were uncovered in student teachers ability to apply theoretical knowledge to applied problem solving activities. Further work has highlighted the area of conceptualisation as a key component in the problem solving process (Delahunty, 2014).

Understanding the nature of task design has implications for the development of problem solving skills. Developing flexible problem solving skills, as described by Kalyuga and Hanham (2011), must be predicated by supporting the learner in effectively engaging with the problem and scaffolding the problems so as to support the effective application of their cognitive resources. Differentiating between task difficulty and introducing extraneous cognitive load is paramount to the successful develop of fundamental knowledge, leading to more flexible problem solving skills. Within initial technology teacher education (ITTE) it is important that student teachers experience purposeful learning tasks that support strategically their problem solving skills and are able to apply it to the design of educational problem solving tasks in the future.

Conclusion

To varying degrees, task design can affect the application of students' cognitive resources. The experimentation presented both expected (low efficiency with you manipulate intrinsic cognitive load) and unexpected (no statistical difference from the manipulation of extraneous load). However, it can be argued that the manipulation of extraneous load may have been impeded by inflexibility in conceptualising the problem effectively. The research concludes that the ability to effectively engage in the given problem and apply previous knowledge was impeded by the design and nature of the task. In addition, how students conceive tasks can affect the application of their cognitive resources. Specifically in Graphical Education, careful consideration must be given to the use of *legacy* tasks (even if manipulated), if its remit is to develop contemporary problem solving attributes.

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Challenging design thinking in the classroom

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Abstract

Little attention has been given to the cognitive flaws that are inherently a feature of the decision-making aspects of 'Design Thinking' in an educational setting. As such design activities are framed as 'positive'; a force for good, often based upon an assumption that design represents a rational activity that brings about conscious planned change in the made world.

However an alternative rationale for 'Design Thinking' recognizes the implicit nature of metacognitive processes that can be used to identify cognitive limitations and increase levels of criticality and reflection. Such criticality can be considered as central to critical pedagogies, critical theory and critical thinking through a central theme of 'agency' - as in the intentional ability to exercise some control over one's thinking and subsequent existence and action.

This paper reports on a small pilot project, which seeks to challenge learners thinking about 'Design Thinking'. As part of this research the aim was to engage learners in metacognitive processes using a series of debiasing and reflection tools presented in the form of an acronym as part of an enhanced 'Design Thinking' strategy. Using a one-hour 'lesson study' approach pupils engaged with a series of activities with each activity designed to reveal flaws in their existing 'Design Thinking' approaches.

The project was also developed in the context of a modified approach to Initial Teacher Education based around 'third space' principles employing 'lesson study' protocols. The initial results and feedback indicated positive learner outcomes in terms of reframing learners understanding of 'Design Thinking' protocols.

The paper concludes that the project resulted in pupils thinking being challenged and that there was a genuine moment, all too rare, where the researcher, the teacher, the trainee teachers and the pupils were all learning at the same time.

Keywords

Design thinking, metacognition, cognitive limitations

Introduction

In previous work (Spendlove, 2008, 2010, 2013) I have examined the 'thinking' elements of 'Design Thinking' and have proposed that critically rethinking the perceived cognitive robustness of 'Design Thinking' predominantly, but not exclusively, in a technology education context offers learners valuable opportunities within and beyond the 'echnology learning environment. Through adopting a critiquing approach to 'thinking' offers learners the opportunity to engage in metacognitive (such as how we monitor and control our own cognitive routines) processes that can identify their own limitations and cognitive flaws associated with their decision making practices. Such metacognitive processes, I would argue, are an essential part of any solution orientated activity particularly when the agent is charged with making 'an essential contribution to the creativity, culture, wealth and well-being of the nation' (DfE, 2013). Within an education context the rationale for such approaches becomes even stronger when the agentive benefits associated with developing metacognitive processes have applications beyond the curriculum. Such 'agency' represents the intentional ability to exercise some control over one's thinking and subsequent existence and action. Therefore as indicated by Bandura (2001, p.1) agency is achieved through "intentionality and forethought, self-regulation by self-reactive influence, and self-reflectiveness about one's capabilities". As previously indicated such qualities, I would argue, are essential when engaging in genuine critical ‘Design Thinking’ processes as part of any Technology education experience. The explicit nature of such metacognition is unequivocally linked to understanding the extent to which we are responsible for our actions and we therefore use our ‘agency’ to make ‘metacognitive judgments about whether or not we were in control’ (Miele, et al. 2011 p.3620).

In previous writing (Spendlove, 2007a; Spendlove, 2007b; Spendlove, 2008) I have explored the extent to which we are in control of decision making processes and in particular how our emotions and sub conscious processing plays a central part in our design decision-making. Such decision making is complex and difficult to untangle as it is implicitly intertwined with biological, social, political, theological, psychological, philosophical, pedagogical and cultural make up and values that all interact with every decisions we ‘think’ we make. As a consequence we are susceptible to involuntary and unconscious cuing (Tversky and Kahneman, 1983) when making what appears to be straightforward decisions and as a consequence our ‘ apophenic’ state is recognized as the inclination to make spontaneous perception of connections and meaningfulness of unrelated phenomena (Carol, 2003).

Given the acknowledgement of cognitive limitations I therefore attempted to put ‘the theory into practice’ as I believe any activity orientated towards ‘Design Thinking’ should, through a metacognitive approach of debiasing (Fischoff, 1982) and reflection, provide a unique opportunity to both expose such cognitive constraints and most significantly, given the educational context, offer the opportunity learn from such limitations in order to improve future decision making. As such through an extended process of abductive reasoning (whilst acknowledging my own cognitive limitations in this process) a reduced list of ‘cognitive flaws’ (appendix one) having specific relevance within technology education when dealing with uncertainty were identified (Spendlove, 2013) in the form of an ‘inventory of design thinking cognitive flaws’. Each cognitive limitation was drawn mainly from the literature on psychology and represents a cognitive bias that can be considered to distort ‘Design Thinking’. Such distortion represents concepts such as mistaken beliefs, misinterpretation of cues and data, unrecognised biases and preferences and other heuristics which may ultimately limit the agents full engagement with users, contexts, systems and processes.

Developing a metacognitive activity

The intention was to engage learners in a more rigorous ‘Design Thinking’ approach that will have relevance within and beyond their technology education activities. This was to be achieved through a ‘lesson study’ activity as part of a one year Post Graduate Certification in Education (PGCE) Initial Teacher Education (ITE) course. Working with a small group of ‘trainee teachers’ a one hour ‘Design Thinking’ lesson was developed which was to be taught to two different groups of pupils to enable the lesson to be developed and refined whilst also analysed in relation to how the two lessons differed. The lessons were to be taught to year 10 (age 14-15) pupils in an all boys selective grammar school. As such the ‘Design Thinking’ activity was considered to have a central focus on creative, innovative, empathetic activity orientated towards design processes, problem resolution and product development for ill-defined contexts, through application of a particular form of critical and metacognitive thinking.

In order to make the activity both engaging and memorable an acronym of ‘IDEAS’ (table 1) was created to challenge existing ’Design Thinking’ heuristic strategies and as a consequence students were challenged to rethink their assumptions that they engaged in robust decision making in the pursuit of problem resolution based upon:

- Implicit assumptions
- Self serving biases
- Causal explanations
- Unsustainable fallacies

Given that this was a relatively short input to pupils the acronym of ‘DT IDEAS’ was used as a central feature of the ‘lesson study’. This was in addition to the trainee teachers receiving a strong and coherent input on design thinking as a central feature to their PGCE course. The trainee teachers, a group of six, along with the University Tutor and class teacher were all involved in the co-construction, planning and delivery of the lesson, which took place three months into their training. Through this on-going project with the aim was to establish pedagogical approaches aimed reconceiving the ‘thinking’ elements of designerly activity by identifying opportunities for pupils to be challenged through:

- Participatory co-creation activities
- Conceptualisation of engagement with problem owners

- Reconceiving authentic contexts and solutions
- Application of specific critical design thinking skills

The lesson was structured around the five broad themes of the acronym (table 1) with each letter of the IDEAS acronym focussing upon a cognitive limitation for which an interactive teaching episode was planned designed to illustrate the relevance related to design scenarios and processes that the pupils might typically engage with.

D = Don't T = Trust I = Illusions D = Decisions E = Emotions A = Anchoring S = Self serving bias

Table 1: Acronym used and cognitive focus

As this was a pilot there were five key questions that were the focus of attention as follows:

1. Would the content be able to be presented in an engaging and accessible manner?
2. Would pupils engage with the delivery method of the lesson?
3. Would the pupils be able to work through the activities given the limited time?
4. Would the pupils be able to recall the acronym?
5. What aspects of the acronym would pupils identify as being of value in relation to their design and technology examination coursework (which typically involves designing a product).

Finally a further dimension to the pilot was the extent to which a lesson study approach based upon a developmental activity was a suitable means for developing trainee teachers pedagogical repertoire. This will be dealt with elsewhere however the initial feedback and analysis suggests that this was an effective method of trainee teacher development.

Research, data and method of analysis

The methods of data collection were predominantly located in the qualitative paradigm in that the research aims are not to generalize but rather to "elucidate the particular, the specific" (Creswell, 2007, p.26). As such the research was conducted both formally and informally allowing for serendipity and planned activities to weave together to provide meaningful insights. The research was grounded in a largely constructivist philosophical position' (Bogden & Biklen, 1998). This also allowed myself to operate in both an ethnographic role (Marshall & Rossman, 2006), working in the classroom in order to capture meaningful moments whilst occupying a different role when capturing the trainee teachers perceptions through more formalized structures. Such an ethnographic approach can be considered to be a central feature of lesson study in that the researcher is subsumed within the classroom as a learner, practitioner and researcher often occupying each role simultaneously. The use of my formal and informal observations were a central feature of the research and can be legitimized as a valid research tool for investigating the lesson study activities as they allowed me 'the opportunity to gather 'live' data from 'live' situations' (Cohen *et al*, 2003, p.305) in real time. The sample can be regarded as purposeful in that both the trainee teachers and pupils were selected for the study as they could "purposefully inform an understanding of the research problem and central phenomenon in the study" (Creswell, 2012 p.300).

In order to also address the questions previously identified data was collected in several ways. Firstly the lesson was video recorded to provide backup data to be able to refer back to for any critical incidents. Given the relatively early stage in the trainee teachers development the video also provided useful feedback on how they had individually delivered aspects of the lesson – however in identifying this it is important to note (but not fully examined in this paper) that a central feature of the lesson study was not on teacher performance but on whether pupils had grasped the key concepts.

Secondly, following each of the lessons a semi-structured post lesson review between the trainees, the teacher and myself took place and was audio recorded and analysed (again not a focus within this paper).

Finally in addition to the note taking that I undertook within my ethnographic remit a formal method of eliciting pupil responses was required in order to identify if they were able to recall the acronym and secondly whether they could identify how they considered how they would apply what they had learned. To do this a #dt-ideas twitter sheet was developed. The rationale was that the twitter style feedback restricted responses to short (140 character) tweets, which required the pupils to synthesize their response into a brief statement related to the most productive areas.

Research findings

As indicated previously there were five key questions that were a focus of the overall study. In this paper I am focusing on questions four and five related to the pupils recalling and application of the IDEAS acronym. As previously stated an explicit aim of this activity was to enquire would the pupils be able to recall the IDEAS acronym at the end of the lesson? Whilst this may appear a relatively modest aim given that it was requiring a low level response by pupils it also has to be understood in the broader context of the delivery of a complex theme in a simplified way. Therefore whilst a modest aim; the outcome was that 20 of the 22 pupils were able to completely recall each word of the acronym was considered positive.

The second focus of this paper considers what aspects of the acronym would pupils identify as being of value in relation to their design and technology examination coursework (which typically involves designing a product) but more specifically what aspects of the IDEAS acronym would encourage them to engage more purposefully with aspects of 'Design Thinking'. In relation to this over half the pupils made specific reference to self-serving bias. This is captured by pupil responses where they have reflected upon self-serving bias when designing for example:

Pupil 7: I think self-serving bias is what most people fall prey to because you are the one designing it not the customer

Pupil 12: was not aware of self-serving bias

Pupil 13: self-serving bias is my most common error

Pupils could also see the value of being aware of self-serving bias when designing:

Pupil 15: in my gcse coursework I could use self serving bias when I have an idea and it isn't that good

Pupil 16: I will take other people into account when designing

Pupil 17: don't think of designs just for myself

Likewise almost half of the pupils made specific comments about being aware of anchoring being of use to them:

Pupil 6: anchoring and self serving bias were the most useful because they tricked me when I was trying not to be tricked

Pupil 1: Using the 4x4 method to prevent 'anchoring' or fixation

Pupil 3: anchoring and self serving bias have been very useful in the way I think about designs

Pupil 4: don't get fixated

Pupil 5: you can use anchoring to make sure that you don't get fixated and get lots of ideas if different varieties

Pupil 6: anchoring and self serving bias were the most useful because they tricked me when I was trying not to be tricked

Pupil 10: good ideas to help design and stop anchoring and develop ideas

Pupil 11: anchoring is so annoying!

Pupil 12: anchoring is the one which helps me most

Pupil17: when thinking about what I will make – not anchoring as I could think of a better idea than the one I'm anchored two (sic)

In addition to considerable attention being focused on self serving bias and anchoring, pupils were also able to identify the value of the acronym for example:

Pupil 6: Opened my eyes to something I was blind to

Pupil 7: I think it was good using an acronym to help remember the ways we can get lost

Pupil 9: I will use the acronym to use and maybe it will help to stop me from getting fixated (…)

Pupil 12: it is a relevant acronym so it is easy to remember

Pupil 13: dt-ideas would stop me from designing existing products

Discussion and conclusion

From my previous research I have identified a series of recognised cognitive flaws (appendix 1) that can be considered to have relevance to 'Design Thinking' activities. Within the context of this project I have presented such limitations in the form of an 'IDEAS" acronym (table 1) to pupils as part of a one hour 'lesson study' activity which presented short episodes of teaching dedicated to each letter (and subsequent cognitive flaws) of the acronym as part of a metacognitive approach of debiasing (Fischoff, 1982). From this short input pupils were both able to recall the acronym at the end of the lesson as well as being able to reflect on which cognitive limitations, as presented within the acronym, would awareness of help them in their future approaches to designing. Such reflection illustrates the inherent value derived from this unique learning opportunity through illustrating how such cognitive limitations can be exposed in an accessible manner in order to potentially improve future decision making when engaged in 'everyday' designing.

In examining the practice of 'Design Thinking' I am therefore reconceiving the often implicit assumptions based around practice as indicated by Cross (1990) who identifies that a by-product of informed practice is arguably our ultimate goal; better designers. A dichotomy is whether in education we are pursuing the same goal and if we do what vision of a designer do we hold?

My view is that the pursuit of a goal based around the 'traditional view' of the designer when considered in an educational context is misplaced and likewise a goal predicated by form, aesthetics and manufacturing is also limited. However a broad view of design(er) thinking within an education context based upon rich metacognitive processes provides a sound rationale for general education and has applications beyond the Technology curriculum. This does not mean that a curriculum shaped by aesthetics, form and manufacturing is not of value, it simply means that it represents one of the many diverse routes of Technology education. However I would also argue that design orientated activities should have an established set of core principles that recognize criticality, reflection and metacognition whilst celebrating creative design(er) thinking and nurturing confidence.

In choosing to focus on the 'cognitive flaws' selected within this study I am acknowledging that the areas I have chosen represent a relatively small number of the extensive list of cognitive limitations identified in a vast range of psychological literature. The areas chosen were however selected through an extended process of abductive reasoning (whilst acknowledging the potential cognitive flaws in this process) as having specific relevance within an educational context. In acknowledging this limitations of the study, the overwhelming feeling was that this was a highly successful attempt to draw theory and practice together with the initial results illustrating that if presented in an appropriate way pupils can engage in metacognitive processes of debiasing and can recognize the value of such approaches. Perhaps even more encouraging is the anecdotal data that several months after the lesson pupils were still referring to the acronym and the class teachers was able to refer back to such limitations as pupils worked through the designing aspects of their coursework.

This small-scale research project was significant in that it drew together several key themes including lesson study, design thinking, new forms of teacher training and teacher pedagogies. Disentangling each is part of the role of this paper and subsequent publications however it is also worth reflecting on the whole experience in a broader sense in addition to reflecting upon the immediate data presented. In essence the experience represented a risky, creative and rich learning experience for all. The opportunities for success were matched by the opportunity for failure. At times when developing the 'Design Thinking' activities within a lesson study activity as part of a new approach to teacher education it all seemed to be too great a challenge. Yet it also represented the essence of a vibrant learning community. At times the class teacher, the trainee teachers and myself did not know how to proceed. Equally at times we hankered after the safety of knowing what to do next. Ultimately however we embodied what education should be in that we engaged with uncertainties in order to challenge boundaries and make progress. As a result pupils were challenged and engaged and there was a genuine moment, all too rare, where myself, the teacher, the trainee teachers and the pupils were all learning at the same time.

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Appendix

Inventory of Design Thinking Cognitive Flaws

Cognitive flaw	Definition
Anchoring	The establishment of an initial judgment (called the anchor) from a simple feature and then adjusting the estimate, to form a final judgment. Adjustment to the initial judgement, however, is usually constrained and conservative, as a consequence the final judgment is biased towards the original anchor judgement (Tversky and Kahneman, 1974)
Affect Heuristic	A positive (like) or negative (dislike) evaluative feeling toward an external stimulus (e.g. some hazard) that allows us to ''lubricate reason'' allowing us to be led astray or manipulated—inadvertently or intentionally— silently and invisibly (Slovic, 2007)
Apohenia	The broad term applied for identifying or perceiving patterns in often random or meaningless data – where such patterns are neither present nor intended (Carol, 2003)
Attentional Bias	The tendency to selectively attend to personally relevant information over neutral information (Mathews and MacLeod, 2005).
Availability Heursitic	A person is said to employ the availability heuristic whenever he estimates frequency or probability by the ease with which instances or associations could be brought to mind (Tversky and Kahneman,1973).
Confirmation Bias	Seeking information that is consistent with one's own views and discounting disconfirming information (Griffiths 1994).
Focussing illusion	Bias that occurs when concentrating on just a single good, presented in a single response framework, is liable to inflate respondents' perceptions of the importance of that good and hence raise their desire for that activity/good (Schkade and Kahneman, 1998).
Optimistic Bias	The often mistaken belief that the chances of experiencing a negative event are lower (or a positive event higher) than that of one's peers (Weinstein, 1980).

Cognitive processes as indicators for student aptitude in engineering design

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Abstract

This paper will discuss the cognitive processes involved in solving engineering design problems and examine a methodology for identifying the cognitive processes employed by students that can be indicators of potential problem solving success. Additionally, this paper will highlight preliminary cognitive research findings from a study of high school pre-engineering students to provide an example of implementing the described methodology.

Keywords

Technology, engineering, design, cognition

Introduction

Engineering design is now a critical feature of both technology education (Asunda & Hill, 2007) and science education (NGSS Lead States, 2013). The *Next Generation Science Standards* in the United States has even declared engineering design to be an equal component of science education as scientific inquiry (NGSS Lead States, 2013). The increased focus on engineering design can be ascribed to the belief that it provides relevancy to students, motivation to learn content, promotes critical thinking, and makes engineering careers more accessible to all students (Hosni, 2013). Additionally, it is considered as an essential approach for addressing major challenges our modern world faces (Hosni, 2013; National Research Council, 2009). Therefore, it is important that educators enact the proper interventions to ensure that students are able to properly employ the engineering design process to produce the most viable solutions to authentic challenges or issues.

It is evident there is a broad societal case for incorporating engineering in K-12 education systems due to its believed ability to promote economic progress (Douglas, Iversen & Kalyandurg, 2004). In 2006, Wicklein recommended technology education to establish engineering design as its core focus to begin appropriately infusing engineering into a students' general K-12 education. Gattie and Wicklein (2007, p. 8) summarized Wicklein's (2006) motives for focusing on engineering design in technology education as: a) engineering design is better understood and valued than technology education, b) engineering design elevates the field of technology education to a higher academic and technological level, c) engineering design provides a defined framework to design and organize curricula, d) engineering design provides an ideal platform for integrating mathematics, science, and technology, and e) engineering provides a focused career pathway for students. Additionally, Kelley (2008) notes that the engineering profession has identified the important role K-12 education plays in the success of post-secondary engineering education. As a result, incorporating engineering design into curriculum and standards initiatives has been an increasingly popular trend. However, the engineering design process can be challenging to understand, teach, and evaluate (Dym, Agogino, Eris, Frey & Leifer, 2005).

Recently, the concept of engineering design has been viewed as a replacement of the older concept of technological problem solving (NGSS Lead States, 2013). In technology education, technological problem solving has often been a central theme for organizing and developing curriculum and instruction. Technological problem solving has been described as a design process that emphasizes devising a solution idea to a problem, making a model or prototype of the solution, evaluating the solution idea by conducting a series of tests, and making design alterations through a trial-and-error method of iteratively testing the solution model/prototype (Kelley, 2008). Kelley (2008) declares that a notable difference between technological problem solving and engineering design is the increased emphasis on analysis and optimization through the mathematical prediction of how well the solution idea will solve the identified problem. Therefore, engineering design can be considered a directed form of cognition to solve authentic problems using the proper procedures and resources to effectively develop a solution design in the most efficient manner utilizing appropriate mathematical procedures and scientific investigations.

Much like Roberts (1994) emphasized about the teaching of design, the purpose of teaching engineering design can be the change in a student's cognitive skills. This change in cognition can provide students with the abilities necessary to effectively and efficiently solve design problems. However, as Grubbs (2013) describes, even after four decades of design research there is still minimal agreement on how people design and limited examinations on effective ways to bridge design research with teaching and learning strategies. Additionally, much of the design cognition research has focused on studying post-secondary engineering students or practicing engineers (Grubbs, 2013) and limited research has been conducted with an emphasis on K-12 student design cognition (Lammi & Becker, 2013). Therefore, it is important that researchers examine the cognitive processes involved in engineering design to understand the way a primary or secondary student's thinking can influence the outcome of their engineering design process. Conducting research of this nature can be applied to curriculum development or to a teacher's instruction to help determine potential interventions that assist students in employing the engineering design process (Mastascusa, Snyder & Hoyt, 2011) to produce the most viable solutions to authentic challenges or issues. Additionally, studying the cognitive processes employed by students as they enact the engineering design process to solve authentic problems can be used as a means to evaluate curriculum effectiveness in helping students to develop as effective problem solvers (Kelley, 2008). Consequently, the following sections will highlight procedures to be assembled into a methodology to study student engineering design cognition at the primary and secondary education levels in a manner that can highlight potential indicators for developing more effective solutions to design problems for the purpose of improving curriculum and instruction.

Mental processes in technology education

In 1973, Halfin sought to explain the cognitive approach to solving design problems by examining the writings of high-level inventors, innovators, designers, and engineers, such as Thomas Edison, Frank Lloyd Wright, and Buckminster Fuller. Through this study, he inferred 17 mental processes for technological problem solving that he then validated and operationally defined through a Delphi study consisting of a panel of 28 experts in technology and engineering fields. Halfin described these processes as "functional or intellectual skills, which are random or ordered methods, strategies, or operations used by a technologist to accumulate knowledge about an artifact or to solve a technological problem (p. 205)." Using the Delphi panel, he wanted to operationally define these processes to delineate the way in which each is used and to determine how each can be identified through observations. Halfin believed that general definitions of the processes would have little practical application in the interaction with technology on a daily basis. Consequently, he developed a list of well-described mental processes employed during technological problem solving which has been used and can continue to be used as a foundation for examining engineering design cognition. As Halfin stated, these 17 mental processes appear stable over time, as they are the way in which technologists utilize, process, and accumulate knowledge. The 17 mental processes and summary of their operational definitions are provided in Table 1.

Halfin's (1973) technological problem solving processes were also revalidated in 1999 through a Delphi study conducted by Wicklein & Rojewski. The results of this study confirmed the continued relevance of all 17 processes. Furthermore, Wicklein and Rojewski's work led to the identification of 10 more potential mental processes. Although the Delphi panel indicated an additional 10 potential processes, the researchers made no attempt to determine whether these processes were duplicative to the original 17. Therefore, these additional processes have not been used in current research involving engineering design cognition.

Assembling a method for examining engineering design cognition

Hill (1997) later expanded upon Halfin's work to establish a procedure for assessing the mental processes students employ to solve design problems. In the late 1980s and early 1990s technology education literature was brimming with references related to problem solving and the importance of this cognitive approach to students' education. Therefore, Hill believed it was imperative for technology education professionals to develop strategies for designing and implementing curriculum focusing on technological problem solving. As a result, Hill created a computer analysis tool called the **O**bservational **P**rocedure for **T**echnology **E**ducation **M**ental **P**rocesses (OPTEMP). This tool enables a person to simultaneously view video recordings of students working to solve design problems and code the mental processes they employ using the aforementioned list of 17 mental processes. The OPTEMP tool computes the total time each mental process is employed and the total number of times each process is used.

Cognitive Process	Operational Definition Summary
Analyzing	The process of identifying, isolating, taking apart, or performing similar actions for the purpose of setting forth or clarifying the basic components of a phenomenon, problem, opportunity, object, system, or point of view.
Communicating	The process of conveying information (or ideas) from one source (sender) to another (receiver) through a media using various modes. (The modes may be oral, written, picture, symbols, or any combination of these.)
Computing	The process of selecting and applying mathematical symbols, operations, and processes to describe, estimate, calculate, quantify, relate, and/or evaluate in the real or abstract numerical sense.
Creating	The process of combining the basic components or ideas of phenomena, objects, events, systems, or points of view in a unique manner which will better satisfy a need, either for the individual or for the outside world.
Defining Problem(s)	The process of stating or defining a problem, which will enhance investigation leading to an optimal solution. It is transforming one state of affairs to another desired state.
Designing	The process of conceiving, creating, investing, contriving, sketching, or planning by which some practical ends may be effected, or proposing a goal to meet the societal needs, desires, problems, or opportunities to do things better.
Experimenting	The process of determining the effects of something previously untried in order to test the validity of an hypothesis, to demonstrate a known (or unknown) truth, or to try out various factors relating to a particular phenomenon, problem, opportunity element, object, event, system, or point of view.
Interpreting Data	The process of clarifying, evaluating, explaining, and translating to provide (or communicate) the meaning of particular data.
Managing	The process of planning, organizing, directing, coordinating, and controlling the inputs and outputs of the system.
Measuring	The process of describing characteristics (by the use of numbers) of a phenomenon, problem, opportunity, element, object, event, system, or point of view in terms, which are transferable. Measurements are made by direct or indirect means, are on relative or absolute scales, and are continuous or discontinuous.
Modeling	The process of producing or reducing an act or condition to a generalized construct, which may be presented graphically in the form of a sketch, diagram, or equation; presented physically in the form of a scale model or prototype; or described in the form of a written generalization.
Model/ Prototypes Constructing	The process of forming, making, building, fabricating, creating, or combining parts to produce a scale model or prototype.
Observing	The process of interacting with the environment through one or more of the senses (seeing, hearing, touching, smelling, tasting). The senses are utilized to determine the characteristics of a phenomenon, problem, opportunity, element, object, event, system, or point of view. The observer's experiences, values, and associations may influence the results.
Predicting	The process of prophesying or foretelling something in advance, anticipating the future on the basis of special knowledge.
Questioning/ Hypothesizing	The process of asking, interrogating, challenging, or seeking answers related to a phenomenon, problem, opportunity, element, object, event, system, or point of view.
Testing	The process of determining the workability of a model, component, system, product, or point of view in a real or simulated environment to obtain information for clarifying or modifying design specifications.
Visualizing	The process of perceiving a phenomenon, problem, opportunity, element, object, event, or system in the form of a mental image based on the experience of the perceiver. It includes an exercise of all the senses in establishing a valid mental analogy for the phenomena involved in a problem or opportunity.

Table 1. 17 Mental processes for technological problem solving

Note. The operational definition summaries were developed by Halfin (1973) and refined by Wicklein (1999) and Wicklein and Rojewski (1999).

Kelley (2008) established a method to utilize the OPTEMP tool combined with student think aloud protocols to study student cognition related to solving design problems. The think aloud procedure enables a researcher to examine a student's thought process as they work to solve a design challenge.

This examination can provide insight to how a student is mentally processing the situation from moment to moment. The thinking aloud procedure is a method that requires study participants to continuously speak their thoughts while performing a problem solving task (Van Someren, van de Velde & Sandberg, 1994). Atman and Bursic (1998) state that this verbal protocol analysis is a formidable method for assessing and understanding the cognitive processes engineering students employ to develop a design solution. The verbalizations of one's thoughts can be captured along with student observation video recordings. Collecting audio and video of students thinking out loud while solving a design problem is extremely important because the think aloud method can be weak in capturing the non-verbal processes involved in problem-solving (Cross, 2004; Laeser, Moskal, Knecht & Lasich, 2003). As Lammi and Becker (2013) state, the verbal and visual protocols complement each other to provide richer information about the thoughts and actions in the engineering design process.

Kelley (2008) and Kelley, Brenner and Pieper (2010) utilized this methodology to study what mental processes students employed to solve design problems. However, these researchers only studied students for approximately 30 minutes and did not observe the students completely solving the problem. Therefore, the entire process students take to create a final solution to the design problem has not been studied in a manner that enables one to compare the mental process data to the actual solution outcome. As a result, the author combined Kelley's (2008) research method with a carefully designed engineering problem to enable the comparison of the mental processes used by the students and quantitative data related to the effectiveness of their final solution.

Engineering design problem

As Petrina (2010) notes, the proper analysis of engineering cognition requires data to be collected from a person in-interaction-with carefully developed engineering problems that enable the obtainment of the desired research objectives. In this case, the author is focused on identifying cognitive strategies that could be potential indicators for creating the most successful solution to an engineering design problem. Therefore, a problem was created in a manner that enabled students to work alone to develop a solution in an effort to minimize student-to-student interference while thinking aloud, allowed the observation of participants completing the engineering design process from start to finish, mandated that students fully define the problem, required students to identify the desired criteria and constraints, and resulted in the collection of quantitative data for solution effectiveness. These quantitative solution effectiveness data can be used to determine a ranking of student-generated solution performance. This information can then enable a researcher to compare and contrast the cognitive processes used by participants who developed the best-performing solutions to the participants who developed the least effective solutions with a purpose of determining potential cognitive indicators for creating more effective solutions.

The engineering design problem designed to meet the above-mentioned research objective attentions the issue of continuous access to clean water in a developing nation after the onset of a natural disaster. Water in these situations needs significant purification. However, water purification units can be expensive and not easily obtained. Therefore, the engineering design brief tasks the participants to design an inexpensive, easy to use, easy to assemble, durable, and low maintenance water purification system using low cost, readily available materials to quickly remove contaminants from water. The participants are focused on reducing the turbidity of a contaminated water sample. A focus on reducing the turbidity allows the collection of quantitative data using turbidity sensors for evaluating the effectiveness of the solution while providing a means to rank the student-generated solution outcomes.

Consequently, this methodology allows a researcher to identify trends in the mental processes employed by students in relationship to the effectiveness of their prototype to determine potential cognitive indicators for creating better-performing solutions. The author utilized this methodology to study eight advanced pre-engineering students as they worked over two hours each to design, make, and evaluate a working prototype as a solution for an authentic engineering design problem. The purpose of this study was to determine what mental processes advanced pre-engineering students employ to completely solve a design problem and which processes led to better solution results in hopes to enhance the understanding of engineering design cognition. The following section will discuss the preliminary findings of this study to provide an example of implementing the described methodology.

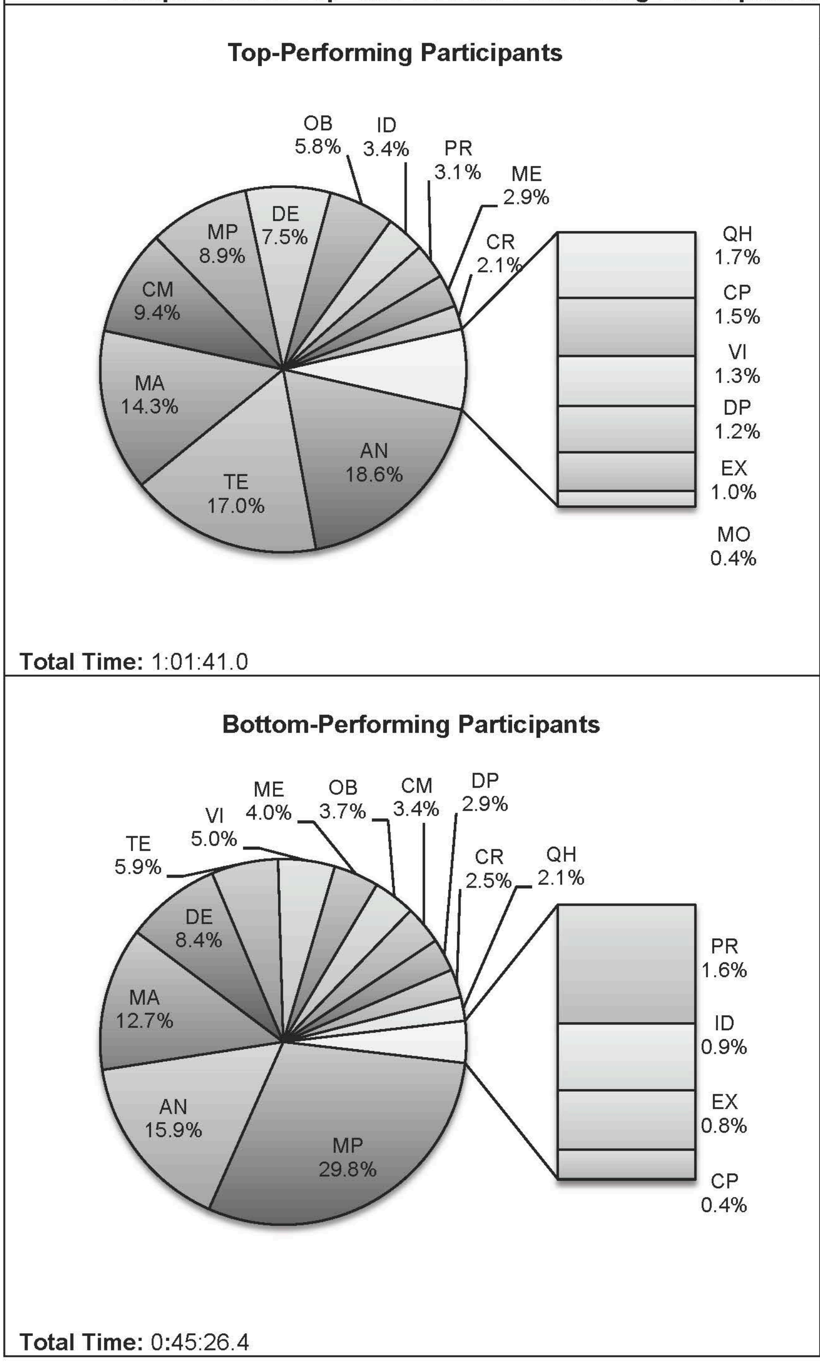
Preliminary findings

The verbal and observational data of eight advanced pre-engineering high school students, along with design journals were gathered while they worked independently to solve the engineering design problem described earlier. Two coders using the 17 mental processes for technological problem solving independently coded these data. The coding process was facilitated using Hill's (1997) OPTEMP computer analysis tool. The outputs of this tool provided the number of times each mental process was used and how much time was taken for each process. After each coder coded each of the participant engineering design sessions, a Pearson's correlation coefficient was used to determine the inter-coder reliability of the results. This analysis indicated that the coders were in agreement as to what mental processes were used by each participant and consistent in coding the processes with an average coefficient of .915 (n = 17, p = 0.00) for the participants. To then achieve the research objective, the researcher gathered the turbidity data of the participants testing their designs to determine participant ranking of success in solving the engineering design problem. Using the participant solution effectiveness rankings, the researcher compared cognition data between the top two performing participants and the bottom two performing participants. This comparison helped identify differences in the cognitive processes between these four participants, which may be potential indicators for creating better performing solutions.

The top participants devoted the large percentage of their problem-solving time to employing the cognitive processes of *Analyzing* (18.6%), *Testing* (17.0%), *Managing* (14.3%), and *Communicating* (9.4%). However, the large percentage of the bottom participants problem-solving time was devoted to employing the processes of *Model/Prototype Constructing* (29.8%), *Analyzing* (15.9%), *Managing* (12.7%), and *Designing* (8.4%). The major differences between these two groups are the percentages of time employing the processes of *Testing* and *Model/Prototype Constructing*. The top participants took 17.0% of their time *Testing* and re-*Testing* their solutions, while the bottom participants took 5.9% of their time employing this mental process. This difference is a reflection of how the bottom-performing participants were not observed iteratively testing, improving, and re-testing their solutions. Additionally, the bottom participants were observed focusing more of their time on constructing their prototypes, while the top participants were observed taking 20.9% less of their time for employing the process of *Model/Prototype Constructing*. A graphical comparison of the average percentage of time taken for each process used by the top- and bottom-performing participants during the entire engineering design session is provided in Figure 1.

When examining the overall cognitive processes of the top- and bottom-performing participants, some perceptible differentiations can be seen. For example, the top participants took 6.0% more of their time utilizing the *Communicating* process. It was observed that the additional *Communicating* time involved participants documenting their research and recording design alterations. This can be an indication that effective communication and documentation of the design process can enhance problem-solving capabilities. Additionally, the data suggests that the participants who were more thorough in planning, and directing their design practices by employing the *Managing* mental process were the participants who produced better solution results.

The data were also segmented into three main phases of engineering design, which were solution design, solution construction, and solution evaluation. This information indicates which cognitive processes the two different groups of participants employed at different stages of the design process. Examining the processes of the top- and bottom-performing participants can enable the further identification of cognitive indicators for engineering design success. For example, an analysis of this data indicates a difference in the time devoted to the processes of *Testing*, *Observing*, *Interpreting Data,* and *Experimenting* between the top- and bottom-performing participants. These processes can be thought of as scientific actions within the design process, which can be used to enhance the effectiveness of a solution. The top participants took 14 more minutes *Testing*, three minutes more *Observing*, three minutes more *Interpreting Data*, and almost a half a minute more of their time *Experimenting*. Conversely, the bottom participants utilized a large portion of their time employing the *Model/Prototype Constructing* process as opposed to the more scientific processes. The top participants enacted more iterations of testing their solutions, making observations, interpreting the outcome data, and then experimenting with design changes to improve their results. The bottom participants were fixated on building the solution to the design problem and were content after assessing their solution once. Therefore, this type of information can be used to inform the development of engineering design curricula and instruction. A graphical comparison of these participants by the 3 phases of engineering design is provided in Figure 2.



Key	
Mental Process	**Code**
Analyzing	AN
Communicating	CM
Computing	CP
Creating	CR
Defining Problem(s)	DP
Designing	DE
Experimenting	EX
Interpreting Data	ID
Managing	MA
Measuring	ME
Modeling	MO
Model/ Prototypes Constructing	MP
Observing	OB
Predicting	PR
Questioning/ Hypothesizing	QH
Testing	TE
Visualizing	VI

Figure 1. Comparison between top- and bottom-performing participant mental processes.

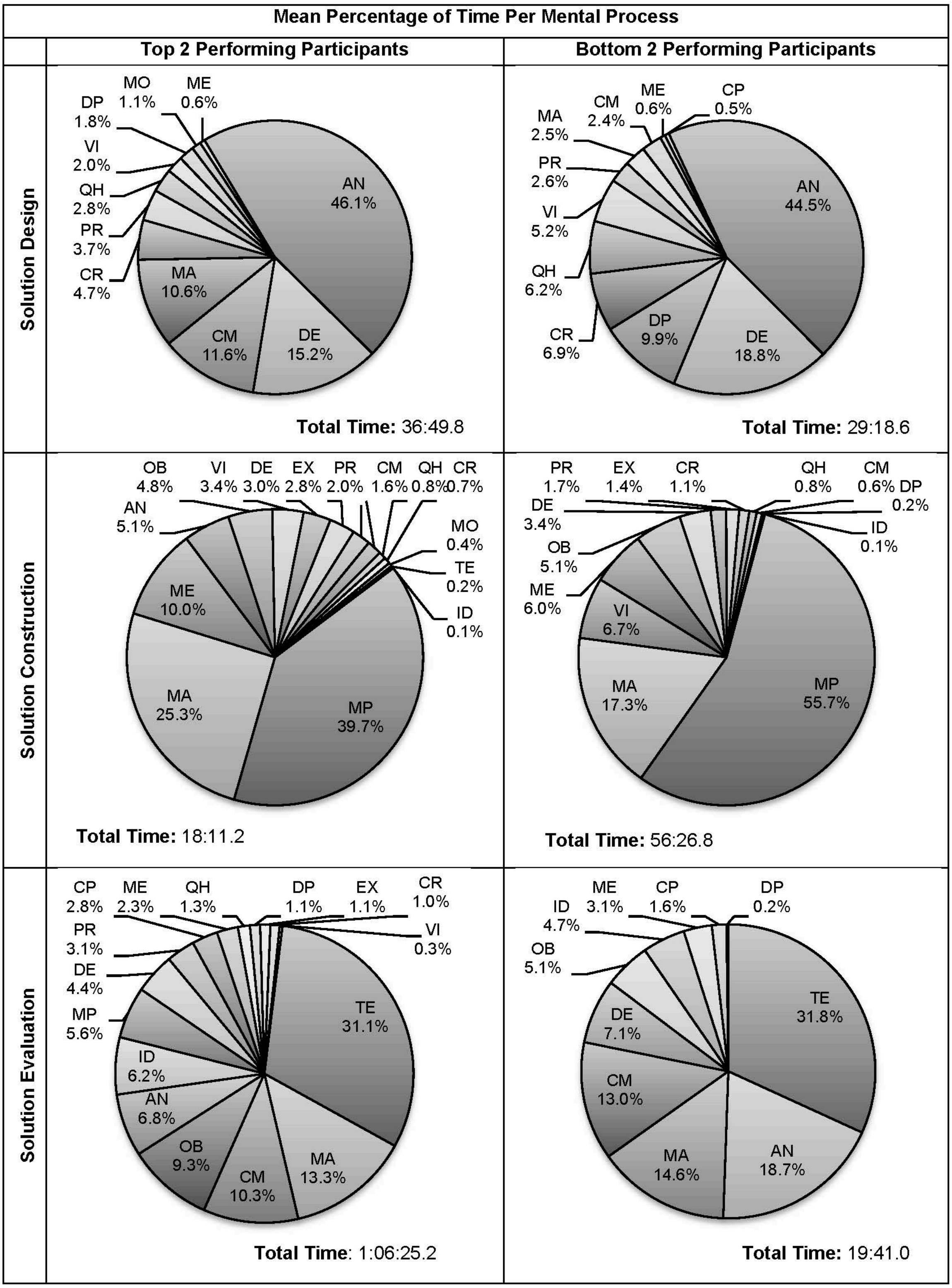


Figure 2. Comparison between top- and bottom-performing participant mental processes by engineering design phase.

Implications, recommendations, and conclusion

An examination of the cognitive processes employed by students as they work through an engineering design problem can provide a means of evaluating the effectiveness of curricula designed to develop effective problem solvers (Kelley, 2008). Examining student design cognition utilizing the methodology presented in this document can help bridge the gap between design cognition research and the teaching of engineering design by directing the development of technology and engineering curricula and instruction to focus on the cognitive traits that are employed by those who develop the most effective solutions to design problems. For example, the preliminary findings presented can indicate that technology educators should promote:

- Dedicating more time employing the *Communicating* process by stressing the importance of documenting their engineering design procedure.
- Devoting more time employing the process of *Managing* and less time employing the mental process of *Model/Prototype Constructing* by practicing analytical design planning.
- Allotting more time to employing the scientific mental processes of *Testing*, *Experimenting*, *Observing*, and *Interpreting Data* by practicing iterative cycles for testing and redesigning using the appropriate mathematical procedures to understand the testing data in an effort to optimize the design.

Due to the implications of the analysis of data collected through the presented methodology, it is recommended to employ these procedures to examine the cognitive processes of a larger sample of students at various experience levels. As a result, conducting cognitive research following the methodology and recommendations presented in this paper can help begin to provide the information necessary for understanding how to improve the teaching of engineering design in a manner that can help students learn how to create the best possible solutions for a design problem.

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The purpose of technology education in preschool – Swedish preschool staff's descriptions

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Abstract

In 2010 technology became emphasized as a subject in the revised curriculum for the Swedish preschool. Two years later 42 preschools were scrutinized by the Swedish Schools Inspectorate. The resulting report revealed that the preschool staff lacked knowledge about technology in general and felt insecure regarding the subject's application in the preschool practice. There is relatively little research on the area, but even so some studies have shown the same tendency. To increase the knowledge of the existing situation in the preschool the aim of this study was to investigate how preschool staff describe the purpose of technology education in preschool. Data was collected through an open-ended questionnaire. A stratified sample of 10 % of all the preschools in the investigated municipality resulted in the questionnaire being sent out to 139 preschool teachers and day care attendants. The return rate was 73 %. The data was analyzed using a conventional content analysis to create categories from data. Five categories were formed to describe the preschool staff's descriptions of the purpose of technology education: 1) to develop children's interest in technology, 2) to make children aware of the technology around them and through that making the technology available for them, 3) to give children an awareness about how technology works, 4) for children to develop abilities and knowledge to be able to create, invent and solve problems using technology, 5) to prepare children for future learning. All together these categories cover all aims but one for sustainable development stated in the steering documents for the preschool and it seems that these respondents have a more developed understanding of technology in preschool than the ones the Swedish Schools Inspectorate reported in 2012.

Keywords

Technology education, preschool, preschool staff

Introduction and background

Today's society demands each individual to have knowledge about technology in order to make informed choices in both their everyday life and in professional activities. Learning about technology has to start early and the school system plays an important role for each individual, from preschool and through the school years. The Swedish government has stressed the importance of making efforts to stimulate interest in the subject early by revising the curriculum for the preschool which now puts a greater emphasis on technology (Swedish National Agency of Education, 2010). The government also assigned The Swedish National Agency for Education to plan and perform actions to support preschool children's interest in technology (Regeringsbrev, 2012). Given the new emphasis on technology the question of how the preschool staff understands the purpose of technology education in preschool arises. This is evident in how they go about fulfilling the technology goals of the curriculum. This investigation will seek the answer to how the preschool staff, including preschool teachers and day care attendants, describe the purpose of technology education in preschool.

Few studies have been conducted regarding preschool staff reflections on technology education in preschool. Hellberg and Elvstrand's (2013) study showed that preschool staff describe technology in a limited way and the participants experienced their limited understanding of technology to be a problem in the preschool practice. Regarding the purpose of technology education in preschool a literature search resulted in one American study (Bairaktarova, Evangelou, Bagiati, & Dobbs-Oates, 2012). The study investigated how teachers described engineering (technology and engineering are here regarded as synonyms) and why it should be introduced in preschool through questionnaires, interviews and observations. The teachers described engineering as "the science of creating something" and gave examples like "engineering is figuring out how and why things work" and "making/developing products/solutions based on clients' needs/wants". When asked about why engineering should be introduced in preschool they answered working with engineering "encourages teamwork, problem solving and thinking outside the box" (ibid., "What do teachers think…", para. 2).

The revision of the curriculum for the Swedish preschool meant greater emphasis on children's learning in subjects like mathematics, science and technology (Swedish National Agency of Education, 2010). Regarding technology the curriculum now expresses two technology specific goals, instead of one. The preschool should strive to ensure that each child develops their ability to 1) "identify technology in everyday life, and explore how simple technology works" and 2) "build, create and construct using different techniques, materials and tools" (Swedish National Agency of Education, 2010, p. 10).

In Sweden the purpose of introducing technology in preschool is stated in a document from the Ministry of Education describing the background to the changes in the preschool curriculum. (Utbildningsdepartementet, 2010). It states that the purpose of technology education in preschool is to make children aware of the technology that surrounds them and give them an understanding of how that technology can be used to simplify and solve problems in our everyday life. Children should investigate and analyze technical solutions and create and construct, through exploratory activities, thereby gaining an understanding of our everyday technology. Also, sustainable development should be included in technology education. The preschool staff are said to play an important role by encouraging curiosity and creativity as well as creating positive attitudes towards technology. In a scrutiny made by the Swedish Schools Inspectorate (2012) where they, among other things, looked at how 42 preschools were working to fulfill the technology goals of the curriculum, activities addressing the aims described above were not evident. Learning technology did not seem to be a prioritized area. It was reported that technology was difficult for preschool staff to grasp. Critique was also aimed at the staff way of acting as role models, mainly from a gender perspective.

Problem statement and aim of the study

The introduction has shown the desired curriculum emphasis on technology education in Swedish preschools. At the same time, this research area is juvenile. How the Swedish preschool staff describe the purpose of introducing technology in preschool does not seem to have been investigated at all. Hence, the aim of this study is to seek answer to the question: *How do preschool staff describe the purpose of technology education in preschool?*

Methodology

Data were retrieved from a questionnaire used for another larger study. That questionnaire was sent out to 10 % of the preschools in the investigated municipality, distributed mainly through the internet but also by paper to those who requested it. Choosing 10 % of the preschools, instead of 100 %, enabled the presence of one of the researchers when the questionnaires were filled out giving several benefits like informing about ethical aspects verbally and minimizing non-response.

The sample included preschool teachers and day care attendants in a Swedish municipality and was stratified randomly with respect to the portion of public and private preschools, geography and demography, with the ambition to achieve a representative sample (Hartas, 2010).

For this study one open ended question from the questionnaire was analyzed. The question was: What do you consider to be the purpose of technology education in preschool? The answers were analyzed qualitatively using a conventional content analysis, as described by Hsieh and Shannon (2005), to create categories inductively in order to describe the variations in data. A consensus estimate (Stemler, 2004) was conducted for the independent analyses of two of the researchers to estimate an inter-rater reliability and resulted in 76,2 % agreement, thereby passing the recommended limit of 70 % (Stemler, 2004). The study was conducted with regards to the ethical considerations of the Swedish Research Council (Vetenskapsrådet, 2011).

Results and analysis

Response rate and participants

139 people received the questionnaire, of which 102 answered giving a response rate of 73 %. These participants consisted of 7 men and 95 women, 39 day care attendants and 63 preschool teachers, 16 of whom had some form of higher education qualification including technology and its didactics.

Descriptions of categories

Five categories were formed to capture the respondents' descriptions of the purpose of technology education in preschool. The categories are presented below with title, definition and two quotes (translated from Swedish) that exemplify the respondents' answers. The first quote (Example 1) is a typical answer for the category and the second quote (Example 2) is an answer derived from the question about the respondent's reflections on the curriculum and how they describe a possible way of working with respect to that. This example aims at providing more concreteness and specificity. For category 5 no example 2 is provided. Each category description is followed by an analysis of its relation to references presented in the background.

The purpose of technology education in preschool is…
…to develop children's interest in technology (Category 1)

The category describes that the purpose is to develop children's general interest in technology at an early age. Children should think it is fun and be curious about technology.

Example 1:"Arouse curiosity and interest in the field. Show that technology is fun and interesting and ultimately make the technology subject in school more attractive."

Example 2: "Let children start from their own idea about what they want to do, be a support in their search for solutions. Offer lots of materials. Don´t confine, use recycling materials and natural materials which allows them to use a lot. It should be fun, and then the children can tell each other what they did and how".

Almost a fourth of the respondents were placed in category 1 (see Figure 1), which is a fundamental aspect of Swedish preschool technology education. It was the primary aim from the government in their assignment to the Swedish National Agency for Education (Regeringsbrev, 2012). The category relates to the ministry's (Utbildningsdepartementet, 2010) statement that the preschool staff should strive to create positive attitudes towards technology by acting as role models. The Swedish Schools Inspectorate (Skolinspektionen, 2012) criticized the staff in this matter as they did not see this in their scrutiny in 2012.

…to make children aware of the technology around them and by that making the technology available for them (Category 2)

In this category, the aim is to show that technology is everywhere in our everyday life and it is not necessarily difficult or complicated. Knowledge about the simple technology and practice to try out how artifacts can be used might encourage children to explore more complicated technology as well. Gender equality is also an aspect in this category since conscious work with letting both girls and boys use and explore all sorts of technology results in both girls and boys having access to all sorts of tools and artifacts.

Example 1: "Partly to make the everyday life easier for the children but also with educational aim. To show children that technology is everywhere and is not necessarily difficult to apprehend."

Example 2: "That we as pedagogues offer materials so children can test technology. That we as pedagogues are present and can help children develop there thinking about technology. That we show children the simple technology."

This category represents the document from the Ministry of Education (Utbildningsdepartementet, 2010) that also states that children should be made aware of technology that surrounds them and that they should gain an understanding of how technology can be used to simplify their everyday life. The category also relates to the curriculum goal about identifying everyday technology and exploring how simple technology works, the goal that the Swedish Schools Inspectorate (Skolinspektionen, 2012) did not see at all in their scrutiny of the preschool practice and is here expressed by a fourth of the respondents.

…to give children an understanding of how technology works (Category 3)

Children should come closer to understand how technology works by exploring on their own or with the help of a pedagogue, initiated either by themselves or by the pedagogue. Children's interest and curiosity about technology is present here as in category 1, but here it serves as a force to seek knowledge. How technology works includes the construction of artifacts and mechanisms, how they look inside and how they can be put together in a system and the affect they have on each other. The category also includes technology's relationship to society.

Example 1: "So that children can gain an understanding of how things work, how it all connects and how we are part of it. That we can influence it in different ways."

Example 2: "Try how the seesaw at the playground works. What happens if there is a child at one end and no one at the other end? What happens if there is an adult at one end and a child at the other?"

The category links to the aims of the Ministry of Education (Utbildningsdepartementet, 2010) that children could gain technological understanding by investigating and analyzing technical solutions.

…for children to develop abilities and knowledge to be able to create and invent technology and solve problems using technology (Category 4)

The purpose for this category is that children need to develop various abilities like creativity, divergent thinking and self-confidence. They need to understand that one problem can have many solutions. Included is also man's role as a creator of technology. This knowledge will make children aware that they can be creators and inventors.

Example 1: "To develop their thinking, strengthen their self-esteem and gain the understanding that one problem can have many solutions."

Example 2: "You can go to a job site and talk about all the machines and ask what they do. Shovels, excavators, mowers etc. Then you use what you have learned and build something yourself and search for more info".

Category 4 links to the aims of the Ministry of Education that states that children should gain an understanding of how technology can be used to solve problems and that children, by creating and constructing, can gain an understanding of our everyday technology. In the category, it is also described how abilities like creativity, divergent thinking and self-confidence are important in these processes. This was also described in the American study (Bairaktarova et al., 2012) where the staff described how engineering play/work encourages these abilities.

…to prepare children for future learning (Category 5)

Here the aim of technology in preschool is described as a preparation for future learning, mainly in school. This preparation can be primary, the goal of learning is expressed to be preparing for school, or it can be secondary where the goal is, through fun activities, to learn about what the children find interesting and by doing so giving them a basic knowledge which will be useful later on, in school.

Example 1: "Technology, like any other subject, is important to include as experiences in preschool which leads to the children better being able to grasp the knowledge in school."

Category 5 stands alone without any connection to either previous research or the statements from the steering documents implicating that this is not a primary aim of the area but perhaps a positive effect of the preschool education.

The five categories were formed to encompass all of the descriptions from the respondents. Table 1 presents how the respondents' answers are spread over the categories. Since one answer can be included in several categories the total adds up to more than 100 %. Respondents placed in no category either did not answer the question or gave an answer to vague to interpret. As shown in the table the answers are rather equally spread over category 1, 2 and 3, whereas category 4 and 5 include fewer answers. Figure 1 shows how many categories each respondent's answer includes. More than half of the respondents have been placed in one category and a third have been placed in two, three or four categories. Table 2 shows how the categories are distributed within five of the participating preschools.

	Relative number of respondents
No category	12
Category 1	31
Category 2	34
Category 3	32
Category 4	22
Category 5	9

Table 1. Relative number placed in each catégorie

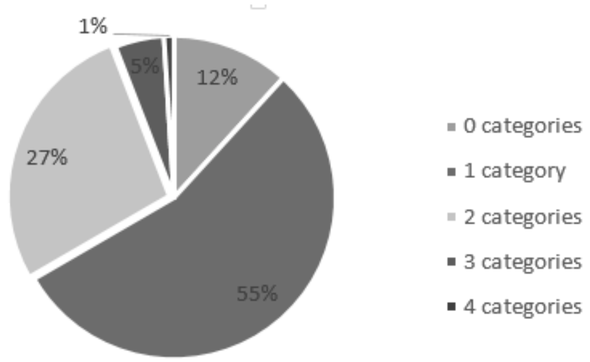

Figure 1. Relative number of categories each respondent's answer cover

	Category 1	Category 2	Category 3	Category 4	Category 5
Preschool 1	1	4	2	1	0
Preschool 2	3	2	3	1	1
Preschool 3	2	2	1	2	0
Preschool 4	5	7	5	1	1
Preschool 5	1	2	5	3	1

Table 2. A sample of five preschools extracted from the research material and their coverage of the categories

Discussion

It has been two years since the Swedish Schools Inspectorate (Skolinspektionen, 2012) concluded from their scrutiny that preschools are not addressing technology in the way that they are obliged to do according to the curriculum. This study shows that after further two years preschool staff in total now have thoughts about technology education more in accordance with the curriculum and the document from the Ministry of Education (Utbildningsdepartementet, 2010). The five categories together cover all aims stated by the Ministry of Education except for the sustainable development aspect. This is quite surprising since many preschools in Sweden prioritize environmental questions and for that have been certificated with the award "School for sustainable development" or "Green flag". A possible reason for the absence of this aspect in the respondents' answers is that they see sustainable development as something more general and therefore do not connect it explicitly to technology.

The participants describe arousing interest in technology, supporting children's knowledge in technology and exploring technology according to the first curriculum goal of technology. The participants also address the gender aspect. All of these aspects were pointed out as shortcomings in the report from the Swedish Schools Inspectorate in 2012. Of course, all of the preschool staff do not cover all of the categories in their descriptions of the purpose of technology education. In fact, most of them cover only one or two categories (see Figure 2). So a question that arises is what do the collective descriptions from all the preschool staff in each preschool look like. Does one preschool in general cover all of the presented categories and if so, how do the staff work to ensure that these separate competences come together to benefit the whole preschool? Or do the staff at one preschool generally have a more consensual understanding? The answers to these questions probably have a great impact on the preschools abilities to work with technology. The data produced for this study does not include full information about the respondents' workplaces and can thereby not provide answers to these questions. However, the data that do exist indicate that the staff at each preschool together cover the categories rather well in their descriptions (Table 2), looking at only the question about the purpose of technology education (Examples 1 above). When we look at the other question (Examples 2 above) it is more difficult to interpret since many answers are short and limited. This, of course, is due to the limitations of a questionnaire.

The results of this study are recurrently compared to the report from the scrutiny made by the Swedish Schools Inspectorate (Skolinspektionen, 2012). Of course there are limitations to the extent of which these two results are comparable since there are differences in method and sample. The differences in results could thereby be due to either the time past since the scrutiny which is two years, the geographic spread of the sample which in the scrutiny were national and in this study limited to one municipality, or to how data was produced which in the scrutiny was by several methods like observations, interviews and document analyses, and this study has used a qualitative questionnaire.

Still, when comparing our results to the Swedish Schools Inspectorate's scrutiny we can see a difference, at least in the way preschool staff utter about technology. How they act in the preschool practice and if their actions harmonize with their rhetoric has not been the object for this study. That is a question for further research.

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Swedish students' view on technology
Results from a pilot study using an adaptation of the PATT-SQ questionnaire

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Abstract

Technology has been a compulsory subject in Swedish school curricula since 1980. Over these 35 years the curricula have been revised several times. Today technology has its own curriculum which is no longer shared with natural science subjects, and the students are supposed to get 200 hours of technology education during compulsory school (school year 1-9, 7-15 years old). However, even though technology is established as a school subject in the curriculum, there are concerns being raised concerning students attitudes towards the subject. That it might be amongst the subjects students like the least. This calls for a more thorough study of students' attitudes and factors influencing their attitudes.

To accomplish this, we decided to use the PATT-short questionnaire (PATT-SQ, see Ardies, De Maeyer, & Gijbels, 2013) on students in school year 6 to 9 (12-15 years old). This study reports the validation of the questionnaire in a Swedish context. To allow for a more elaborated analysis, open-ended questions were added in the areas of students' definitions of technology and their view on technology as a school subject. The students' views as expressed in the open-ended questions were assessed and quantified using Mitcham's (1994) four types of technology as: *object – knowledge – activities – volition.*

The results from the validation show that the PATT-SQ questionnaire mainly is adaptable for Swedish conditions. It also show that some questionnaire categories might be gender biased. The results also indicate that students that expressed a more elaborated view of technology also have a higher interest in the school subject technology and express the importance of technology. However, gender differences were noticed in that these correlations were stronger for boys than for girls.

Keywords

Technology education, attitude, interest, PATT, secondary school

Introduction

In a recent study by the Swedish Schools Inspectorate (Skolinspektionen, 2014) a decrease in how interesting Swedish students find technology education throughout school year 5 to 9 (11-15 years old is reported as seen in fig. 1.

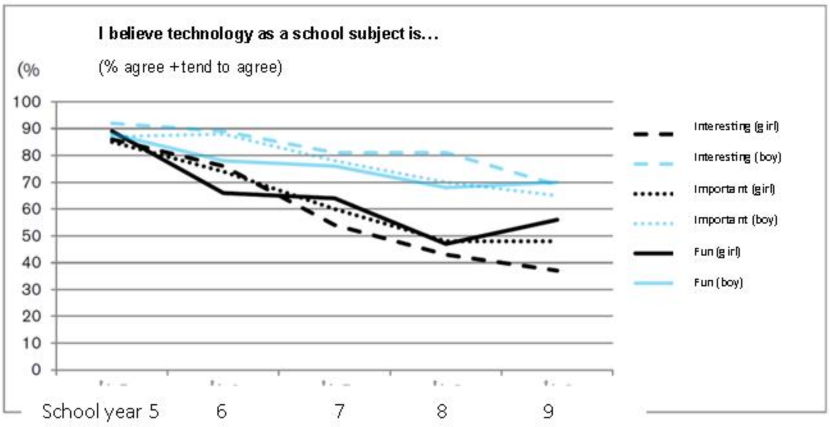

Figure 1. Decrease in interest and importance, translated from Swedish (Skolinspektionen, 2014)

Even though students interests towards school and school subjects on a general level decreases at these ages, the decrease in interest seems especially strong in relation to the technology as a subject. However, Sweden does not stand alone with decreasing student interest. In a recent Belgian study (Ardies J. , De Maeyer, Gijbels, & van Keulen, 2014) similar results are presented over a two years' time.

The study of pupils' attitudes towards technology (PATT) has a long history in technology education research. It was first developed in the 1980s by Raat and de Vries (1986). The intention was to explore students' interest and attitudes towards technology. It was considered interesting to use the data for strengthening the subject's status and display that technology as a school subject was important for younger children as well. The first results from the PATT studies showed that students had an unclear view of what technology is and that girls found technology less interesting and less important than boys did (Boser, Palmer, & Daugherty, 1998). In these questionnaires students' attitudes towards the technological field are surveyed from a range of perspectives: their career aspirations in technology, their interest in technology and technology education, their attitude towards technology, gender patterns in technology, consequences and importance of technology and difficulties they experience within the technology subject. The PATT questionnaire has evolved since then and has recently been shortened (Ardies, De Maeyer, & Gijbels, 2013) to consist of fewer items and re-named PATT-short questionnaire (PATT-SQ).

This study has a twofold aim: to translate and validate the PATT-SQ (Ardies et al., 2013) for Swedish conditions and to start exploring new ways of using the questionnaire. To survey students' attitudes is of course interesting in its own right, because as educators we care that the school subjects should be engaging and entail positive experiences. But do attitudes towards a subject also have other consequences?

Some researchers describe interest synonymously to attitude, for example Lindahl (2003) and Schreiner (2006). By doing so, however, one misses an important distinction that can be made between these two concepts, since you actually could have a negative attitude towards something and still be very interested (Krapp & Prenzel, 2011). It can be stated that an interest has to be towards something, for example technology education (Krapp et al., 2011) and it can be seen as a motivational factor for getting engaged within the subject (Hidi & Ann Renninger, 2006; Krapp A. , 2002). On a more general level it has been shown that interest in a subject is correlated positively with knowledge in that subject, especially in higher grades (Krapp A. , 1999). Also attitudes toward technology have in some cases been seen to correlate positively with a students' knowledge (Gamire & Pearson, 2006). If we assume that the ability to explain and contextualize technology in some way reflect the students' knowledge, it would be interesting to study what attitudinal factors affect this. Students often have a narrow view of technology, describing technology as artifacts and more specifically high-tech artifacts (de Vries, 2006). Similar results have been reported for American adults (ITEA, 2004). Thus, on a general level, there is a gap between the general public's view of technology and more elaborated descriptions of technology, such as Mitcham's (1994) fourfold definition of technology as *object–knowledge–activities–volition*.

Research in attitudes towards technology (and attitudes in general) often aims to find factors that can predict a student's attitude, such as their parents and family, gender, socioeconomic background and teachers etc. (Davies & Brember, 2001; Lindahl, 2003). In this study, correlations between students' views of technology and attitudinal factors will be of special interest to explore.

Background

Technology as a school subject has been mandatory in compulsory school in Sweden since 1982 (Hallström, Hultén, & Lövheim, 2014). The national curriculum has been changed and revised several times. The last major revision was made in 2011 (The Swedish National Agency for Education, 2011). Technology shares education hours with the natural science subjects, which are 800h (out of 6 785h including all subjects), from school year 1-9 (7-15 years old). Students are supposed to get an equal share between the four subjects (biology, chemistry, physics and technology) of approximately 200h during school year 1-9. The overall aim of the school subject technology calls for the technology literate citizen:

> Technological solutions have always been important for man and for the development of society. The driving forces behind the evolution of technology have often been a desire to solve problems and meet human needs. In our time, more exacting demands are imposed on technological expertise in daily and working life, and many of today's societal and political decisions embody elements of technology. To understand the role of technology for the individual, society and the environment, the technology that surrounds us needs to be transparent and understandable. (The Swedish National Agency for Education, 2011, p. 254)

As stated here, the Swedish school subject technology has a wide and civic aim. Regarding attitudinal factors, it can be noted that interest is in fact a stated aim for Swedish technology education:

Teaching in technology should aim at helping the students to develop their technical expertise and technical awareness so that they can orient themselves and act in a technologically intensive world. Teaching should help students to develop their interest in technology and their ability to deal with technical challenges in a conscious and innovative way. (The Swedish National Agency for Education, 2011, p. 254)

This stated aim, to develop interest in the school subject technology is shared by several other school subjects. But how do you develop students' interest in something? To learn more about what constitutes interest and what factors that interact with interest, as in this study, can give important insights on how this challenging aim could be approached.

Method

To measure students' interest in and attitudes towards technology PATT-SQ was used (Ardies et al., 2013). The survey consists of 24 items which the student responds to on a 5-graded Likert scale. The PATT-SQ has its origin in the PATT-questionnaire developed in the 1980s by Raat and de Vries (1986) as the outcome of a series of interviews with pupils. Later the questionnaire was developed further and adjusted for American conditions (Bame & Dugger, 1989) The number of items was recently reduced by reduced and used by Ardies et al. (2013). The respondent chose how well he or she agrees with a statement. To analyze the data the items are grouped into several categories (Lovelace & Brickman, 2013). The used PATT-SQ survey (Ardies et al., 2013) consists of six different categories. These categories are presented below with an item example:

Career – respondents' career aspirations in technology
For example: ″I would like a career in technology later on″
Interest –Interest in technology and technology education
For example: ″There should be more education about technology″
Attitude – Negative attitude towards technology
For example: ″I do not understand why anyone would want a job in technology″
Gender – Gender patterns in technology
For example: ″Boys are able to do practical things better than girls″
Consequences – Consequences and importance of technology

For example: ″Everyone needs technology″

Difficulties – Perceived difficulty in the technology subject

For example: ″To study technology you have to be talented″

The survey was translated from English and therefore the items and categories needed to be revalidated for a Swedish context. One item needed a different translation: ″If there was a school club about technology I would certainly join it″ (Bame et al., 1989; Ardies et al., 2013). Sweden doesn't have a tradition of school clubs and the item was changed to something that Swedish students' could relate to. Sweden has something called *students' choice* where the student can choose a subject of their own. The item was translated to "If technology was available as a student choice subject I would certainly choose it".

To better validate the survey, the gender items were elaborated into three different word sequences. One with the original *"Boys are better than girls… (Gender M)",* one with the opposite statement *″Girls are better than boys… (Gender F)″,* and a third version including both types of statements (Gender F+M).

To validate the categories the internal reliability is measured in each category using *Cronbach's alpha* (α) (Lovelace & Brickman, 2013). For the validation the aim is an *α*-value >0.70 as recommended by Lovelace and Brickman (2013). In this specific study the interest category that consists of six statements is reduced to four statements to enhance focus on school technology and not technology in general. These will be used to define a student's interest in technology education. Since an interest towards something can be followed by an engagement in the same (Hidi et al., 2006; Krapp A., 2002): in this case an engagement in the school subject technology.

Apart from the 24 items which the student responds to on a 5-graded Likert scale, two open ended questions were added to let the students describe their views on technology. These are: *"Describe what you consider to be technology (not the school subject technology)″* and *"If you were to describe the school subject technology for anyone who has not studied it in school themselves, how would you describe it?″* To quantify the answers concerning students' view on technology, Mitcham's (1994) four ways of describing technology are used (*objects-activities-knowledge-volition)*. The respondents view score 0-1 points on each of the four ways of describing technology (total score 0-4 points and is named "Mitcham score"). To score in the object category the respondents has to write that technology has to do with man-made objects. In the activities category the process of making or using technology must be mentioned. To score in the knowledge category the respondent need to use technology as an example that requires knowledge, "how to/know how". The final category, volition, includes respondents who express technology as a human will to improve or control technology consciously. Typical examples for Mitcham score are:

1 point - "Computers, Cellphones and Tablets" placed in the category *Objects*

2 points - "I'm thinking of electronics and to build things" placed in the categories *Objects* and *Activities″*

3 points - "How things work and how to fix them" placed in the categories *Objects, Activities and Knowledge*

4 points - "It is knowledge about electricity, technical gadgets, how they are made, how they can become more environmentally friendly, the evolution within technology, how things are built etc."

Lastly, to study if and how students' views on technology are correlated with their attitudes towards technology, the respondents' Mitcham score is correlated with the attitude score using Pearson correlation.

Data collection

To gather data for this pilot study, four schools were visited. The schools were selected by availability after a teacher survey to get a result from different schools. The sample includes one suburb school, one small town school and two private schools from different areas and different profiles. Students in school year 6-9 (12-15 years old) were asked to fill in the survey and the total number of respondents was 173 (89 girls, 81 boys, 3 N/A). In the correlation analysis 9 (5 girls and 4 boys) respondents were removed due to the fact that they had no written comments on any of the open ended questions.

Results

The results from the validation and results from the study of respondents' views of technology are presented below, followed by the correlations between student attitudes and Mitcham score.

Validation

To validate the survey and the six different categories Cronbach's α was used. Each category should meet an α >.70 (Lovelace et al., 2013). The results are then compared with the original PATT-SQ (Ardies et al., 2013) as shown in table 1.

Table 1. Category internal reliability using Cronbach's α coefficient

Category	N Items	N Valid Respond-ents	Cronbach's α Pilot Swe-den	Cronbach's α Belgium
1 Career	4	169	.912	.92
2a Gender M	3	156	.902	.8
2b Gender F	3	130	.867	
2c Gender F+M	6	115	.856	
3 Consequences	4	162	.723	.72
4a Interest	6	166	.761	.84
4b Interest (school technology)	4	166	.790	
5 Difficulties	4	168	.744	.64
6 Negative attitude	4	168	.632	.81

The different items in each category are well correlated with each other except within the Negative attitude category. With the exception attitude, the results' of Cronbach's α show that the translation and adaption for a Swedish context is reliable. However the Gender category shows that there are some differences in the answers depending on how the item is presented. One reason why the category 6 has a lower α-value might be that all these items are presented as negative statements which might be harder to interpret. Also there are big differences between boys and girls in category 6 (boys α .748 girls α .494). The Cronbach's α-level is very sensitive when using few items (10 or less), therefore the inter-item correlation and the individual answers analyzed. The inter-item correlations should range between .2 to .4 (Briggs & Cheek, 1986). The inter-item correlation mean in this case is acceptable .3.

Student views of technology

Results from the students' view on technology are shown in table 2. Of the valid 164 respondents, 14.6% describes technology as something else that does not fit the model of Mitcham's four ways of describing technology. Examples of those answers are "Don't know", "Technology is technology" and "Not fun. Love soccer"

Table 2. Distribution of students' Mitcham score

Mitcham score	Frequency	Percent
0	24	14,6
1	32	19,5
2	69	42,1
3	33	20,1
4	6	3,7
Total	164	100,0

The most common view on technology is technology as an object. The most common combination is object-activities, only 2 of 39 respondents that score 2 points including activities relate this to knowledge. Of the 164 participating students, 45% see technology as knowledge.

Correlations between student views of technology and their attitudes towards technology

The Mitcham score correlations with attitude categories 1 (career), 3 (consequences), 5 (difficulties), 4b (interest in technology education) and 6 (negative attitude) are presented in table 3.

Table 3. Pearson correlation of Mitcham score and Attitude categories

	Mitcham score	1	3	4b	5	6
Mitcham score	1	.097	.389**	.271**	-.094	-.193*
Girl	1	.065	.461**	.268*	-.064	-.067
Boy	1	.216	.353**	.409**	-.078	-.386**

** p<.001 (2-tailed).

* p<.05 level (2-tailed).

The results indicate that there are three categories that are correlated with the students view on technology; 3 consequences, 4b interest in technology education and 6 negative attitudes. There are also differences between boys and girls. Interest and negative attitudes have a stronger correlation for boys, while consequences has a stronger correlation for girls.

Conclusions and future research

The survey seems to be a good tool for continued use. A category that early on seemed to be strange in a Swedish context was the *Gender* category. This category needs a deeper investigation to understand how respondents actually interpret the statements. The gender statements seem to trigger gender conscious responses in general, instead of showing their view on gender issues in technology more specifically.

The results from the pilot study indicates that a student with a high Mitcham score has a higher interest in technology education, a less negative attitude towards technology and see the importance of technology. The correlations are even stronger when it comes to boys, especially regarding negative attitudes, which does not seem to affect girls at all. It is also shown that these students in general do not see knowledge as a part of technology. They are mostly focused on describing technology as artifacts and activities. The fact that they do not consider technology as a distinct form of knowledge can of course be a consequence of the way the questions are posed, but it can also say something important about their ways of understanding technological knowledge more generally. It could also mean that the students in this study have gotten their view on technology from somewhere else but school, if so; what hinders the students from seeing technology in a greater context? This must be further investigated, for example, through complementary in-depth interviews with students and by transforming these open-ended questions into quantifiable ones in a revised PATT-SQ.

Why participating students with a low Mitcham score tends to have a lower interest in technology education might be explained by the fact that the students' knowledge is held back because a lack of interest, as was shown in relation to higher education by Krapp (1999). Or, it might be the other way around: students that have a deeper understanding of technology develop a higher interest. Either way they do seem to affect each other, which mean that increasing one should in fact increase the other. If we want technologically literate citizens in the future, students' interests in technology need to be addressed.

The aim of future research is to collect data using the validated survey but on a national representative sample. That survey will make it possible to determine the national interest and attitude towards technology education in school year 6-9 (12-15 years old). Parallel to that a search for schools that use different methods to increase interest will begin. The survey will be used to examine the interest level and attitudes correlated with their view on technology. The intention is to find out if some schools actually are able to increase interest in technology education, improve attitudes and reach a greater knowledge in technology. To do this, the questionnaire needs development regarding student views on technology. To eliminate some of the other factors that can have influence on the respondents' interest and attitudes, predictors that have been used in earlier PATT studies have to be used. Moreover, the schools that scores better need to be studied more deeply. We need to find a good example of how to develop that technologically literate citizen. With the future studies the hope is to reach greater understanding of how high interest and high technological knowledge may be developed and how they interrelate.

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Teaching and learning system thinking in technology

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Abstract

Complex technological systems have emerged during the last decade as an important strand in technology teaching in several national curricula for compulsory school. However, even though understanding the systemic aspects and connected nature of contemporary society, it remains unclear what such understanding entails in detail, and even more unclear what may constitute good teaching. We present the results from a teaching-learning design project on the topic of large societal and complex technological systems, which are seen as constituted of transformation and transport, acting on matter, energy and information.

The main results are a suggested and evaluated plan of teaching developed in collaboration with a team of technology teachers, as well as descriptions of how pupils' system thinking is constituted in terms of four basic aspects: Resource and intention of the system; System component constitution; Process and transformation in components and system; Network character. In total, a teaching plan spanning four lessons was realised in four different classrooms, with classes' sizes ranging 15 to 25 pupils in the ages 14 and 15. The teaching design progresses through focusing specific parts of various systems, for example the transformation of polluted water to clean water in a water purification plant as part of the water supply system. There is an emphasis on the function of the part in relation to the system on the one hand, and on how the part is and can be realised technically, taking care to relate the latter to what is taken up in other curricular strands of technology. The last part focuses the examination of technological systems as constituted by interacting and meaningful parts, where their network nature may emerge.

Keywords

Complex technological systems, phenomenography and variation theory, system thinking, teaching and learning technology

Introduction

Complex technological systems, such as the water supply system, internet or the railway transportation system, have emerged during the last decade as an important strand in technology teaching in several national curricula for compulsory school. However, even though understanding the systemic aspects and connected nature of contemporary society, it remains unclear what such understanding entails in detail, and even more unclear what may constitute good teaching. This study attempts to contribute towards alleviating this through collaborative research with technology teachers, both generating possibilities for teaching and explicating what constitutes understanding in the context of complex technological systems.

Research questions

- What may constitute basic aspects of understanding complex technological systems from the perspective of learners?
- What are productive ways of teaching that may facilitate discerning and understanding such basic aspects of complex technological systems?

Literature

This research project concerns teaching and learning of technological systems, which are complex systems of technical and human components that facilitate much of the experienced needs of modern society, such as internet (information), water supply system (matter) and the power grid (energy). Systems that are not tangible and consist of components and connections on different levels as well as human interaction could be described as complex technological systems. In the literature, there have been several attempts to explicate what technological systems are and what may be valuable to know about them (cf. Dusek, 2007; Hughes, 1987). However, there has been little research that investigates what pupils may understand about such systems, or how teaching may be organised. Nevertheless, there is some research recently carried out that concluded that pupils in the later years of compulsory school understand the structure of systems better than they understand the intention and interaction of technological systems (Koski & de Vries, 2013; Svensson, 2011; Örtnäs, 2007), and that teachers lack knowledge about system thinking and are unfamiliar with how to teach about complex technological systems (Klasander, 2010; Svensson & Klasander, 2012).

Understanding technological systems imply system thinking. Empirical studies so far suggest that the basic capability in (complex) systems thinking is the recognition of a meaningful framework of relationships connecting seemingly isolated events and components to become an interconnected whole, also operating on a different level (Assaraf, Dodick & Tripto, 2011; Jacobsen & Wilensky, 2006) – i.e. seeing something *as* a system (cf. recognising a phenomenon, as described in Marton & Booth, 1997). This is difficult since many aspects of systems are never directly experienced (Hmelo-Silver & Azevedo, 2006).

Theoretical underpinnings

The study is theoretically, analytically, as well as methodically, in line with the phenomenography and variation theory tradition (see, for example, Marton & Booth, 1997 and Marton & Tsui, 2004). Learning is understood as the learning of something, and that there are some aspects that are more critical for learning than other aspects. While learning is understood as individual, one important consideration in this project is the collective nature of expressions of knowledge in classroom situations, in whole class as well as in small group discussions (cf. Ingerman, 2013).

Research design

We present the results from a Swedish design research project, where six technology teachers in compulsory school collaborated with the research team. The collaborative phase – which concerned design, realisation and reflection regarding teaching of technological system – resembles an action research approach, geared towards generating design, and thus part of the broader design research movement (The Design-Based Research Collective, 2003) and more specifically similar in many respects to a learning study (Marton & Pang, 2006). However, the analytical phase of the project address questions that falls outside the scope of most action and design research, and concerns fundamental queries on learning processes and the constitution of technological systems as a knowledge area.

The starting point for the project was previous research on teaching and learning technological system (Klasander, 2010; Svensson & Ingerman, 2010; Svensson, 2011), in particular Svensson's phenomenographic study of pupils' experiences of technological systems and their implications for teaching in terms of three key dimensions: resource, intention, structure. The collaborative work started with four seminars in which technological systems as knowledge area was discussed with the ambition of forming a shared understanding in the group. Then followed two rounds of teaching design and reflection. The process was carefully documented through audio and video recordings as well as notes and collection of written material. Throughout the process elements of analysis were interspersed, and can be seen to have a dialogical relationship to the reflection in the teacher-researcher meetings. Thus, there is a gradual shift from action research owned jointly by teachers and researchers towards the analytical process, carried out by the researchers, at the latter part of the project.

The teaching and the setting

Technology is a separate subject in the Swedish curriculum with specific knowledge requirements for year 6 and year 9. Technological system as part of the subject is poorly established and the content is not described in detail in the curriculum (Skolverket, 2011). Klasander & Svensson (2012) point out that individual teachers lack the knowledge and experience to teach about systems. The teachers that became involved in the project, was the result of a positive selection process, where they volunteered, and all of them showed an engagement as technology teachers and were formally qualified as technology teachers.

The initial seminars considered aspects such as connections to the technology domain context (transformation, transportation, control, regulation and storage) and concrete ways of making comparison across different systems.

The teaching plan consisted of four lessons focusing technological systems. The first lesson took its starting point from the pupils' daily morning habits – the pupils were put in groups without a theme introduction with the assignment to document their morning habits, and sort habits into common groups. They were then asked to consider what was needed in order to facilitate these different groups of habits. The second and third lesson focused constructing physical or representational models of systems, in some cases of different systems and in some cases of different components within a system. One part of the fourth lesson consisted of group presentations of their models, and comparisons and relationships between the models. Another part of this lesson (or in some cases a fifth lesson) focused group discussions on what would be the consequences of disaster or major malfunction in one or several systems in society.

The teaching design was realised in four different classrooms by four different teachers, as normal lessons in the subject technology. Their classrooms consisted of 15-25 pupils in each. The design allowed for variation in realisation, and the teachers accordingly adapted it to the local school tradition and their personal way of teaching. One class was in their final year in compulsory school (15 years old) and the others were in the second last year.

Data collection

Classroom teaching was documented through audio and video recording with high technical quality. Several video and audio recordings were made in each classroom. One camera focused the teacher, and two others focused small groups of pupils, both when they interacted in the whole class setting and had separate discussions or practical work. Complementing interviews were made with a small set of pupils. The teachers were asked to reflect immediately after the lesson. All interviews were recorded, as well as seminar discussions with teachers and researchers, and all data stored securely.

Analysis

Throughout the analysis, we used the video material as a whole, since it was important to keep the quality of an overall understanding of the teaching. It was also important to identify key events and the type of knowledge about technical systems that was expressed, both in teaching and in pupils' conversations. No overall transcriptions were made, but selected sections of the material have been transcribed as the analysis progressed.

In relation to the first research question, we primarily focused on one specific part of the material, when pupils presented models of different systems. In total about 25 groups with pupils presented. Through comparing what was said about systems by different groups in their presentation, and drawing on aspects identified in previous studies; resource (matter, energy and information), intention (the aim with system for individuals and society), structure (components and connections between components and other systems), we identified four basic aspects that in different ways connect to system thinking. These aspects were descriptive of the whole material in the sense that the extent to which they were dealt with in the presentation constituted the variation in quality of the presentations.

In relation to the second research question, we made use of the basic aspects identified in the first analysis to characterise the realisation in the four different classrooms. Part of this was done iteratively and included revision of the teaching design. In the next step we identified indications of productive ways of teaching across the variation between classrooms in relation to different expressions of systems thinking. Thus, we can suggest how different aspects of the teaching connect to and are reflected in the qualities in the presentations.

Results

Insights on understanding of technological systems

The results show a range of how pupils in creating models/representations and in descriptions may articulate their knowledge of system aspects, appropriate for the level and scope of teaching. On an overall level, we identify four basic aspects of system thinking along which independent qualities in different student expressions align. They connect to and constitute both (physical and principle) organisation and (technical) function of the specific system discussed. In abstracted form, they are:

A. Resource and intention of system, and delimitation of system in relation to intention.
B. System constitution in terms of components (structure)
C. Intra function of components and inter component function in system (process and transformation)
D. Network character

In this context of this paper, we will point to three examples (out of the 25 group presentations) of how such expressions take concrete form. They all have clear qualities of student reasoning about technological systems, expressing one or several of the basic aspects identified. The empirical material as a whole indicates that the different aspects not necessarily may be easily simultaneously expressed – no examples include all aspects at the same time, and it is not clear that one example may be categorised as 'better' than another. However, in some examples, several aspects are simultaneously present at the same time, which we see as valuable. We will detail one such example for illustrative purposes.

The first example concerns a presentation of a water system, focusing distribution of water to households using water towers etc. This example has a typical quality in that the system structure constitution is very clear and delimited in the pupils' expression, and is put in relation to the overall intention of the system (aspect A & B). The expression could develop in quality, for example, through opening the system towards the surroundings and connected systems and/or through adding technical detail of the components.

The second example concerns a presentation of systems connecting to a public transport bus, for example, to electricity, education, wages, planning, traffic rules, petrol, building roads. This example has a quite unusual quality in that the network structure of systems becomes explicit (aspect D). The expression could develop in quality, for example, through making clear the delimitations of the system considered and/or through adding technical detail of the components.

The third example concerns a presentation of a water system, focusing the distribution of water *within* a house, towards the background of the water supply system in society. This example has a strong quality in relation to the technology knowledge domain in that it explicates the process of the water flow in the house and, in particular, the transformation of water (such as from cold to warm, from clean to dirty). They also connect this process to regulation and control in relation to the purpose of water availability at the turn of a water tap, the specific function for the individual user of the system. (basic aspect C against the background of A & B, now including a level of specificity in relation to the individual component of the house and the technical constitution of this component). The expression could develop in quality, for example, through extending the linearly structured process in relation to network dependencies.

The technical quality of the latter example is quite distinctly visible, for example, in the following quote:

> *Boy A - There is an electrical box for the house and a heating boiler, the water is coming here into the heating boiler where the cold water is heated up and then there is also cold water coming out … so the blue line (pointing at a blue string on the model) is cold water and the orange one (pointing at a orange string on the model) is warm water and that one is the main power cable*.

Teaching for learning system thinking in technology

Based on the above descriptions of basic aspects of systems thinking we have identified productive elements of teaching for learning system thinking in technology.

One of the core parts of the design was the open introductory part, where experiences the pupils had in their daily lives – their morning habits – were used to suggest patterns of connections to technological systems. This part of the design seems to be fruitful in supporting the discernment of systems. This was clear both from the general level of system thinking in the presentations of models (almost all pupils displayed clear understanding of some system aspects), but also from the emerging awareness apparent in group discussions about morning habits.

Another part of the design was realised differently in different classrooms. Even though the pupils' construction of a model (in lessons two and three) was common in all the classrooms, the focus and emphasis of the models differed. In one classroom, the pupils constructed models of different 'whole' systems, such as the water supply system, the electricity system or the transportation system. In another classroom, the pupils constructed models of different components of the water supply system or the Swedish electricity system, together constituting the whole system. From the range of presentations it is clear that working with different 'whole' systems gave a low level of technical content. Working with components in some cases gave the results that technical details overshadowed the systemic perspective, while in other cases technical detail and framing was put in relationship to systemic thinking. Looking at the teaching in retrospect, similar patterns can be seen in how the teacher addresses this balance. Our conclusion is that it is important that both the design of the task and how the teacher addresses the content reflects a balance between technical details and the systemic perspective in order for facilitating systemic thinking connected to the technological knowledge domain.

In connection to the classroom where there was a balance, there also emerged a possibility to discuss the system in terms of process, taking into account technical details of how components interacted to propel the system towards fulfilling the overall function of the system. This quality was observed both in the teaching and in some of the group presentations.

Discussion/Conclusion

The results from the study demonstrate that pupils in compulsory school can develop a basic grasp of technological systems without much prior teaching. At the same time, system thinking appear to be challenging both for teachers and pupils. Teachers and pupils here grapple with dealing simultaneously with the network character and the detail of component-system function.

The teaching in this study included establishing notions relevant for discussing systems, such as components, system control, input, process and output. Such notions could be established in relation to 'simple' technical systems, such as the bicycle, computer or the engine, and be taught before addressing complex technological systems (cf. Koski & de Vries, 2013). On the one hand, this would support progression with respect to system thinking in technology, and on the other hand, this would allow focusing complexity and the network character in the kinds of system discussed here.

There are questions that the study indicates would be valuable to address in further research. For example, the results point a possible tension between developing system thinking on the general level, or progressing through extensive interaction with and learning about particular systems. This is reciprocal with whether learning about systems in general is better than learning about technological systems in particular and similar learning challenges regarding, for example, complex natural systems (cf. Assaraf, Dodick & Tripto, 2011).

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ICT learning in A Design AND Technology curriculum

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Abstract

Design learning requires a specific ability to handle versatile digital instruments mentally and physically, in addition to drawing skills. Several tools are used during the design activity phase to search for information (Web), realize representations (2D, 3D), organize and state processes (word processing), and shape artifacts with "operative images" (image processing). Yet, in the current French design and technology (D&T) curriculum, the digital technologies are taught by applied arts and mathematics teachers who are not expert practitioners. We intend to understand the place of digital tools as 'instruments' within design activity by using underpinned activity theory (Engeström, 2011; Lebahar, 2007; Ochanine, 1966; Vygotsky, 2012) and ergonomics' studies (Safin & Leclercq, 2009). An attempt is made to bring the didactics of D&T (de Vries, 2008; Ginestié, 2013), mathematics (Balacheff, 2010; Gueudet & Vandebrouck, 2009), and TPACK (Koehler et al., 2014; Voogt et al., 2013) together for this analysis. We sought to determine the how, what, when, and why D&T teachers can teach using digital technologies. We also tried to show that digital technologies can enhance teaching technology, if:

- the tasks the teacher has prescribed are relevant to the D&T objectives in high school,
- the teacher has the knowledge and skills to use technology,
- the tools' functions can be taught as not "magical" instruments,
- an "interdisciplinary instrumental orchestration" is made, and
- 2D or 3D representations lead to a new "drawing space".

Using the technological and pedagogical content knowledge (TPACK) research, the present research was based upon a curriculum analysis of the French D&T high school diploma (the STD2A baccalaureate) and upon four criteria presented by Angeli and Valanides (2009): identifying the learning objectives, selecting content, planning didactical material, and designing the learning environment.

Keywords

TPACK, models, digital instruments, operative images, drawing space.

The D&T curriculum, known as Sciences and Technologies, Design and Applied Arts (STD2A baccalaureate), appeared thirty years ago (1982) in French high schools, and was transformed and rewritten twice. The first re-write was in 1996, the second in 2011, which is when the curriculum specifically required interdisciplinary design and ICT learning and involved mathematics and applied arts (AA) teachers.

Among other things, mathematics teachers have to look at digital pictures with the help of freeware programs that AA teachers have generally never studied or used ("Design et arts appliqués pour le cycle terminal STD2A", 2011; "Enseignement de mathématiques de la série STD2A-classe terminale", 2011). By analysing the STD2A curriculum, and with the design activities at stake, we intended to look for digital tools' place, especially mandatory models representations, such as drawings, technical drawings, simulations, 2D and 3D.

The technological and pedagogical content knowledge (TPACK) research provides a relevant theoretical framework for determining the learning of digital tools and their use by the AA and mathematics teachers. An attempt was made to display similarities between the TPACK model as well as the complex psychological interactions and potential connections between TPACK and activity theory.

The methodology is based on a curricular analysis of four criteria: identifying learning objectives, selecting content, planning didactical material, and designing the learning environment (Voogt et al., 2013). The findings are presented and all the TPACK components are reported. The outcomes and conclusions regarding the role of "magical artefact" in a new "drawing space" are made.

Literature review

Design activity consists of organizing tasks to design an artefact model that does not proceed from an existing model (Lebahar, 2007). When a designer wants to achieve a task (e.g., sketching an artefact with 3D software), he/she carries it out as a design activity (Rogalski, 2008), through decisions he/she expresses with exhibited actions, interactions with other subjects, as well with inferences and assumptions.

The design activities of architects, designers, and design students has been thoroughly analyzed by Lebahar (2007) and Tortochot (2012). A portrait has been illustrated within complex interactions (Figure 1), where the basic elements of the digital tools take place and appear in the stages of the (2), (4), (5) and (6) interactions.

First, the designer is a psychological subject interacting with design tasks that organize the changing representations of artefact models to reduce design uncertainties (2), such as from doubtful sketches to accurate 3D models. Sometimes, other subjects directly interact with different representations states or steps (step 2, twice), for example in a design learning framework, design teachers separately assess the student's work by taking into account verbal or no-verbal statements that shape the written, graphic, or schematic design outcomes.

Aside from that, the designer speaks with himself/herself to create decisions about his/her design activity (1). This takes place within the designer's consciousness. To define consciousness, Vygotsky speaks about "experiences just like experiences that are simply experiences of objects" (1997, pp. 71-72). In Lebahar's (2007) study, consciousness is a "cognitive split", that sequentially allows the tasks to be planned in a working context.

In this way, the designer builds his/her design skills (3), such as by using his/her knowledge and meta-knowledge, value system, imaginary world, cleverness, and dispositions. The designer fits his/her activities into external knowledge (4), with the Internet as a significant part, for instance.

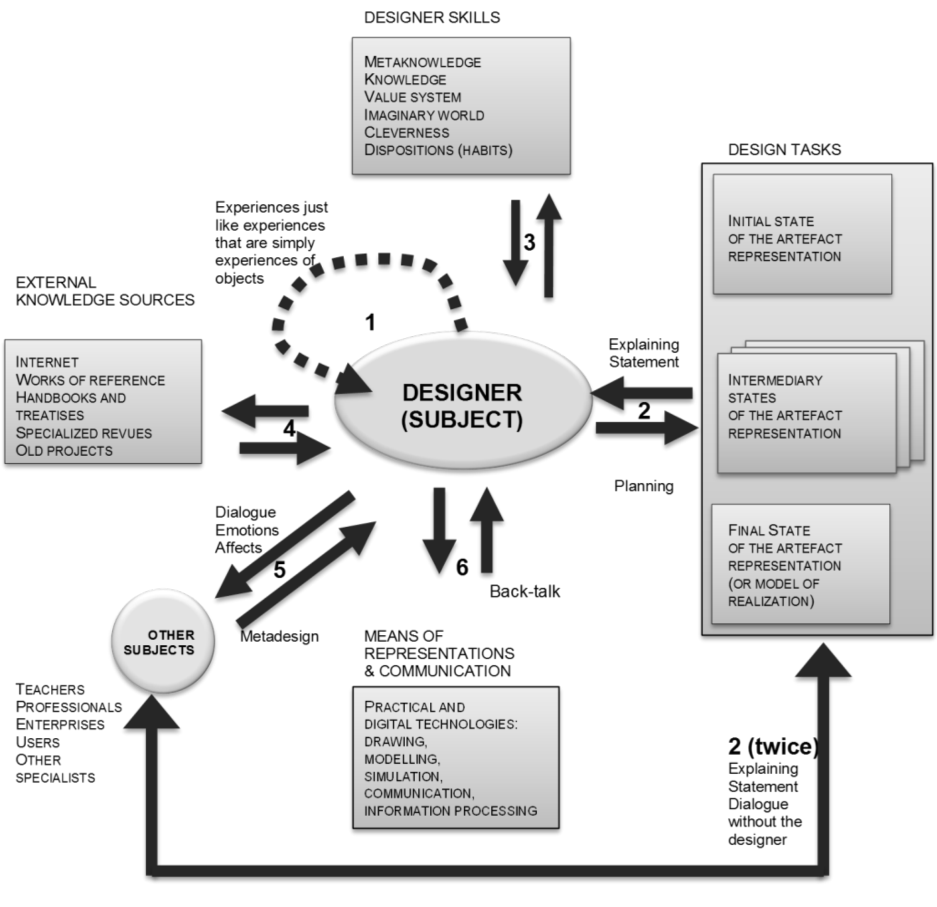

Figure 1. The interactions' complex.

The designer also interacts with other subjects. He/she generates a 'metadesigned' shape (5) thanks to a stated, shared, and distributed activity (needs assessment). (Steen, 2013). The design activity becomes a metadesign activity; the design tasks are planned in a collective work and the design project becomes a process based on metaknowledge, like so many representations of associated and discussed skills (see the following example of SketSha: 1.3.). At last, the designer's subject enters into dialogue with a range of representations and tools or instruments –including the digital– that he/she uses to realize the design (6).

Representations are essential instruments to carry out the design activity allowing the modelling of forms, features, and achievements from an abstract design. Ochanine (1971, p. 304) called these representations "operative images". They have two functions. First, they set a cognitive function (the designer's subject can shape the desired data he/she collected). The second is a regulating function (the subject uses the 'operative image' as an artefact to act with the data).

Artefact is a polysemous word that has been precisely defined (Lebahar, 2008):

- as an object, artefact is a substance, a spatial entity (e.g., furniture);
- as a system, it can be led by an outside or inside dynamic (e.g., vehicle);
- as a commodity, it may be a production or a consumption (e.g., smartphone);
- as a symbol, artefact is a symptom, a magical object, an aesthetic object (e.g., advertising or logotype or 3D images).

Artefacts require the instrumented designer activity before, during, and after this activity. It is a psychological and social reality far from the idea of an artefact-generated activity and far from the technical devices (Rabardel & Béguin, 2005). When a psychological subject acts on an object to modify it, or to reach a goal, the behaviour is intermediated by an instrument. The subject builds this mediation/reflection to establish its social relationship networks and, so, to act in (and with) its environment (Ginestié & Tricot, 2014). The instrument is like an 'intermediary object' for it is a future artefact representation and also a mediation tool between the design network stakeholders (Grebici, Rieu, & Blanco, 2005).

The digital tools are basically linked with the design activity because models (handmade drawings, scale-models, prototypes, 3D sketches) and numerical systems (graphic applications, 2D and 3D, etc.) are design and training means (Lebahar, 2008). These tools take a central place in design achievement and creativity during the collaborative process inside teamwork (Glaveanu et al., 2013).

Handmade sketches actually allow one to plan the activity, to control and attest the superimposed representation tasks. Safin, Juchmes and Leclercq (2011) attempted to create a closer environment of a handmade sketchbook with digital tracing paper layers; 'SketSha' program is set up to shared sketches with overlaid drawings that interact or not.

The authors called this digital environment a "drawing space" (2011, p. 22) in which the significance of the gesture of draughtsman must help its interpretation and the anticipation of design back-talk (Schön, 1984, p. 5). This is "a reflective conversation with the materials of the design situation" in which sketches tell another sense and another idea compared to what the author thought. Thus, there is a reflection in action and even with drawing space in a digital environment. The design evolves in another path.

We attempted to reconcile D&T didactics and TPACK in a former paper (Tortochot, 2013). Through a students' activity analysis, we looked for "the significance of the partnership of learners in the building of TPACK" and we were interested in the curriculum organization and teaching methods (Williams & Lockley, 2012). We did not try to gather activity theory and theoretical TPACK frameworks in our study because it could be another research item.

To follow the theoretical background established by Koehler and Mishra (2009), TPACK components have been collected in a scheme (Figure 2). Three bodies of knowledge interact. These include Content Knowledge (CK), Pedagogical Knowledge (PK) and Technological Knowledge (TK). Their interactions provide three types of knowledge: (a) PCK or the organization and adaptation of topics, problems or issues for learners; (b) TCK, namely the content of technological part in pedagogy; and (c) TPK, when Technology becomes a teaching body of knowledge.

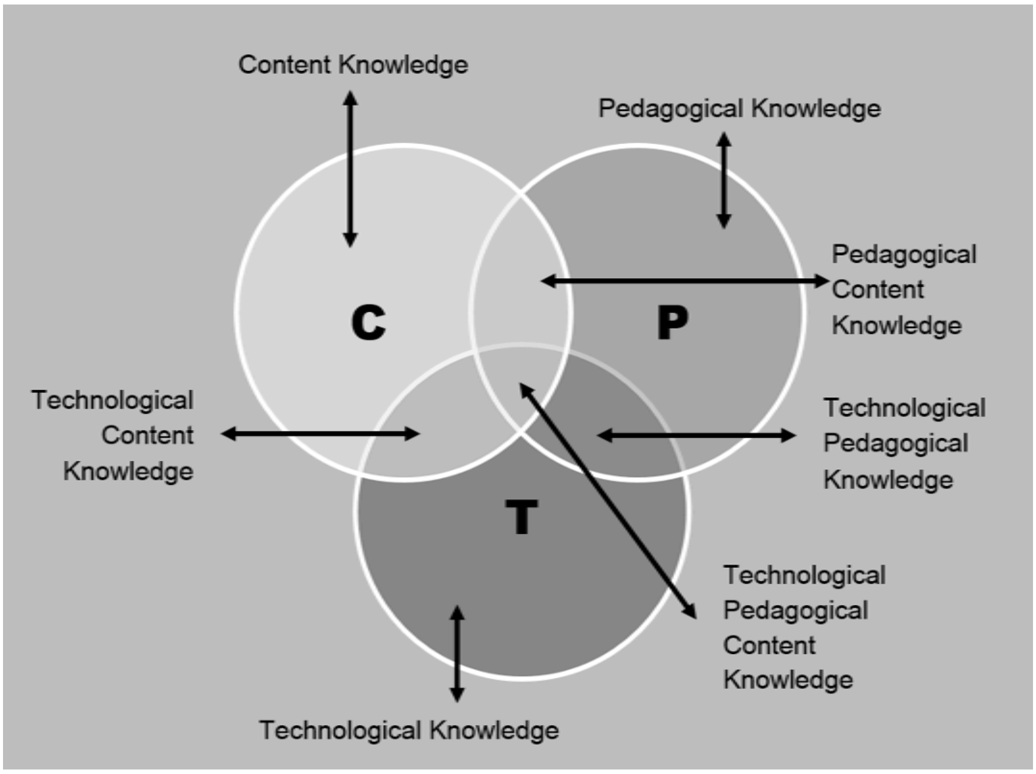

Figure 2. Technological pedagogical content knowledge and its knowledge components. (Koehler & Mishra, 2009).

TCK, TPK, and PCK meet at a central place, displaying TPACK, referring to "knowledge about the complex relations among technology, pedagogy, and content that enable teachers to develop appropriate and context-specific teaching strategies" (Koehler & Mishra, 2014, p. 102).

According to Koehler and Mishra (2014, p. 102) and to design activity theory, the researchers wanted to demonstrate "that teachers need to have deep understandings of each of the above components of knowledge in order to orchestrate and coordinate technology, pedagogy, and content into teaching." We can talk about an 'instrumental orchestration', when teachers are taking into account learning situations and available artefacts to purpose a 'pleasant play' (Gueudet & Vandebrouck, 2009). This is for the didactical planning and also for its realization.

Through design didactics (taking into account the special training tasks within design learning) AA teachers could lead pupils to create new problems thanks to these representations and not to solving problems with it (Lebahar, 2007). Unlike design learning, representations do not generate new problems in mathematics, but to solve problems. They are like 'statements' or 'utterances', located between action – means to act – and verification – evidence to control – in a problem-situation (Balacheff, 2010). Darricarère and Bruillard (2010) underlined that mathematics teachers also consider the digital tools as 'magical' to realize beautiful and attractive pictures.

Methodology

According to Voogt et al. (2013), the researchers looked for measuring the teachers' TPACK, bearing in mind that we gathered no students' products or classroom observations, but some documents, written by D&T pedagogical experts, for the French Ministry of Education, amongst the didactical material of the STD2A baccalaureate.

Eight texts can be downloaded from the pedagogical website of the Ministry, called 'EDUSCOL'. The chose three files for this paper, and we accurately presented just one, due to the space constraints. While these documents do not report TPACK vocabulary, these files do include CK, PK and TK, and all interactions between the types of knowledge, as we tried to demonstrate.

To begin and organize the curriculum analysis, we used four criteria (Voogt et al., 2013, p. 8): identifying learning objectives, selecting contents, planning didactical materials and designing the learning environment.

Findings

The official papers referred to in the STD2A curriculum plan aims to help both AA and mathematics teachers to teach ICT (EDUSCOL, 2011a). They describe tasks that the teachers can do, but they do not explain what teachers have to do. As a matter of fact, the purpose of these guidelines is not to impose a mandatory content upon the learning situations. The introductory text of didactical material bears this phrase as an epigraph - "These documents can be freely used and modified in scholarly learning activities".

In a second place, the guideline precisely recommends to "explain the functioning of some digital graphic tools, so that it allows [the user] to control them" (EDUSCOL, 2011a, p. 3). The first analysis we chose to analyse was the topic of chromatic cube. The second one was the Bézier curves. The last was the grey scale for digital images.

In a single course, mathematics' teachers have to work on colours with image processing freeware, namely to explore some geometrical topics and some rules of colour separation (EDUSCOL, 2011b). The first exercise is on space spotting, dividing a simple solid with a plan and on parallel perspective. This is a kind of 'orchestration' which advises teachers to use a video projector to benefit from the colour quality and from plans' movement the JAVA Applet generates.

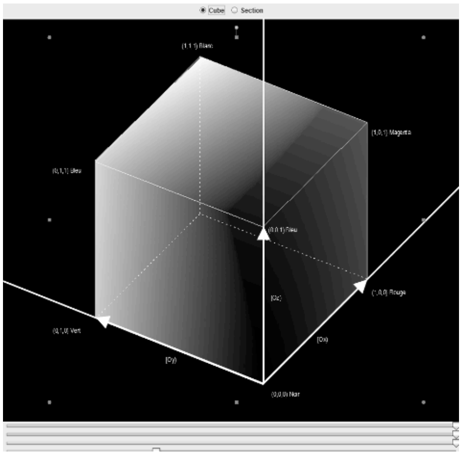

Figure 3. Chromatic cube.

After a presentation of the chromatic cube with its three axes (Figure 3), its origin (black), the opposite point (white), the three vertexes (red, green, and blue, e.g., RGB), teachers required students to find the original point with two different views (the first is displaying the white point; the second the black one) (Figure 4).

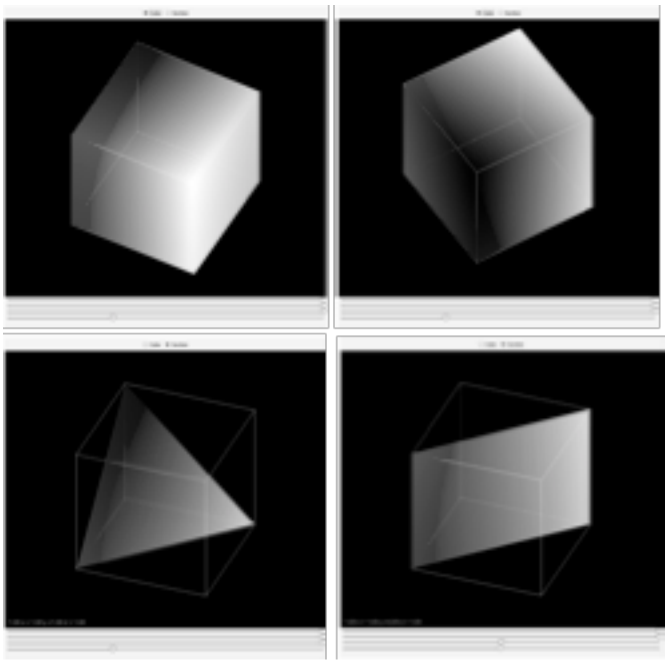
Figure 4. Different geometrical shapes.

To follow the first exercise, using the JAVA Applet, students have to draw plans whose vertexes are the cube vertexes, where points situated in the middle of the edges (Figure 4). Some mathematical questions are posed on sections that create new shapes (triangle, rectangle, hexagon, etc.), on plan equations, on two plan intersections bringing a straight line D, called 'chromatic axe', i.e., the grey axe between both black and white points.

In this learning situation, students' training is supported by the objects' analysis in space. Such a problem leads design students to reconsider the organization of images' colours that they can see on a digital screen. Students can be designer of these images or just consumers. As designers facing a chromatic cube (TK), students could be led to 'operative images' (TCK and TPK), in order to highlight the data they need (cognitive dimension: TPACK). So, students could work and act with image processing editors (regulative dimension: TPACK orchestration) without the spontaneous belief in a magical function.

Table 1 shows how the recommendation contributes to the TPACK, pointing out and planning potential teachers' activities and desired students' tasks.

Table 1. Design Activities and 'Operative Images' Suggested by Instrumental Orchestrations (Chromatic Cube) in the Intersection with Knowledge

	File 1 Chromatic cube
Content Knowledge (CK)	Millions of colours within a geometrical volume
Pedagogical Knowledge (PK)	Analysis of space objects
Technological Knowledge (TK)	Discovery of the JAVA Applet allowing to draw the chromatic cube
Technological Content Knowledge (TCK)	To obtain a good quality of colours and a movement perception, using videoprojection
Pedagogical Content Knowledge (PCK)	To spot in space To divide a simple solid with a plan To draw a parallel perspective
Technological Pedagogical Knowledge (TPK)	Useful properties of parallel perspectives
Technological and Pedagogical Content Knowledge (TPACK)	Learning situation led with the videoprojector, with all the students and dialogue with the group

Table 2. Design Activities and 'Operative Images' Suggested by Instrumental Orchestrations (Bézier Curves and B&W Pixels) in the Intersection with Knowledge (EDUSCOL, 2011 c & d)

	File 2 Bézier curves	File 3 Black & White Spreadsheet (pixels)
CK	Photos and layers with Bézier curves	Photos
PK	Connection of two curves	Functions of reference Equations
TK	Dynamical geometry software (GeoGebra)	Spreadsheet Free image processing software (XnView, The Gimp, etc.)
TCK	Place of geometry in architecture	Composition of the pictures' grey scale
PCK	To handle points and vector graphics upon architectural pictures	To handle functions and formula in a spreadsheet To write a Cartesian equation of a circle and an ellipse
TPK	Analysis of an architectural component	Discovery and handling of pictures' grey scale
TPACK	Analysis of a document and process engagement Operation of simple situations: connection of 2 curves Calculation of angles and lengths	Structure of a digital picture

When design, mathematics, & TPACK meet, representations take on a more significant place, especially in design models. Software programs allow students to create models and to build scientific knowledge thanks to instrumented experimentations and observations. Bruillard, Komis, and Laferrière talked about "environments linked to very small worlds and modelling" (2013, p. 11).

Discussion

Thanks to the knowledge that scientifically constitutes digital tools, students who learn designing have to stop their exploitation, by chance, as simple ideas' mediator. The STD2A curriculum recommends a bigger autonomy in the use of digital instruments in order to enhance their creativity (Design et arts appliqués pour le cycle terminal, 2011, p. 5); representation becomes a constructive control system component of design skill, helping and achieving a better design tasks' planning. Digital tools finally give the necessary and operative autonomy in tasks' planning because students know the instrument and still know why, when, and how to use it when they represent the artefact model.

The distance the students set with digital tools and their relationship between appropriated gestures and conceptualisation, allows them to apprehend the systems to build a digital culture. This space could lead to linking the experiences of "users and underpinning concepts of carried out systems" (Drot-Delange & Bruillard, 2012, p. 77). There use without TPACK does not permit them to discover or to build the design skills, except with a "verbalization of situations, allowing to distancing from deeds and to build concepts" (idem). It is a statement process, i.e., a single event, sustained by an utterer and a particular person addressed (Ducrot & Schaeffer, 1995), being able to lead to metaknowledge, and in the case of design learning, to metadesign (see interaction [5] in Figure 1).

The multidisciplinary nature of digital intermediary objects, especially in a design learning activity, is closer to a teacher's didactical planning. In this way, analysed samples prescribe real illustrations of 'instrumental orchestrations'. The significance the teachers give to issues they present to students, takes up a singular status in design process (Brandt-Pomares, 2011, p. 67). When the use of digital instruments within mathematics or design learning is completely mastered, these instruments permit the design process for potential help in the training they carry out.

Table 3. Findings on Design Activities and 'Operative Images' Suggested by 'Instrumental Orchestrations' in the Intersection with Knowledge

	File 1 **Chromatic cube**	**File 2** **Bézier curves**	**File 3** **Black & White Spreadsheet (pixels)**	**Didactical planning: complex interactions' components and theoretical background**	**Teachers**	**Students**
CK	Millions of colours within a geometrical volume	Photos and layers with Bézier curves	Photos	**External resources** at all the digital screens (theatres, TV, Pads, Smartphones, etc.) : '**magical artefacts**'	Math & AA: Yes	Yes
PK	Analysis of space objects	Connection of two curves	Functions of reference Equations	**Planning** of mathematics knowledge	Math: yes AA: no	No
TK	Discovery of the JAVA Applet allowing to draw the chromatic cube	Dynamical geometry software (GeoGebra)	Spreadsheet Free image processing software (XnView, The Gimp, ...)	Software to handle as **representation & communication instruments**	Math: yes AA: no	No
TCK	To obtain a good quality of colours and a movement perception, using videoprojection	Place of geometry in architecture	Composition of the pictures' grey scale	**Explanation** of parts of the pictures we see on all the screens: '**operative images**'	Math & AA: Yes	No
PCK	To spot in space To divide a simple solid with a plan To draw a parallel perspective	To handle points and vector graphics upon architectural pictures	To handle functions and formula in a spreadsheet To write a Cartesian equation of a circle and an ellipse	Different and superimposed **tasks** to master the **representations** with mathematical **tools**	Math & AA: Yes	No
TPK	Useful properties of parallel perspectives	Analysis of an architectural component	Discovery and handling of pictures' grey scale	Understanding of **artefacts**' mechanisms (pictures, structures, drawings, etc.)	Math & AA: Yes/no	No
TPACK	Learning situation led with the videoprojector, with all the students and dialogue with the group	Analysis of a document and process engagement Operation of simple situations of connection of two curves Calculation of angles and lengths	Structure of a digital picture	All the available **digital tools** to explore and to **design** the complicated reality and its **representations**: a new '**drawing space**'	Math: yes AA: no	No

Even if teachers do not know the contents and believe 'magical artefacts' (external sources, immediately available with intermediary objects like digital screens) or do not master a part of PK, they explore and use TK, TCK and TPK in their learning. The didactical planning (fifth column, Table 3) is a path to achieve TPACK, e.g., a digital 'drawing space'. Students and teachers together learn during the training process and build themselves, in "experiences just like experiences that are simply experiences of objects" (Vygotsky, 1997, p. 71-72).

Conclusion

Thus, TPACK in design learning could be an integrative didactic, fond of the other propositions, and mastering the needed learning materials. In comparison, the designer enters into a dialogue with many specialists. E.g., engineers, sociologists, economists, anthropologists, ergonomists,, and, so, assimilates an expanded knowledge. For instance, to comprehend the ICT approach in scientific knowledge could reveal many available operative images for designing (Angeli & Valanides, 2009). Such research may exceed and erase the 'magical' components that intermediary objects generate and the students seek to understand. The tasks the teachers have to prescribe to are relevant with D&T objectives in the high school if their knowledge and skills allow them to use TPACK.

It is interesting to consider a new 'drawing space' which could be situated within the representation modalities linked to digital tools. It comes from an experimental field dedicated to the structure of new design skills or abilities far away from amazing or 'magical' instruments. Also, it comes to a mathematical model the architects already use to generate design models with computers (Marin, Lequay, & Bignon, 2009).

Students must be able to understand the tools that they use and why they can understand new shapes. It turns out that the teachers' tasks within an 'interdisciplinary instrumental orchestration' allow them to optimize digital tools. But the object remains 'magical' if the teachers' tasks do not allow them to understand of 2D and 3D practices. The risk is to represent artefacts thanks to digital instruments without mastering or handling mediated knowledge. However, there is a potential reflection in action (Schön, 1984), where learning designs could evolve in another path.

For the moment, this study must be completed. The other documents of the French Ministry of Education have to be analysed to check the initial findings. Also, we have to organize an inquiry into actual teachers and students' activities of the STD2A baccalaureate to understand the real impact of TPACK.

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Developing civil technology teachers' professional knowledge through communities of practice

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Abstract

In South Africa at senior high school level technology is offered as four specialised subjects: Engineering Graphics and Design, Civil Technology, Electrical Technology and Mechanical Technology. Teachers who were trained to teach traditional technical subjects, such as Industrial Arts, Technical Drawing, Woodwork and Metalwork are now responsible for teaching these fairly new technology subjects. However, they have not received sufficient training from the Departments of Education for teaching these new subjects. Thus, they need to develop their professional knowledge which comprises school knowledge, subject knowledge and pedagogical knowledge. This could mainly be done through continuing professional teacher development (CPTD). However, there are also not sufficient CPTD opportunities to develop their professional knowledge. To deal with the lack of CPTD opportunities and to develop these teachers' professional knowledge, researchers have established a community of practice (CoP) at the University of Johannesburg as a strategy to develop teachers' professional knowledge in Civil Technology. Based on the researchers' involvement in an industry-sponsored, school-focused model for CPTD, the CoP involves the university, the provincial department of education, schools and the private sector as stakeholders. Emanating from the researchers' prior involvement in CPTD are eight criteria to evaluate CPTD for the development of teachers' professional knowledge. The agenda for the CoP is co-determined by the stakeholders and is also based on these criteria. The purpose of the research was to determine to what extent the CoP can be conducive to developing teachers' professional knowledge. The research question that underpinned this research was: What are Civil Technology teachers' experiences of the CoP? A qualitative study was conducted where data was collected through the observation of the teachers during the CoPs and open-ended questionnaires and group interviews. The main findings were that the teachers gained discipline knowledge and acquired instructional methodology (pedagogy) from which learners can benefit. The presentation and organisation of the CoP influenced the learning of the teachers.

Keywords

Continuing professional teacher development, community of practice, civil technology education

Introduction

Technology as a new subject was introduced to the South African educational scene with the implementation of Curriculum 2005 in 1998 in the Senior Phase (SP), that is, in Grades 7 to 9 with the age group of learners from 12 to 15 years. The specific aims of technology as a SP subject is to contribute towards learners' technological literacy by giving them opportunities to develop and apply specific design skills to solve technological problems, understand the concepts and knowledge used in technology education and use them responsibly, and purposefully and appreciate the interaction between people's values and attitudes, technology, society and the environment (DoE, 2002).

In 2006 the new curriculum was extended with the introduction of the National Curriculum Statement (NCS) for the Further Education and Training (FET) phase (Grade 10 – 12) with the age group of learners from 15 to 18. In technology education the traditional technical subjects were replaced by new technology related subjects: Engineering Graphics and Design, Civil Technology, Electrical Technology and Mechanical Technology.

This paper focuses mainly on civil technology education which is offered within the FET phase of the high school curriculum. The subject civil technology was developed from a group of technical subjects, namely Technika civil, building construction, bricklaying and plastering, woodwork and woodworking which was offered by the different departments of education during the apartheid era in South Africa. The primary aim of these subjects was the education of the learner for career readiness. Each subject had a theoretical (knowledge) and a practical component with the emphasis on manipulative processes and techniques.

Civil technology is a combination of the above-mentioned technical subjects and is based on the philosophy of technology education, which means that a whole new approach has to be followed. Technological knowledge for instance, is a combination of conceptual knowledge and procedural knowledge, which differs from the knowledge of technical subjects (Engelbrecht, 2008). Technical subjects do not take the philosophy of technology education into account (Ankiewictz, 2003) which means that some technical teachers tend not to facilitate civil technology education in the way it should be done. They are confronted with changes regarding the assessment of learners, teaching methodology and new subject content knowledge. It is therefore necessary that teacher professional development include both skills development and an improvement of content knowledge in order to prepare and equip teachers for the changes required in the new content framework.

Regarding the professional development of teachers to cope with change in the South African education context, Rollnick and Brodie researched the quality of teaching and compiled a report for the Centre for Development and Enterprise (Bernstein, 2011). They found that once-off workshops such as those implemented by the Department of Education (DoE) were not effective. The report suggested that teacher professional development should take place in interaction with other teachers and with experts acting as "critical friends" in developing professional learning communities (communities of practice) wherein teachers could learn from one another within a support framework (environment of mutual trust). The focus should be on both subject-matter knowledge (discipline knowledge) and pedagogical content knowledge (Bernstein, 2011).

Addressing the shortcomings of the continuing professional teacher development (CPTD) of practicing civil technology teachers may be the only way to equip them with the necessary skills and knowledge to make the paradigm shift from their old subjects to civil technology (Potgieter, 2004; Engelbrecht, Ankiewicz and De Swardt, 2007).

To address these needs, the University of Johannesburg's Unit for Technology Education has established a Community of Practice (CoP) as a strategy to involve all stakeholders in civil technology education: the university, the provincial department of education, the schools and the private sector. The aim of this intervention is the extension of teachers' content knowledge, instructional methodology and skills.

This study aimed to explore the experiences of civil technology teachers on the role of CoP as a form of CPTD. The research question that underpinned this research was: What are Civil Technology teachers' experiences of the CoP?

Theoretical background

The aim of this paper is to describe and interpret the experiences of a group of civil technology teachers within a CoP as a form of CPTD.

Continuing professional teacher development (CPTD)

CPTD can be seen as ongoing education and training for practising teachers, addressing the rapid and numerous changes taking place in education and aiming to extend their content knowledge, instructional methodology and skills (Engelbrecht et al., 2007). According to Steyl (1998) CPTD mainly serves two purposes: the empowerment of unqualified teachers in order to assist them to survive in a profession for which they are not yet qualified and the further development of qualified teachers within a specific content area. Steyl (1998) further identified the following aspects which are usually addressed in CPTD programs:

- Equalisation of teachers through upgrading academic and professional qualifications, as well as classroom skills and teaching strategies;

- Efficiency of classrooms and schools as microcosms through proper management training;
- Classroom competence through effective input on subject knowledge, theory, subject methodology and educational philosophy;
- Change brought on through curriculum development, social awareness programmes and CPTD for new roles such as multicultural teaching or religious and sex education; and
- Empowerment through action research and teacher-led initiatives.

According to Steyl (1998) the following four aspects will be required for any intended CPTD to be successful:

- A careful selection of appropriate participants, that is, those that have the biggest need of this particular training and who are motivated to use it to full advantage;
- Efficient organisation, that is, the right environment to enable effective learning to take place, the right time of the day/school year and smooth administration. These aspects are frequently overlooked and may have disastrous effects on the quality of the CPTD provided;
- Effective delivery of the content of a CPTD programme. Good trainers who are knowledgeable, credible and skilful at enabling learning should be used in CPTD activities. A common weakness in CPTD delivery is to invite trainers who are experts in their field but who cannot communicate effectively with their audience. They need to be able to involve and motivate the audience into full participation; and
- Reviewing the success of a CPTD intervention with a view to improving the quality of activities and learning for the next time.

Engelbrecht (2008) identified the following criteria that could be used for developing and facilitating suitable professional development experiences for technology teachers:

C1	CPTD should develop a teacher's school knowledge
C2	CPTD should develop a teacher's discipline knowledge
C3	CPTD should develop a teacher's pedagogic knowledge
C4	CPTD should develop and enhance a teacher's personal subject construct
C5	CPTD should include theoretical experiences
C6	CPTD should include practical experiences
C7	CPTD should include reflective experiences

There are a number of models that can be used for CPTD of which the most commonly used are a centralised or school-focused CPTD model, where teachers from different schools receive training at a central venue; a decentralised or school-based CPTD model, where training takes place at the teacher's own school; and the cascade CPTD model where senior staff are trained at a central venue and who are expected to train their fellow teachers at their schools (Engelbrecht et al., 2007).

Community of practice (CoP)

Wenger, McDermott and Snyder (2002) define communities of practice as "groups of people who share a concern, a set of problems, or a passion about a topic, and who deepen their knowledge and expertise in this area by interacting on an ongoing basis."

In the South African educational context, Rollnick and Brodie (Bernstein, 2011) proposed seven elements for the effective professional development of teachers within professional learning communities:

1. The piecemeal, workshop-type professional development currently prevalent in South Africa is not effective.
2. A focus on a few important instructional priorities over a long period of time is most effective.
3. Actual school and classroom data is an important source for teacher learning.
4. Teachers learn best through interaction with other teachers and with experts acting as "critical friends" in professional learning communities, in an environment of mutual trust.
5. High-quality professional development should immerse participants in enquiry, questioning and experimentation, and act as a model for enquiry forms of teaching.
6. There should be a focus on both subject-matter knowledge and pedagogical content knowledge.
7. Reform strategies must be linked to other aspects of school change, such as whole-school development and curriculum change.

The above elements suggest a movement away from once-off workshops, emphasising rather collaboration between teachers in the form of peer support. Educational support groups can act as a structure in which development can take place over a long time where teachers can learn in collaboration in CoPs and in an environment of trust, addressing actual classroom practices (White, 2012). CoP members should form relationships around common interests where they have the opportunity to learn from each other by sharing knowledge and experiences (Lesser & Storck, 2001).

The following are ways in which CoP members may be benefited:

- Through the communication of new knowledge and conveyance of new skills among each other;
- Group members may obtain important information;
- Sharing best practices;
- Inexperienced members may benefit from the guidance and mentorship of experienced members;
- Change can be managed by the members (White, 2012).

By identifying gaps and finding ways to solve them, CoPs take responsibility of their own learning. CoP activities may include the following: problem-solving sessions, learning new skills and competences and inviting guest speakers which may enhance their development (Wenger, 2000).

Research design and methodology

This study focuses on continuing professional development opportunities for civil technology teachers and their experience of development opportunities within a CoP. The aim of the study is to describe teachers' experiences and, for this reason, a qualitative research approach has been followed.

The purpose of the CPTD which formed the focus of this study was to upgrade teachers' classroom skills and teaching strategies and to provide teachers with subject/discipline knowledge and instructional methodology.

CPTD workshops were organised in collaboration with the Gauteng Department of Education (GDE). The programmes were planned with officials from the GDE addressing challenges that teachers experience in teaching the new civil technology curriculum in the province. The members of the CoP for civil technology included the co-ordinator for civil technology from the GDE, four subject facilitators, 30 civil technology teachers and three academic staff of the university involved in technology teacher education.

The approach adopted for this CoP was a continuous (long-term) school-focused model for CPTD where training was managed by staff of the University of Johannesburg (Engelbrecht, Ankiewicz and De Swardt, 2007).

The CoP workshops took place at the facilities of the university's technology education unit. During the year, two such workshops were facilitated with 12 teachers attending the first workshop and 27 the second workshop. The first workshop focused on assessment in civil technology and, more specifically, on the development of assessment rubrics and the quality assurance of question papers. The second workshop addressed design and organisational aspects within civil technology as subject: house styles in South Africa, building regulations, planning and organising construction activities and approaches for developing practical assessment tasks.

Data was collected through observation, group interviews (workshop discussions) and open questionnaires (workshop evaluation). Data gathered was analysed through the constant comparative method and the findings grouped into three main categories underpinned by subcategories as suggested by Merriam (1998).

Each teacher and provincial official who attended the CoP workshops received an attendance certificate issued by the university.

Findings

To determine the impact of the CoP workshops and thus the outcomes of the school-focused CPTD, teachers and provincial officials completed open-ended questionnaires after each workshop. For the two workshops a total of 31 teachers and officials completed the questionnaires. Teachers were asked the following question:

Write a few sentences on your experience of today's CoP.

The findings are organized into three main categories and sub-categories as summarised in figure 1 below.

Main categories	1. Teachers gained discipline knowledge through the CoP	2. Teachers acquired instructional methodology (pedagogy) through the CoP and learners can benefit from it	3. Presentation and organisation of the CoP influenced the learning of the teachers
Sub-categories	1.1 Teachers gained conceptual knowledge of Civil Technology 1.2 Teachers gained procedural knowledge of Civil Technology 1.3 Teachers need more CoP training/exposure 1.4 The CoP provides opportunities for teachers to share information and learn from each other	2.1 Teachers acquired instructional methodology of Civil Technology 2.2 Teachers acquired knowledge and experience in assessment methodology 2.3 Learners benefit from the teachers who have attended the CoP	3.1 Presentation of the CoP enhanced the learning of teachers 3.2 The design (structure) of the CoP presentations supports teachers in their learning 3.3 The interactive nature of the CoP promoted the teacher's understanding of Civil Technology 3.4 Teachers enjoyed the CoP and experienced it as rewarding

Figure 1: Summary of the three main categories and sub-categories of the findings.

The three main categories are supported by the following sub-categories with comments made by the teachers in the open-ended questionnaire:

- **Main category 1**

Teachers gained discipline knowledge through the CoP

1. Teachers gained conceptual knowledge of Civil Technology

   The teachers mentioned that they learnt about concepts such as house styles and building regulations. This was an indication that the teachers developed conceptual knowledge of Civil Technology.

   "The importance of building regulations and the different building styles were very interesting and broadens your insight on the subject"
   "Different house styles and regulations made me become aware of disasters and to plan correctly"
   "Styles of houses in RSA very interesting and insightful"

2. Teachers gained procedural knowledge of Civil Technology

   Teachers felt they gained a better understanding of the technological process which is supposed to be followed with the execution of the practical assessment task (PAT) applicable to each grade.

   "PAT – all the technological processes (*stages)* are important especially on reporting after the model has been completed"
   "Development of PAT was clear and well informative"

3. Teachers need more CoP training/exposure

   "We need more of this type of sessions"
   "Looking forward to the next CoP thank you"
   "Very enlightening – this should be done on a regular basis"

4. The CoP provides opportunities for teachers to share information and learn from each other

   "The meeting was informative and I think we meet often so that we can learn from each other"
   "Opened up a wide area of discussion"
   "Networking with other educators, sharing information"

- **Main category 2**

Teachers acquired instructional methodology (pedagogy) through the CoP and learners can benefit from it

1. Teachers felt empowered through developing their pedagogy (instructional approaches, strategies and skills).

Teachers acquired instructional methodology of Civil Technology

"Goeie voorbeelde van sekere kritiese probleme/vrae, byvoorbeeld kreatiewe response, opstel van vraestel, ontleding van vraestelle op 'n eenvoudige manier" (Good examples of certain critical problems/questions, for example creative responses, setting of questions, analysing question papers simplified)
"Motivation to adopt new methods"

2. Teachers acquired knowledge and experience in assessment methodology

   "I have been exposed to very interesting concepts like how the formulation of rubrics are undertaken."
   "I have gained more insight on the designing of rubrics and assessment"
   "The exam paper was also very profitable to me especially how to cover the taxonomy questions of an exam"
   "You as a teacher think you can set question papers and rubrics … but these guidelines help a lot to see where you go wrong"

3. Learners benefit from the teachers who have attended the CoP

   "…. but these guidelines help a lot to see where we go wrong and how to improve to benefit the learners"

- **Main category 3**

Presentation and organisation of the CoP influenced the learning of the teachers

The teachers experienced the facilitation and the methodology of the workshop as excellent, well managed, well presented and well organised.

1. Presentation of the CoP enhanced the learning of teachers

   "Presentation was educational. It was knowledgeable"
   "The topics was well chosen"
   "The presentations were well structured and much needed"
   "Thanks to presenters. Presentations are well prepared and informative."
   "It was extremely nice to be treated and spoken to as a professional."

2. The design (structure) of the CoP presentations supports teachers in their learning

   "Informative, very directional"
   "Very empowering, enlightening and progressive"
   "Good to know more on a higher level"

3. The interactive nature of the CoP promoted the teacher's understanding of Civil Technology

   "Opened up a wide area of discussion"
   "The interactive presentation is most valuable"
   "The related inputs/questions ease our understanding"

4. Teachers enjoyed the CoP and experienced it as rewarding

   "We enjoyed the session."
   "A wonderful learning experience"
   "Keep up the good work to run CoP in future"
   "I had a good experience"
   "Worth attending"
   "Well done"
   "It was so nice and fruitful, I gain a lot of information and experience"

No negative responses were received from the participants.

From the needs identification sessions (group discussions) the members of the CoP identified the following topics that could be considered for discussion at future CoP workshops:

- Minimum requirements for low cost housing
- Green building
- Temperature control during the placing of mass concrete
- Engineer/contractor – shared experiences
- Structural failure – why?
- Latest construction technologies/methods/materials

It is recommended that experts be used for the discussion of advanced aspects in the building/construction industry.

Conclusion

From the needs identification sessions (group discussions/interviews) it became clear that teachers need support with subject content and innovative pedagogy. The workshop evaluations (open questionnaires) revealed that the teachers welcomed the CoP initiative which gave them a forum to interact and share experiences, ideas and fears with peers from different schools and subject facilitators from the provincial department. One of the key elements for the success of the CoP is to focus on value and, therefore, future topics should be interesting, appealing and more advanced. To accomplish that, experts from industry should be invited to participate in the CoP. The CoP can be used to good effect for CPTD regarding civil technology education which will also enable the teachers to develop their personal subject construct (Banks, Barlex, Jarvinen, O'Sullivan, Owen-Jackson and Rutland, 2004).

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Assessing design & technology skills in primary education

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Abstract

Solving technological problems by designing, accomplishing and evaluating solutions is an important objective in primary education. Teachers, however, find it difficult to assess students' abilities for design. This paper describes the Skills Rubric Design: an instrument for formative and summative assessment of these skills. It was developed in an educational design research project and represents the design process in the form of a rubric consisting of five stages and sixteen sub skills. In the rubric, characteristic student behavior indicative of performance with respect to each sub skill is described in detail and in three levels of competence (unsatisfactory, satisfactory, excellent). The instrument was evaluated for validity with design education experts, teacher trainers and teachers in primary education and found useful for assessment and for help in developing design assignments.

Keywords

Design skills, design & technology education, assessment, primary education, teacher training

Introduction

In many countries, too few young people chose studies and careers in the field of science, engineering, design and technology. Recent surveys estimate the number of students that take STEM (Science, Technology, Engineering, Mathematics) courses or programs in higher or vocational education in the Netherlands to be close to 25%; even lower than the average in OECD (Organisation for Economic Co-Operation and Development) countries which is close to 40% (Rocard et al., 2007; Malik, 2014; Dutch Technology Pact 2020, 2014). If this is to be changed, it is important to start at an early age, that is, in primary education. Choices are made at an early age and many students seem to lose appetite for science and technology long before they enter vocational training (cf. Turner & Ireson, 2010).

Several problems have to be met to redress this. Design and technology receives very little attention in terms of teaching time. Estimates derived from secondary analysis of the results of the TIMSS and PISA studies, especially of the questionnaires filled out by teachers, suggest that in the Netherlands, approximately 4% of teaching time is devoted to science and design & technology. This is considerably lower than the OECD average of 10%. Of the representative sample of primary teachers (N=179) in the TIMSS study, 13% report never to do an experiment in class. Only 5% of the pupils are exposed to inquiry and/or design learning full circle: starting with a question or problem and ending with evaluating and reporting the outcomes. Most schools limit design teaching to reading texts or making an occasional artifact from an instruction manual. When asked for reasons, Dutch teachers point to pressure from the national assessment system, which focuses heavily on basic language and math skills (Meelissen et al., 2012). It is small wonder that with so little stimulus and practical experience, primary teachers find it difficult to evaluate their students' potential talent and skills for solving technological and design problems (Van Keulen, Slot & Boonstra, 2013).

Theoretical background

This study is part of a larger project on developing, implementing and investigating an instrument for formative and summative assessment of primary students' skills for design and technology as well as for scientific inquiry. Results from the preliminary stage of the research project were reported in Van Keulen et al. (2013). The present study draws on this and on findings recently reported (in Dutch) by Van Keulen and Slot (2014).

Inquiry and design

This study draws on approaches to developing skills through inquiry and design based teaching and learning, such as the 'informed design process' (Hacker & Burghardt, 2004) or the 'framework for learning through investigation' (Harlen & Qualter, 2009). Such frameworks are derived from authentic work of engineers, technicians, designers and scientists, and describe the process of designing a solution for a problem in terms of stages in a design cycle or the process of reaching an answer to a question in terms of stages in a research cycle. These approaches draw on genuine questions and problems as stated by the learners. Questions or problems and the resulting approaches are not necessarily new to science or technology, but they should be new and intriguing to the learners.

Skills development

A learning objective of this educational approach is the development of skills necessary for design or inquiry and not the ability to come up with the correct answer to the question or the correct solution to the problem. It should be distinguished from guided or unguided rediscovery or reinvention approaches which aim at students correctly reproducing textbook facts, theories, laws, explanations or design solutions. These approaches have been criticized as being too difficult for students when ill-defined and minimally guided, and unauthentic when guided and 'cookbooked' (Van Keulen, 1995; Kirschner, Sweller & Clark, 2006; Rourke & Sweller, 2009; Alfieri, Brooks, Aldrich & Tenenbaum, 2011).

Embodied cognition

A curious mind is necessary to have a question. In analogy, a drive for improvement leads to stating design problems. These dispositions are fundamentally human. Perception and actions are necessary to understand the affordances of the material world (Gibson & Pick, 2000; Thelen & Smith, 1994) and are a prerequisite for design and technology as the human activity that utilizes and increases these affordances. Design based learning hence is in close harmony with the view that cognition is embodied and concepts like strain, potential, space, etc. are metaphorically derived from bodily experiences (Nersessian, 2008; Shapiro, 2011; Niebert, Marsch & Treagust, 2012).

Technological literacy

The focus on development of skills for design and, more general, for problem solving elaborates on the role of STEM-education in developing citizenship through developing technological literacy (Reed, 2007; Moyer & Everett, 2012). Citizens at the very least need to cope with technology without anxiety and this obliges schools to have students interact with technology in ways that helps them develop a positive attitude and basic survival skills. Design based teaching aiming at skills development is a promising strategy for this, since previous experiences with activities like trouble shooting, retrieving information, and evaluating the functionality of products may help citizens to deal with future artifacts of which we cannot at present communicate any knowledge.

Assessment

Another part of the theoretical framework comes from the field of assessment. Skills development can do very well without assessment. Why devote precious time and other resources to assessment? One of the best reasons is that assessment informs teachers and learners about the process and the progress being made. Hunches become explicit, adjustments can be made, and different learners can receive personalized feedback. A third important reason is that students have the right to be informed about their talents. They have to be able to make choices for their future careers on the basis of a valid and complete cross section of their abilities in various domains. It is also worth noting that teachers from the TIMSS sample report that an important reason for them not to devote time to science and technology is the (growing) pressure from mandatory tests on literacy and numeracy. Apparently, subjects that are not assessed receive less attention and are taken less seriously by these teachers. Therefore, assessing technology education is as relevant as ever (cf. Mottier & De Vries, 1997, Garmire & Pearson, 2006; Pellegrino, Wilson, Koenig & Beatty, 2013). However, 'design' is a complex concept and assessing the capacity for such an amalgam depending upon knowledge, skills, attitudes and personal characteristics is complicated. Paper-and-pencil tests will not do. Assessing the final product is relevant but does not shed light on all sub skills. Moreover, trivial mistakes or lucky shots may invalidate judgments that only take into account the product. Design results in a product but it is also a process. In order to do justice to all stages in the design process, an instrument is needed that uses information from all stages. Products can be analyzed; processes can be observed. In this study, the aim is to develop rubrics that can convey feedback, promote student learning and produce valid and reliable judgments on all stages. "A rubric is a scoring tool that lays out the specific expectations for an assignment. Rubrics divide an assignment into its component parts and provide a detailed description of what constitute acceptable or unacceptable levels of performance for each of those parts" (Stevens & Levi, 2006, p. 3).

Instruments

This study elaborates on the Skills Monitor Inquiry and Design (SMID) described in Van Keulen et al. (2013). The SMID is a list of 16 items that combine skills for inquiry and design and allows for scoring on a three-point Likert scale.

However, the skills for inquiry are not completely equivalent with the skills for design. For example, inquiry values the skills for asking curious questions and elaborating explanations, whereas design values skills for recognizing problems and making things better. Some dimensions of the SMID nevertheless tried to address both inquiry and design (e.g., ‘carries out an experiment or design’) and the primary schools teachers had consequent problems to score their students reliably with regard to this sub skill. This new study tries to address this problem.

Research questions

The research questions of this study are as follows:

1. How can the design process (as distinguished from inquiry) best be described in terms of its composing stages?
2. How can each stage best be subdivided in terms of dimensions that reflect the activities and sub skills belonging to each stage?
3. What are adequate indicators of unacceptable, acceptable and excellent levels of performance of students with respect to each dimension?
4. Can experienced primary school teachers use the resulting rubrics to assess design skills of students?

Methodology

The research methodology applied in this study to develop and investigate a rubric is educational design research (Plomp & Nieveen, 2013). In educational design research, a team of experts, educational practitioners and researchers collaborate in developing, piloting, improving and validating ecologically valid educational materials. Educational design research is a genre of research in which the iterative development of solutions to practical and complex educational problems also provides the context for empirical investigation, which yields theoretical understanding that can inform the work of others (McKenney & Reeves, 2012).

A first version of an assessment scoring system in the form of a rubric, the Skills Rubrics Inquiry and Design (SRID) was developed. The stages and dimensions (sub skills) were discussed with nine experts (professional engineers/designers with an academic background; design teachers at faculties of technology in higher and vocational education, science & technology teachers at institutes for teacher training), piloted in a small number of primary schools in the Netherlands and discussed within the research team, composed of researchers and developers from Utrecht University, Marnix University for Primary Teacher Training, and Windesheim Flevoland University of Applied Science. The preliminary results and the applicability of the instrument were discussed with teachers, student teachers, teacher trainers and researchers into STEM-education.

Results

There is no such thing as 'the' design cycle. Any attempt to describe the design process is a rational reconstruction of something that can take many shapes and does not always proceed logically or in one direction. However, few will doubt that design starts with a stage in which a problem comes to the fore, that a set of design specifications is needed, that a solution should be proposed, developed and tested, and that it ends with a product and some sort of presentation (cf. Hacker & Burghardt, 2004). Previous research (Van Keulen et al., 2013) indicated that a cycle with five stages best seemed to fit the performance of pupils in primary education. In this study we elaborated on this. Sixteen sub skills were identified on the basis of the literature and discussions with experts, which were used as the dimensions in the rubric. The level of performance of students of course is a continuum and any subdivision into levels is arbitrary. On the basis of the user feedback (N=22) from that project we settled on three levels: unsatisfactory, satisfactory and excellent, which were subsequently elaborated. This resulted in two instruments (one for design skills and one for inquiry skills), each with 48 cells (16 dimensions and three levels). For each cell, a description indicating characteristic performance was written, based upon literature and experience with inquiry, technology and design and with teaching and observing students (Van Keulen, 1995; 1998). Since attitudes are an important aspect of competence, we also developed a rubric for behavioral dispositions with four dimensions: (1) Pleasure, curiosity and motivation; (2) Initiative and self-control; (3) Communicative and social attitudes; (4) Creativity and innovation. Initial descriptions were discussed with the team and then put to practice in four schools for primary education that participated in the research project. The teachers used the rubrics to inform the development of their own inquiry or design projects and piloted their applicability for assessing students. This process resulted in the first version of the Skills Rubrics Inquiry and Design (Van Keulen & Slot, 2014). Table 1 shows one part, the Skills Rubric Design, in a provisional translation into the English language.

Table 1. The Skills Rubric Design (Van Keulen & Slot, 2014)

Skills Rubric Design			
	Unsatisfactory	*Satisfactory*	*Excellent*
Recognizing and exploring a problem			
1.1. Recognizing problems	Doesn’t recognize a problem. Accepts things as they are. Perceptions have no consequences. “It is broken”. No non-verbal signs of longing or interest.	Is attentive. Wants to know how things are made. Phrases a wish or a problem on the basis of an observation or annoyance. “Couldn’t that be better?”	Has an eye for things that can be improved. Is able to indicate why something is a problem that should be solved.
1.2 Using previous knowledge	No signs that existing knowledge, skills or experiences are used.	Recognizes relations between a problem and previous experiences: “I have seen this before”. Explicitly mentions relevant previous knowledge (“Trusses can make a bridge stronger”).	Has knowledge on many subjects and shows this. Knows many existing solutions to technological problems.
1.3 Problem exploration	Doesn't explore the problem. Is passive. Is not committed to the design task.	Explores intuitively. Looks; feels; uses sensorimotor experiences. Seeks on the internet or other sources. Tries to explain why the problem should be explored in this way.	Explores systematically. Can provide clear reasons for exploring this way. Is not afraid to try new ways. Have specific expectations. Posed focused questions. Finds good sources of information.

1.4 Confining the problem	Doesn't bother whether the problem is too big or complicated for solving. Is led by what is at hand.	Focuses on what is possible to achieve with one's capabilities.	Knows how to confine the problem. Is explicit about what is most and what is less important. Provides reasons for choices.
1.5 Specifications	Doesn't take the requirement of a solution into account. Thinks about solutions without constraints or specifications.	Can justify the solution to the problem with an appeal to specifications	Can take the user's point of view. Starts with formulating specifications. Takes constraints and circumstances into account.
Designing solutions			
2.1 Proposing a solution	Doesn't propose any ideas. Is not able to suggest a solution.	Proposes solutions. Is mainly inspired by existing solutions. Needs confirmation to continue on a track.	Uses the specifications to design solutions. Reasons in terms of function-form or means-goal. Proposes original and creative ideas.
2.2 Choosing a solution	Provides no, or no good, reasons. Wants to do what is fun.	Provides at least one good reason for choosing a proposal.	Critically discusses the choice from the point of view of the specifications. Is explicit about disadvantages and possible trade-offs.
2.3 Making a plan	Doesn't make a plan. Or, plans are sloppy, incomplete or incomprehensible to others	Makes an adequate plan that is comprehensible to other	Makes a detailed plan. Addresses all activities. Schedules. Is explicit about which materials, tools, et cetera to be used. Makes drawings.
Carries out the design			
3.1 Use of materials and tools	Is unable to use the necessary materials or tools. Needs help.	Is able to use the necessary materials and tools.	Is skillful with materials and tools. Decides which materials or tools are most adequate. Provides reasons for choices.
3.2 Making of the design	Is unable to make the artifact, even with help.	Is able to make the artifact, perhaps with some help. Sticks to the plan.	Is independent and careful. Has a repertoire of techniques. Is skillful. Solves problems.
Testing and improving the design			
4.1 Testing the design	Doesn't test the design systematically.	Checks whether the design meets the overall specifications. Judges in terms of 'yes' or 'no'.	Systematically checks whether the design meets all specifications. Is critical and nuanced. Repeats tests. Discovers the most important flaws and mistakes.
4.2 Trouble shooting	Ignores or downplays problems. Doesn't look for causes or solutions.	Is aware of problems or mistakes. Proposes suggestions for	Understands and explains problems. Searches systematically

	Doesn't propose suggestions that would improve the design.	improvement.	for solutions. Uses previous knowledge. Has creative ideas for improvement.
4.3 Redesign	Doesn't succeed to carry through improvements. Is easily discouraged.	Carries through improvements. Is eventually able to meet most specifications.	Solves all problems satisfactorily. Doesn't tinker. Keeps the integrity of the design.
Presenting			
5.1 Giving a presentation	Is unable to give a presentation that outlines the problem, the proposed solution and an evaluation whether the design meets the specifications.	Is able to give a presentation that outlines the problem, the proposed solution and an evaluation whether the design meets the specifications.	Is able to clearly present the whole design process in word and writing. Adequately uses drawings, figures, graphs, and other data.
5.2 Justification	Doesn't indicate whether the design meets the specifications or solves the problem. Just describes what is done or made.	Justifies the design in terms of solving the problem.	Is able to indicate the quality of the design and its components. Uses function-form and other argumentations. Indicates the possibilities for use and improvement.
5.3 Sharing	Doesn't speak about the design. Is not involved.	Speaks when asked and spontaneously about the design. Mentions striking experiences.	Speaks spontaneously, with detail and with involvement about the design, the process, the product and the possibilities for use. Is fully committed.

Conclusions and discussion

This new instrument, the SRID, passed the first tests of validity and applicability according to experts, primary school teachers, and pre-service students. The instrument contains 16 sub skills (dimensions) derived from the steps in the design process, grouped into five stages. Students can now receive rich qualitative feedback with the help of the descriptions of characteristic student behavior at low, middle and high ranges. This is an improvement upon the SMID, which only allowed for scoring on a quantitative scale. Design and inquiry are no longer combined into one instrument. This solves the reported problems (Van Keulen et al., 2013) with validity and reliability. More discussions within the scientific community are necessary to further warrant its validity. It is hoped for that the new instrument will enable teachers to recognize students who have a talent for design and without confusing this with a talent for inquiry. Investigating the applicability of the instrument and the reliability of judgments and predictions by scaling up the number of schools and teachers in the Netherlands working with the instrument will be part of the next round of this educational design research project.

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Enhancing sustainable development in technology education

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Abstract

Sustainable development in technology education is considered internationally to be an important part of technology education and research. The Finnish National Core Curriculum for Basic Education 2004 outlines in the cross-curricular theme of 'Human being and technology' that basic education has to offer pupils fundamental knowledge about technology, its development and its impacts; it also has to guide pupils towards sensible choices and lead them to consider the ethical, moral and equality issues associated with technology. In addition, pupils are required to learn to appreciate the quality of material and work, and to take a critical, evaluative stance towards their own choices and the ideas, products and services offered. Pupils should learn to take responsibility for their environment of objects; to design and produce high-quality aesthetically pleasing products suited to their purposes; and to give consideration, when working, to ethical, ecological and economic values.

The aim of this paper is to examine how teacher education students would enhance sustainable development in technology education. Students (n = 215) were asked to fill out a feedback questionnaire at the end of the Technology Education and Technical Craft course (3 ETCS). As part of the questionnaire, students were asked to reflect on how sustainable development could be more present in technology education lessons and to suggest some concrete practices for teaching. The data were collected from 2012 to 2014 and the answers were analysed and categorised using the content analysis method.

Keywords

Technology education, sustainable development, teacher education

Introduction

Sustainable development in technology education is considered internationally to be an important part of technology education and research. Goodwin (2013) points out that sustainability is a complex and interdependent concept that encompasses environmental, social, economic and cultural dimensions. Each of the dimensions contained within the concept of sustainability can be considered on its own or in concert with the other dimensions (Goodwin, 2013). Pavlova (2009) notes that based on The International Implementation Scheme for the United Nations Decade of Education for Sustainable

Development (DESD), the key areas of the concept have been identified as *society, environment* and *economy* (Pavlova, 2009).

Rockstroh (2013) observes that in the literature of sustainable development, debates have concerned the limitations and inequitable distribution of natural resources, as well as the contamination and destruction of ecosystems. Pavlova (2011) points out that within technology education curricula worldwide, the broad spectrum of environmental education (EE) and education for sustainable development (ESD) approaches are visible. In general, in the countries where environment development aspects are addressed through technology education, the main focus is on environmental impacts that are studied through a life-cycle analysis of the designed products. The emphasis is on production processes, efficiency maximisation, recycling and waste minimisation, design for durability and disassembling (Pavlova, 2011).

Elshof (2005) states that technology education clearly has a role in shaping future debates and discourses. It has the potential to develop students' eco-literacy by encouraging critical thinking and by raising their awareness of various dimensions of sustainable development (Elshof, 2005). Rockstroh (2013) reflects that the community of technology education clearly has the potential to foster designerly thinking and technological literacy in ways that respond equitably to human needs now and into the future, and to work towards sustaining the ecological resources and environments upon which such developments depend (Rockstroh, 2013). Elshof (2011) suggests that technology education would be relevant to the degree that it inspires the creativity of young people to invent what amounts to a 'new', more sustainable world. He sees a clear need for technology to step up to play this role successfully. He claims that, 'new revitalized technology education for the 21st century will be green and bioregional in orientation or it will no longer find a broad constituency' (Elshof, 2011, p. 146). As de Vries, says, 'Design is not just a matter of choosing between alternatives. It can also be the creation of new alternatives' (de Vries, 2005, p. 97).

A study of Finnish primary school aged pupils' motivation towards technology education revealed that, in general, pupils, especially girls, are very interested in studying environment-related issues, inventing solutions for keeping the environment clean and preserving nature (Virtanen, Räikkönen & Ikonen, 2014). We feel that our responsibility as educators is to pass on the best of our knowledge in a way that might encourage students to participate and creatively contribute towards our heritage. We see also that technology education has the potential to inspire teachers and students to become developers for sustainable development. Sustainable development may also provide the leverage point for increasing the value of technology education in the curricula (Goodwin, 2013), but as Elshof (2005) points out, before teachers can organise experiences for pupils to study sustainability issues, they themselves should have the opportunity to explore it to situate sustainable development in their own practices (Elshof, 2009). Therefore, it is relevant to examine what students find important to study in relation to sustainable development in technology education and what might encourage them to see the topic relevant for them.

Sustainable development through technology education in Finland

Sustainable development is mentioned in the general objectives of the 2004 National Core Curriculum for Basic Education (NCCBE) and as a core topic of an integrated subject group of environmental and natural studies. Instruction in environmental and natural studies relies on investigative, problem-centred approach in which the starting points are the pupils' existing knowledge, skills and experiences, as well as the things, phenomena, and events connected to the pupils' environment and the pupils themselves. The latest NCCBE introduced seven cross-curricular themes for Finnish education, one of them being 'Responsibility for the environment, well-being, and a sustainable future'. The objective of this theme is to augment pupils' abilities and motivation to act for the environment and human well-being in order to raise environmentally conscious citizens who are committed to a sustainable way of life (NCCBE, 2004).

In many countries, technology education has evolved from craft education (Alamäki, 1999). As early as 1866, Uno Cygnaeus, the founder of Finnish general education, considered 'technological' content to be an important aspect of craft education (Rasinen, Ikonen, & Rissanen, 2011). Another of the cross-curricular themes is 'Human being and technology'. The objectives of this theme require that basic education offers pupils fundamental knowledge about technology, its development and impacts; it also has to guide pupils towards sensible choices and lead them to consider the ethical, moral and equality issues associated with technology. These themes should have a central emphasis on educational and teaching work. However, cross-curricular themes are integrated into different subjects and much of technological content of the 'Human being and technology' theme is studied during craft subject lessons, in particular those devoted to technical work (Rasinen et al., 2009).

Objectives that can be seen to support sustainable development in 'Human being and technology' are those of

- Helping pupils to understand the individual's relationship to technology and to learn to use technology responsibly.
- ffering knowledge about technology, its development and its impacts, and the environment.
- guiding pupils towards sensible choices and to considering the ethical, moral and equality issues associated with technology.
- guiding pupils to take a position on technological choices and to evaluate the impacts of today's technology-related decisions on the future. (NCCBE, 2004.)

In addition, the objectives of crafts require that pupils learn to appreciate the quality of the material and work, and to take a critical, evaluative stance towards their own choices and the ideas, products and services offered. Pupils should learn to take responsibility for their environment of objects, to design and produce high-quality, aesthetically pleasing products suited to their purposes, and to give consideration, when working, to ethical, ecological, and economic values. The core tasks of crafts, in relation to sustainable development, are to awaken pupils' sense of responsibility and awareness of quality in their work and choices of materials. Pupils will learn about the maintenance, conservation and repair of materials and products and about recycling and reuse (NCCBE, 2004).

At the moment, the Finnish National Core Curriculum (NCC) is undergoing a process of reform, which will finish by the end of 2014. According to Finnish National Board of Education, the need for a renewed core curriculum stems from the major changes our world has undergone since the beginning of the 21st century. The effects of globalisation have increased, as have the challenges for a sustainable future. Some of the principles of planning the new curriculum process include a sustainable future, technological change and working with knowledge. In addition, international aspects and global responsibility should be considered with regard to the objectives, content and practices of the renewed core curriculum (Finnish National Board of Education, retrieved 11.9.2014). The new core curriculum is currently at the draft stage. Examination of the draft indicates that the ideas of sustainable development are visible to some extent in the content of the craft education. The viewpoint of sustainable development is emphasised more in the upper grades of primary school (grades 3-6) than in the lower grades, however. According to the draft, crafts educate citizens to be ethical, have a sense of awareness and to be participative. Furthermore, one of the goals of craft education is to challenge the pupil to observe critically the consumption and production habits of humans from the perspectives of justice and ethics (Finnish National Board of Education, 2014, p. 51). From the teacher's point of view, the new core curriculum seems to provide guidelines with regard to targeting the teaching of sustainable development through craft and technology education.

Participants and procedure

The aim of this study was to examine how students training to be primary school teachers would enhance sustainable development in their technology education studies. The data were collected between 2012 and 2014. In total 293 students were asked to fill out a feedback questionnaire at the end of the Technology Education and Technical Craft course (3 ETCS) and 73% of them (*n* = 215) answered the questionnaire

As part of the questionnaire, students were asked to reflect on how sustainable development could be more present in technology education lessons and to suggest some concrete practices for teaching. Students' answers were analysed and categorised by using a framework (see Figure 1) that illustrates how the learning process and therefore the level of understanding of technological competence is developed. The following levels describe the mental processes of students' understanding:

Level 1. *Procedural knowledge*: gaining fundamental information about technological phenomena, various materials or tools and the usefulness of technology.

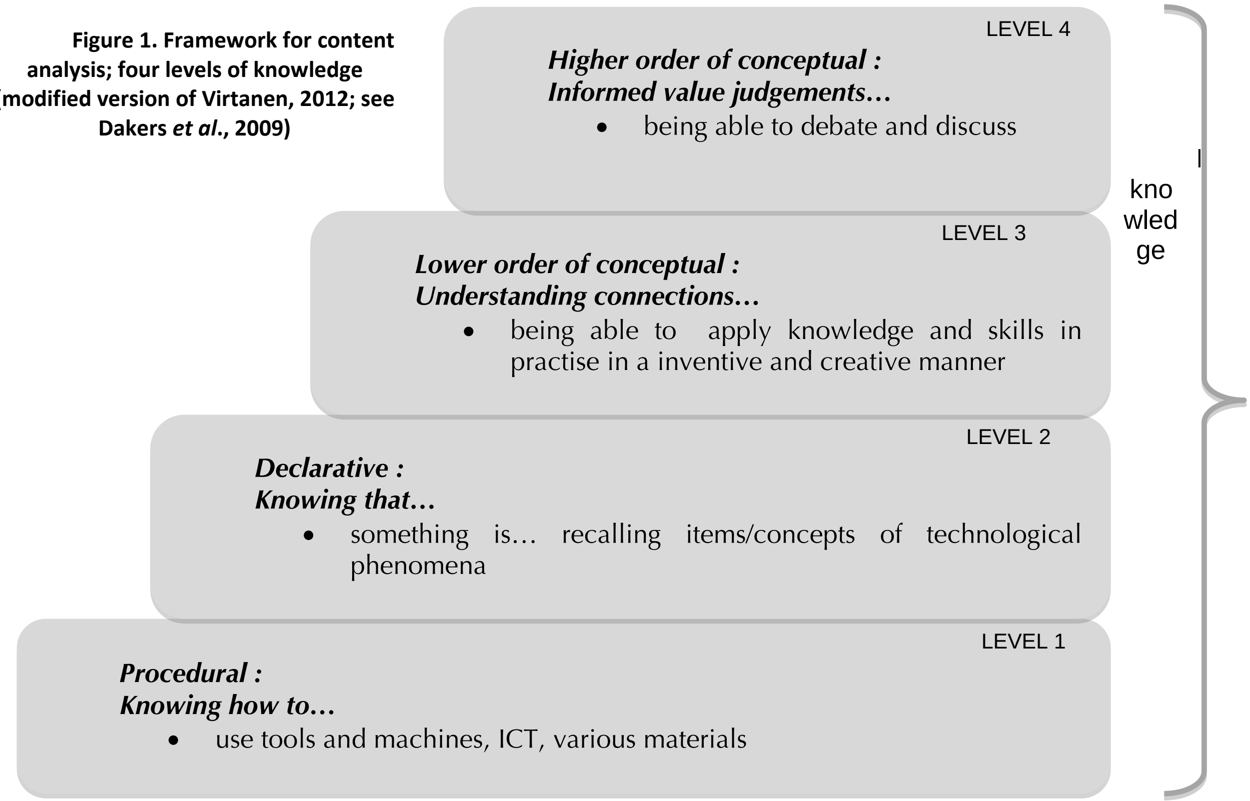
Level 2. *Declarative knowledge*: being able to recall items of technological knowledge or phenomena, to identify and explain their usefulness in everyday life and to apply them in simple situations.

Level 3. *Lower order conceptual knowledge*: being able to apply knowledge and skills in practice and combine them to create inventive solutions in order to solve a problem.

Level 4. *Higher order conceptual knowledge*: being able to think critically and offer arguments, and to make connections between 'real world' conceptions of technology and those given in context.

Levels 1 and 2 describe the fundamental levels of technological competence: knowing how to do something and knowing what something is. Levels 3 and 4 describe the higher levels of learning: understanding, application, invention, debating and critical thinking. Levels 3 and 4 comprise many conceptual and functional levels, such as knowledge of materials and tools, know-how and the understanding of the concepts of technology and their application (see Dakers, Dow, & McNamee, 2009). It is important, we find, that the knowledge one has is being applied or put into practice in an inventive and creative manner. The innovation process is associated with brainstorming, problem solving, innovativeness, inventiveness, designing, modeling, evaluation, experimental approaches and creativity, as well as aesthetic and ethical aspects.

Figure 1. Framework for content analysis; four levels of knowledge (modified version of Virtanen, 2012; see Dakers *et al*., 2009)



Results

In the data, 76.3% of the teacher education students were female, 20.5% were male and 3.2% were unknown. At the beginning of the questionnaire, students were asked to select the statement that best described their personal approach to planning and teaching with regard to sustainable development. Almost half of the students (49%) answered that they would always try to plan and teach with a sustainability-based focus. Moreover, 34% said they would like to include more aspects of sustainability if it was well suited for the project being made during the technical work lessons. Some (13%) of students would like to be more involved in the planning and teaching aspects of sustainability-related projects but did not know where it would fit in to technical work and technology education studies. A small number (4%) answered that in their opinion sustainable development has nothing to do with technical work and technology education. Students were also asked to reflect and ideate on how sustainable development could be more present in technology education lessons and to suggest some concrete practices for teaching. The suggestions (f = 368) were analysed and categorised by using the framework presented (Figure 1).

There were 23 suggestions in relation to Level 1 (see Figure 2). The most common (f = 11) suggestion was a general lecture about the theme or the provision of information about recyclable materials and projects. The rest of the suggestions at Level 1 were mentioned only a few times. They dealt with learning about the concepts of 'life-cycle analysis' or 'ecological footprint' (f = 5), having a written assignment about sustainable development (f = 4) and preferring local materials and suppliers (f = 3). Most of the suggestions (188) were related to Level 2. Many (f = 73) of the students suggested that more recycled materials should be used in projects during the course. Improvements in displaying efficiency of use (f = 33), recycling and using leftovers (f = 33) during the course were also suggested. In general, students would like to know more about the material options and where the materials are coming from (f = 39). Some (f = 10) suggestions mentioned the use of environmentally friendly machines and tools, techniques, paints, varnishes, etc.

There were 137 suggestions related to Level 3. The most common (f = 38) was that the 'theme working' method, which includes a strong focus on designing and creating long-lasting, useful artefacts (of wood and metal) is a good way to teach sustainable development. Many (f = 27) of the students mentioned restoration and upcycling as good practical ways to enhance sustainable development in technology education. Some (f = 20) students said that design and planning projects should be done in accord with the principles of eco-design. Almost as many comments were about the repair and maintenance of products (f = 19), creating a product completely out of recyclable materials (f = 16) and making products that are long lasting and of good quality (f = 14). A small number (f = 3) wrote that respect for craftsmanship is important. There were 20 suggestions related to Level 4. The most frequently mentioned practical suggestion (f = 12) concerned having a discussion and/or brainstorming about how sustainability might be a part of technology education. Some students (f = 6) suggested discussions about the development of technology and sustainable consumption. Only a few comments concerned learning about the ideology of 'degrowth' (f = 1) and about equality as an aspect of sustainable development (f = 1).

Figure 2. Students' suggestions (f = 368) categorised as levels 1-4

LEVEL 4: (f = 20)
- discussion and/or brainstorming about how sustainability (f = 12)
- discussion about the development of technology and sustainable consumption (f = 6)
- ideology of 'degrowth' (f = 1)
- equality as an aspect of sustainable development (f = 1)

LEVEL 3: (f = 137)
- theme working -method (f = 38)
- restoration and upcycling (f = 27)
- principles of eco-design in design and planning (f = 20)
- repair and maintenance of products (f = 19)
- creating a product completely out of recyclable materials (f = 16)
- making products that are long lasting and of good quality (f = 14)
- respect for craftsmanship (f = 3)

42,7% of the suggestions

LEVEL 2: (f = 188)
- using more recycled materials in projects (f = 73)
- displaying efficiency of use (f = 33)
- recycling and using leftovers (f = 33)
- knowing more about the material options and where the materials are coming from (f = 39)
- use of environmentally friendly machines and tools, techniques, paints, varnishes, etc (f = 10)

LEVEL 1: (f = 23)
- general lecture about the theme (f = 11)
- learning about the concepts of 'life-cycle analysis' or 'ecological footprint' (f = 5)
- having a written assignment about sustainable development (f = 4)
- preferring local materials and suppliers (f = 3)

57,3% of the suggestions

Discussion

Our findings indicate that primary school teacher education students are interested in enhancing sustainable development as part of their technology education courses. More than half (57%) of the students' suggestions were categorised as Level 1 or Level 2, which refer to learners' *procedural* and *declarative knowledge*: knowing how to do something and knowing what something is (see Figure 2). The transfer of these forms of knowledge tend to be one-way processes in which the learner simply receives instruction from an expert, thereby developing her/his ability to memorise 'how to…' or accepting and knowing that 'something is the case' (Dakers et al., 2009, p. 386). Students' suggestions mainly concerned the more frequent use of recycled materials in projects and the idea that teachers should provide more information about materials and their sources. Students also hoped that teachers would show and encourage the more efficient use of materials and leftovers. Students' suggestions demonstrated that they hope to get more direct guidance and instruction but are willing to apply the principles of sustainable development in their future work. The focus in the course is on hands-on practices, meaning that students have a good opportunity to see the importance of the use of various materials. We think that the skills learned by creating something concretely are an essential part of technological literacy.

The ideology in our technology education courses is based on concrete problem-solving activities and the learning method known as 'theme working'. Almost half (43%) of the students' suggestions were categorised into Level 3 or Level 4, which refer to learners' *conceptual knowledge*: understanding, application, invention, debating and critical thinking. Students' suggestions most commonly concerned the theme working method and the use of principles of eco-design. The theme working method includes a strong focus on designing and creating long-lasting, useful artefacts. We think that when principles of eco-design are taken into account in design and planning, this encourages designerly thinking and technological literacy in sustainable development. Students mentioned that tasks concerning upcycling and the repair and maintenance of products provide good practical opportunities to enhance teaching about sustainable development in technology education. These results show that many students are engaged with the stated problems and tasks and that they see the potential of the theme working method in relation to sustainable development.

Technology education as technical work in Finland has a long history of being a subject that focuses on hands-on activities. However, the balance between concrete hands-on practices and discussions can be varied pedagogically in many ways. We agree that technology education has the potential to help students to recognise situations as being ethically problematic and will lead them to work with concrete problems, enabling them to have a voice and express their thoughts by negotiating simulated and real-life problems. Technology education would also be relevant to the degree that it inspires the creativity of young people to invent what amounts to a 'new', more sustainable world (see Elshof, 2011; Pavlova, 2009).

Conclusion

There has been increasing recognition of the critical role of education in promoting sustainable life patterns in order to change attitudes and behaviours of people as individuals, including as producers and consumers, and as citizens carrying out their collective activities (Pavlova, 2009). Although there appears to be a consensus about the general goals of sustainable development, there is less agreement about its meaning (UNESCO, 2009). We think that education should provide learners with the motivation and skills for sustainable citizenship. The nature of technology education as a school subject and/or a cross-curricular theme provides a rich context in which the emphasis can be placed on encouraging students' critical thinking and raising their awareness of various dimensions of sustainable development.

Based on the results of this study, teacher education students' are interested in enhancing sustainable development within technology education courses. Their suggestions demonstrated that many students hoped to get more concrete and practical instruction in their future work. However, instead of transferring facts and skills from teachers to students, we think that students should be encouraged to think critically and to be engaged in their studies. Only some of the students' suggestions concerned not so much hands-on working but debating and discussion-based activities. The challenge in Finnish technology education in general is to create a balance between concrete hands-on practices and discussions. As teacher educators, we have to try to think about the kinds of competences that will be needed in the future.

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Reflective writing for design & technology: shifting the focus from justification to critique

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Abstract

Justification: an acceptable reason for doing something; critique: a critical analysis (Hornby, 1995).
Reflective writing in Design and Technology (D&T) is usually undertaken towards a project's completion. However, reflective writing limited to the post-analysis phase is not conducive to the higher order thinking which contemporary pedagogical theory (in particular, Inquiry Based Learning, or IBL) aspires to. This paper suggests that when reflective writing is only incorporated immediately prior to summative assessment – a phase in which the student typically has no agency and is certainly preoccupied with essential criteria – it becomes a mere justification of the students' decision-making and outcomes, instead of a critical, embedded analysis of the design project, enabling future learning.

Keywords

Reflective writing, critique, justification, literacy, assessment

Introduction

The inclusion of reflective writing has been shown to enhance literacy, critical thinking and self-efficacy in Design and Art (D&A). Overall, this has resulted in a general shift in the tone of student documentation from the mode of 'justification' towards a mode of 'critique'. Could reflective writing offer similar learning outcomes for Design and Technology (D&T) students?

Whilst writing is incorporated to some extent in the fields of D&A and D&T, its potential as a tool for thinking and reflecting has perhaps not been fully realised. Traditionally, subject choices like D&A or D&T are considered practical rather than theoretical, and less dependent on skills that may be perceived as academic, such as writing. As Owen-Jackson (2013) asserts: "subjects focused on knowledge are perceived as 'academic' and those focused on skills as 'practical,'" (2013, p.64). Consequently, some students are drawn to these areas in avoidance of formal academic writing assessment tasks, as Childers, Hobson & Mullin (1998), Orr, Blythman & Mullin (2004) and Owen-Jackson (2013), have identified. Orr, Blythman & Mullin also go on to say that in their field (Design and Visual Art Education), "the role of writing [has been] questioned" (2004, p. 75). There is a viewpoint that through the artifact, the student communicates without the use of verbal language, using a visual language that is 'wordless'. However, the reality – shared by D&A and D&T – is that the curricula require students to "create, design and write" (2004, p. 75). Furthermore, and of crucial importance, is the knowledge that curricula "are assessed via the textual and the visual" (Orr and Blythman, 2002, p. 1).

In D&T, assessment often takes the format of the prototype and the design record or portfolio – a combination of written, diagrammatic or illustrative tasks that informs a practical component like a design prototype. The written components of a design folio most often include some element of reflective writing or written evaluative statement. The role of the folio is to document design development and evaluate the outcome. Despite common perceptions, therefore, written tasks are a crucial component not only of assessment, but also, ideally, of the courses' inherent thinking and problem-solving requirements.

Reflective writing and key factors

Students' reflective writing can offer insights into their comprehension and engagement. When, however, they have employed a mode of justification, as opposed to one of critique, significant differences can be identified. Justification can often be characterised as a post-production activity in which students seek to present theories in support of already-completed work. Contrastingly, critique occurs throughout the planning and creative processes, underpinning discoveries and accurately mapping the work's conceptual identity. Disparities between these two modes – influencing both the quality of work and students' capacity to execute reflective written tasks – can be categorized as relating to timing and vocabulary.

Timing

The practice of reflective writing appears to be more meaningful when used throughout the working process, rather than just in the last stages and final evaluative statements linked to assessment outcomes. It is important to consider at what points in the design/make/evaluate model (Sanders, 2012) evaluation should occur. Race (2007) reminds us that students in an assessment situation tend to write what they think the assessors want to see, or in the mode of justification. Barlex (1994) emphasises the need for timely undertaking of evaluative practices. He offers practical suggestions for both assessment task design and assessment practices that shift the focus of written evaluations in D&T from a mode of 'justification' – by the students to their assessors – to a mode of 'critique' – in which both have a "dialogic" (Bain, 2012) role.

Barlex (1994), questions the placement of written evaluation exercises only at the end-point, once project work has been completed. In addition, he proposes that students should be collaborators in both evaluation and assessment:

> *This [matter] concerns the assessment of the performance of pupils throughout a project. It is clearly more complex than evaluating a product…*
>
> In assessing a pupil's performance on the various stages of a project you have to consider when such assessment should take place in addition to how it should take place. Ideally, the assessment should take place as the project develops. In this way the rose-coloured hindsight of both pupils and teachers can be avoided. (p. 137).

Hennessy and McCormick (1994) also discuss some limitations of assessment in D&T, focusing on the documentation of the design process:

> Our research… is investigating the question of whether or not pupils are assimilating and developing a coherent view of the design process. One of our central hypotheses is that pupils may merely try to accommodate teachers' aims through superficially and mechanically following the prescribed procedures, whilst simultaneously adhering to their own product-oriented agendas, thus creating a 'veneer of accomplishment'. (p. 100).

Barlex (1994) suggests the use of a checklist (essentially a simplified version of the assessment rubric) to support a more dialogic and incremental approach to assessment and evaluation. Such a method would be similar to those more dialogic assessment practices employed in the field of D&A, where beneficial outcomes such as enhanced vocabulary, critical thinking, and self-efficacy have already been identified.

In a common model of reflective writing, the informal use of a design journal or workbook is combined with a formal process of design evaluation. Barlex (1994) addresses the problematic paradox created by this:

> The intention of the workbook is to reveal the pupil's thinking and decision-making as it has developed throughout the project. It is not intended that it should be produced retrospectively once the practical work has been finished, although such practice is, unfortunately, not uncommon (pp.137-139).

While such a folio documentation process is intended to make the working visible, the problem solving itself does not always progress in a linear fashion, as highlighted by Hennessey and McCormick (1994). Therefore a linear assessment model, designed to mirror the documentation model, may not be the most effective appraisal method.

Many technology education researchers are suggesting ways to improve the synergy between thinking and making or knowing and doing. A pertinent question was recently raised by Martin and Owen-Jackson (2013): "Is design and technology about making or knowing?" (p. 64). They address this question from an historical and contemporary perspective, considering how these different philosophical foci have influenced curriculum and assessment task design. Their findings indicate that intense cognitive learning is required to advance skill-based and practical projects, and that these spheres of learning cannot really be separated into either skill-based or scholarly. They conclude that "good D&T teaching requires a judicious combination of both skills and knowledge" (p. 70). The work presented in this paper proposes that reflective writing can be used to enhance the required balance between skills and knowledge or theory and practice in D&T by engaging critical thinking, observational practices and dialogue around project development and assessment practices.

In the worst-case scenario, the reflective writing of a student in the mode of justification reads like a list of excuses related to the "imperfection and insufficiency" (Saito, 1997, p. 1) of the final prototype. In the best-case scenario, the reflective writing of a student critically analyses each stage of the design process and reflects upon their incremental decision making as well as the final prototype. Arguably, 'critique' and critical analysis rely upon the skills of reflective writing (Padget, 2013). Ideally, the student needs to be able to adequately communicate the development of their reflexive thinking through their reflective writing practice.

Vocabulary

Orr, Dorey-Richmond and Richmond (2010) describe how reflection promotes learning but remind us that the skills for, and literacy in, reflective writing cannot be assumed. In D&A it was commonly found that not only were the skills for reflective writing assumed, but that the meaning of the practice itself was often left entirely open to individual interpretation. This resulted in both educators and students deriving different understandings of what was actually required (Camino, 2010).

In technology we use a range of formal and informal reflective writing practices within design documentation and folios like a 'design journal' (informal) or a 'design record' (formal). The aim of the inclusions of these in assessment is to make the design process, or 'design-thinking' (including incremental decision-making based on experimentation), deep learning outcomes and higher order thinking visible. A deep learning outcome in technology might be described as an increased technological literacy or an increased capacity to synthesise both the theoretical and the practical design components or constraints and respond effectively to them through the application of appropriate materials, techniques and evaluation models.

Lockheart and Wood (Lockheart & Raein, 2012), founders and editors of the Intellect journal *Writing in Creative Practice,* conclude after ten years of research that language and literacy remains the key to reflective writing practice. They have described their ongoing interest in the "designerly" (Cross, 1982) use of language, the role of writing for designers and how it can inform students about their own practice through creative and critical thinking. They assert the importance of "languaging" (Lockheart & Raein, 2012, p. 285) in the evolution of the design research process.

The introductory creative reflective writing tasks applied by von Mengersen (2013) were based on vocabulary building for increased literacy in the mode of reflective writing. The creative and often less-formal qualities of these reflective writing tasks were intended to make the process more student-centred, visible and less formal – more innately linked to the actual process (often in a less-linear way), and providing insight into the creative learnings achieved. The learning was seen to be most effective when:

- Learning journals are used regularly;
- Creative writing methods are introduced;
- Both primary and secondary modes of reflective writing are used (to encourage meta-cognitive awareness);
- Secondary stages of reflective writing are used for summative assessment opportunities and primary stages of reflective writing are used for formative assessment opportunities);
- Reflective writing is used as a tool to promote both creative and critical thinking; and
- Writing tasks consciously build more unique and meaningful vocabulary.

These aspects have been tested in an ongoing research project (The Studio Writing Project 2010-2014) by von Mengersen (2013) with visual art undergraduate and cross-disciplinary design and visual art post-graduate students. This study has clearly indicated that reflective writing tasks which support an expansion of each student's individual vocabulary were among the most meaningful, clearly increasing student self-efficacy.

In seeking to equip students with the skills for effective reflective evaluation, it seems necessary to ensure they have the meta-language to do so. Lockheart and Wood's focus on "languaging" (Lockheart & Raein, 2012, p. 285) encompasses key terminologies that students can use to demonstrate, and perhaps even prompt, higher order thinking in relation to their design process. The table below outlines the differences between terminologies aligned with justification (employed post-production) and critique (ongoing, embedded reflection). It illustrates some of the fundamental differences between disparate terms that need to be understood and addressed in order to more effectively embed reflective writing practices within curricula and assessment design in D&T.

In D&A there has been a movement to develop an alternative term to be used for assessing rigour in design practice. Lockheart and Raein, inspired by Wood (Lockheart & Raein, 2012, p. 286) have proposed 'inquisition' because it is more closely aligned to the principles of 'critique'. Critique, as a philosophical learning and teaching practice in D&T, can be described first and foremost as a close-reading, and secondly, as a sustained reflective analysis. Keirl (2005) describes the concept of critique in relation to D&T education: "Critiquing aids selection of thinking styles. Thus sophisticated critiquing is a form of metacognition. It is reflective and deconstructive." (p. 9). A regular practice of writing has been shown to support both close-reading or increased understanding and the capacity to apply skills of reflexivity. However, in D&T students' skills and vocabulary for the practice of reflective writing can easily be assumed, embedded as they are in tasks like the selection and application of cognitive organisers. Reflective writing for critique suggests that the practice of *critique* should be ongoing, intrinsic to every stage of the design process, and further, that vocabulary for reflection and critique needs to be developed. It is evident that both fields (D&T and D&A) are concurrently seeking to refine literacy terminologies necessary for the demonstration of higher order thinking and, essentially, a shift from justification to critique.

Literacy and the use of vocabulary, it seems, are both crucial to the success and 'quality' or meaningfulness of reflective writing. The literature review in D&T and D&A and the research (The Studio Writing project) clearly indicate that vocabulary expansion and individualization support student efficacy in reflective writing practices related to self-directed design projects. Therefore, if we want to continue to improve the quality and validity of reflective writing in D&T, we need to play closer attention to vocabulary. One simple question may be: are students using the vocabulary of 'justification' or 'critique'?. Keirl (2005) suggests that critique is expressly linked to "more powerful meaning-making opportunities for students' learnings about technologies" (p. 1). If it is the students' reflective vocabularies that make their cognition and meaning-making visible to us, the educators, surely we need to enrich the pedagogy in this area of D&T education. Padget describes his "belief in the primacy of language in the learning process and how this links with creative learning and teaching and critical thinking" (Padget, 2013, p. xi) – therefore highlighting the point that without precise, specific metalanguage with which to articulate their learning, students' efforts cannot be either fully expressed or adequately measured. In reality, and for the purpose of assessment particularly, our students must demonstrate what they know through writing or language. Writing is an assumed mode of communication in many D&T assessment models, including written exams and digital or analogue design portfolios; therefore, vocabulary is vital. Arguably our students are assessed as much by what they write as by what they make. We assess their comprehension, their critical and creative thinking through both the product and the written word. Thus, it makes sense to question when, how and what we are asking students to write. Reflective writing has arguably become a normative practice in D&T, linked to summative assessment and written design evaluations. This research suggests that a creative approach (von Mengersen, 2013) alongside continual (formative) evaluation (Wesley et. al,. 2010, p. 73) may be far more beneficial, with reflective writing practices having been shown to support both critical and creative thinking (Moon, 2008; Padget, 2013). In D&T, both critical and creative modes of thinking are widely acknowledged as vital to "good" design (Wesley et. al, 2010, p. 39). Keirl (2005) has described critique in D&T education as a "disposition" (p. 8). In light of this research, it may be considered that reflective writing has an important role to play in the ongoing evolution of a question-focused design discourse and the evolution of a 'disposition' of critique in D&T education.

Table 1: Literacy Terminologies	
Justification typically:	Critique typically:
provides a list of excuses for a poorly researched, tested and executed prototype	provides a comprehensive summative analysis of the design problem and uses language to evaluate the outcomes
is limited in scope, tends to focus on one or two aspects of the project that did not go according to the 'plan'	is capable of effective synthesis between theoretical and practical aspects of the design process
indicates a limited capacity to adapt and overcome obstacles within the design process	indicates a capacity to explore a wide range of incremental options within the design process
relies on one big idea and an assumptive process rather than a progression of incremental design decisions	offers an expanded view of possible design solutions and considers variables and major/minor adaptations
has left the documentation to the end and shows a lack of synthesis between the evaluation and the prototype	indicates through the documentation process a deep synthesis and organic parallel development; incremental progression within the documentation reflects the detailed nature of the design-based decision making that has been undertaken
has compartmentalisation of the documentation process from the design and prototype generation process	has the research, experimentation, reflective and evaluative observations embedded within both the prototype and the documentation
indicates limited technological literacy and comprehension	indicates a high degree of technological literacy and overall comprehension
indicates limited capacity to take risks and modify ideas during the design process	indicates an impressive capacity to invest in the design project, to take risks and innovate

A closer consideration of the relevant metalanguage may provide further insight. By examining side by side the verbs associated with each mode of thought, it becomes simpler to identify which are promoting extension and higher order responses. Such knowledge is a powerful tool in the construction of assessment and curricula.

Table 2: Metalanguage and Meaning	
Justification	Critique
Synonyms for justify: • explain • support • warrant • legitimise • establish • confirm • defend • excuse • validate • substantiate • absolve	Synonyms for critique: • analyse • review • notice • assess • judge • comment • evaluate • appreciate • appraise • critique • elucidate

("justification", 2014; "critique", 2014)

Note that the vocabulary of justification seems to imply a certain defensiveness. By contrast, the vocabulary of critique seems characterised by a certain freedom, where the outcome is not so strictly defined. The critique metalanguage, essentially, suggests that any criticism is observational, and opens up concepts or works for inspection or examination.

In light of the differences between the two vocabulary sets, it may be useful to ask ourselves some questions when designing D&T curriculum and assessment tasks:

- What role does reflective writing play?
- What are students' attitudes towards reflective writing as a practice? How do they define it? Do they value it?

- How can vocabulary for reflective writing be expanded?
- How can reflective vocabulary enable critical and creative thinking?
- When do students have an opportunity to learn skills for reflective writing?
- When do students have a chance to practice their skills for reflective writing?
- Are there any formative assessments that include opportunities for reflective writing?
- Can students relate the practice of reflective writing to design thinking?
- Are there any opportunities for students to re-visit their insights?
- When does the task of reflective writing take place? At what point in the curriculum and assessment process?

This paper has by its nature asked more questions that it has answered. A brief literature review has been conducted to provide some context for an ongoing discussion into reflective writing and how it may practically support the application of 'critique' as a philosophical concept in D&T. This discussion draws primarily from research conducted in Design and Visual Arts education and indicates how D&T educators face some similar challenges and may, therefore, be able to integrate approaches from D&A that have been successful. The key conclusion that can be drawn (from both D&T and D&A fields) is the fundamental importance of language and literacy in critical thinking around design practice. This paper suggests that the application of critique as a holistic design-thinking practice may be enhanced by the timely inclusion of critical reflective writing tasks embedded throughout the design process in D&T. It asks educators to reflect upon how, where and why they are integrating reflective writing tasks. It suggests that both curriculum and assessment design can be modified to encourage this type of cognitive learning task in a less 'loaded' or formative model, alongside a post-project (summative) assessment-focused one. It is clear that reflective writing can be an important tool in the construction of questions – a vital aspect in the practice of critique. According to Keirl (2005, p. 8), "critiquing is about questioning rather than answering". It would seem that there is further scope to explore the relationship between *critique* and its application through reflective writing. Ideally, this may inform a shift in terms of student thinking and writing from the mode of 'justification' towards the mode of 'critique'.

As Moon (2008) discusses, reflective writing enables critical thinking. This paper outlines provisional research, and asks:

1. Could a shift in focus from justification to critique enable critical and design thinking? Could it be considered as another form of "cognitive" or "communicative" modeling (APU, 1994)?
2. How can reflective writing be used to embed authentic critical thinking practices throughout the design process?
3. Could a shift in focus support self-efficacy and increase technological literacy?
4. Could a regular reflective writing practice enable students to visualize their learning, think critically and evaluate throughout the process of making?

The initial research outcomes suggest that a regular reflective writing practice could lead to:

- More authentic reflective practices, documenting a shift in student perspective and awareness – what Fink (2003) describes as "significant learning" and Harfield (2012) as "transformative learning" (2012);
- Anticipatory thinking – what Atkinson (2012) has described as "the intangible designerly thinking" or "tacit design intelligence";
- A more "dialogic" assessment practice (Bain, 2012);
- Creative problem solving and taking risks (Atkinson, 2012; Bain, 2012);
- Life-long learning or self-learning (Harfield, 2012) or autonomous learning (Bain, 2012).

Conclusion

The nature of *critique* is that of an ongoing inquiry, where the construction of questions is primary. This philosophy can underpin a more effective evaluation process that is embedded throughout the breadth of design development rather than being limited to final reflective statements. Justification is primarily summative, whilst critique can be both formative and summative, with the broader aim of encouraging higher order thinking, life-long learning and above all a questioning or disposition of inquiry. Reflective writing practices encourage metacognitive process through expanding vocabulary, literacy and insight. This paper suggests that the two key factors in applying reflective writing are timing (the placement of writing tasks within design learning) and vocabulary (equipping students with the language literacy and terminology for accurate, more meaningful engagement and self-awareness). In the best sense, reflective writing is possibly about writing to understand even more than writing to be understood (Ong, 1986). A focus on *critique* rather than justification aims to embed the culture of sustained questioning that ideally should reside at the heart of any learning environment or endeavour.

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Fair play? Engineering competitions in science and technology education

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Abstract

Currently in many countries, there is a strong political focus on the need for improvements in STEM (science, technology, engineering, and mathematics) subjects. To this end, state-funded policy initiatives have been launched with the expressed aims to foster learners' interest and participation, and raise student achievement. It is a widely-held belief that competitions are highly engaging activities that motivate students and enhance their learning experience and yet, a modest review of the research on motivation, learning, and creativity reveals that the literature is fraught with contradictions. There is also some debate about the extent to which robotics and other engineering-type competitions actually deepen students' understanding of technological and scientific concepts. A focus on engineering competitions in schools affords an oblique point of entry into the black-boxed discourse concerning STEM education and the race for 21st century skills. In this paper, I draw on Bourdieu's concept of "capital" to problematize the taken-for-granted notion of fair play. By identifying the pedagogical, socio-cultural, and instrumental values embedded in organized activities that prize high achievement and winning, I attempt to unravel the complex interrelations between education, political drivers, and families. I argue that an economic rationale *must not* be the only point of reference, and call upon those committed to Deweyan ideals of fairness and inclusivity to advocate for a curriculum reform agenda that places pupils and their learning at the heart of education.

Keywords

Student competitions, cultural capital, science and technology education, STEM

Introduction

Consensus has been emerging for more than a decade that K-12 education needs to improve—particularly in science, technology, engineering and mathematics (STEM) (Katehi, Pearson, & Feder, 2009). Some technology education researchers support this move as a way to improve the quality of learning experiences (Rogers, 2006); foster interest, motivation, attitude, and participation (Rogers, 2007; Sanders, 2009); enhance student understanding and achievement in science and mathematics (Brophy, Klein, Portsmore, & Rogers, 2008; Gattie & Wicklein, 2007; Sanders, 2009); and develop technological and scientific literacy (Bybee, 2010; Gattie & Wicklein, 2007; Pinelli & Haynie, 2010; Rogers, 2006; Sanders, 2009; Wicklein, 2006). Others contend that STEM education initiatives are driven primarily by vocational and economic goals to ensure an adequate supply of highly skilled people to take up future scientific and technical careers (Banks & Williams, 2013; Dearing & Daugherty, 2004; Hendricks, Ogletree & Alemdar, 2012b; Seymour & Hewitt, 1997; Wicklein, 2006; Williams, 2011) based in part on fear of being "outSTEMmed" (Sanders, 2009, p. 20) in the global economy (T. Friedman, 2005). Indeed, competition is the central concern of several reports and policies that maintain STEM education is key to enhancing innovativeness (e.g., "Competing in the 21st century skills race," "Rising above the gathering storm").

On the face of it, policy initiatives prioritizing the teaching of STEM subjects in K-12 seem necessary for improving the quality of state-funded science and technology education (Kolbe & Rice, 2012; Welty, 2008). However, when underpinned by values of competition, standardization, and efficiency, particular STEM-based reforms (such as No Child Left Behind and Race to the Top in the U.S.) champion "a capitalist, rather than democratic, vision" (Michie, 2012, p. 120) of schooling. More to the point, the prevailing assumption that market-driven practices are self-evidently desirable fails to appreciate the concomitant complexities and risks in teaching and learning. Studies in the education literature from elementary through to tertiary levels, for example, have argued that competitive activities are powerful instructional tools that: spark interest in science and technology (Pliskow, 2008), develop positive attitudes towards STEM subjects (Silver & Rushton, 2008; Welch, 2010; Welch & Huffman, 2011), encourage participation (Conti, Babbit, & Nelson, 2011; Rusk, Resnick, Berg, & Pezalla-Granlund, 2008), increase self-confidence (Bigelow, Glick, & Aragon, 2013; Lessard, 2002), foster creativity (Caron, 2010; Murphy, 2001; Stricker, 2011), promote teamwork (Melchior, Cohen, Cutter, & Leavitt, 2005; Stricker, 2011; Wankat, 2005), motivate learning (e.g., Henderson & Dillon, 2010; Lessard, 2002), improve content knowledge (e.g., Caron, 2010; Carroll & Hirtz, 2002; Robinson & Stewardson, 2012; Stricker, 2011), enhance skills, and inspire the pursuit of STEM-related studies and careers paths (e.g., Buckhaults, 2009; Hendricks, Alemdar, & Ogletree, 2012a; Olson, 1985; Weinert, & Pensky, 2011). Some of these claims have been called into question by scholars who bemoan the paucity of solid evidence, the lack of rigor in research design, and the need for greater precision over mediating processes in competition (e.g., Cameron, 2001; Epstein, 1988; Omdal & Richards, 2008; Potvin & Hasni, 2014). Wankat's (2005) investigation into undergraduate engineering contests, for instance, was unable to determine whether they actually increased student learning. His (2007) survey of K-12 students was also unclear if their participation in robotics competitions inspired them to enrol in post-secondary engineering programs. And while Melchior, Cohen, Cutter, and Leavitt's (2005) detailed evaluation of FIRST robotics competition (FRC) indicated a wide range of positive impacts on participants, they were unable to determine whether students' "strong performance" in high school science and mathematics "was the result of involvement in FRC, or whether FRC attracted strong students, or both" (p. 3).

This paper questions the educational value of engineering competitions in schools by picking apart the educational, vocational, and economic threads entangled in the current discourse of competition within STEM education. Drawing on Bourdieu's (1973) concept of "capital," I will provide examples to illustrate how the "competitive spirit" (H. Friedman, 2013) and desire to win are highly valued traits in politics, education, and middle class family life. Next, I will present a sample of studies of the impact of competitions on interest, motivation, and learning to think about the ways in which they might provide educative experiences that contribute to the betterment of society as a whole. I then challenge the taken-for-granted notion of fair play and share some of my own personal observations as a middle school teacher to problematize the premise of a level playing field. I suggest that the experience of winning or losing is not necessarily a meritocratic process, instead, many competitive arrangements function as sorting mechanisms that maintain the status quo. Given the intense use of competitions in education today, I suggest that a reconsideration of their fundamental purpose in schools is needed, and call on teacher educators, teachers, and parents to imagine what kinds of experiences in S&T education might better contribute to the intellectual and moral growth of young people.

STEM education and competition as a source of capital

Having a long history in schools, competitive science fairs are considered to provide an educational benefit, and yet, at the USA Science and Engineering Festival in 2009, President Obama seemed to conflate children's passion for learning with a country's competitive desire to be number one:

> In many ways, our future depends on what happens in these contests—what happens when a young person is engaged in conducting an experiment or writing a piece of software, or solving a hard math problem, or designing a new gadget. It's in these pursuits that talents are discovered and passions are lit, and the future scientists, engineers, inventors, entrepreneurs are born. That's what's going to help ensure that we succeed in the next century, that we're leading the world in developing the technologies, businesses, and industries of the future. (quoted in Showstack, 2010, p. 395)

Citing the importance of STEM education for increasing America's talent pool, Obama's vision of "leading the world" is an indicator that the processes of globalization have also infiltrated the discourse of education policy. Judging the latest round of international rankings for U.S. students in science and mathematics to be unacceptably "low," he declared, "We don't play for second place here in America. We certainly don't play for 25th" (in Showstack, 2010, p. 395). It may well be that that the significance the President placed on individualism, hard work, productivity and the desire to succeed is a reflection of the Protestant work ethic (Merton, 1938; Spence, 1985), which many believe to be one of the defining characteristics of cultures that place a high value on competitiveness and being number one (Duina, 2011).

Indeed, developing a "competitive spirit" according to Hilary Friedman (2013, p. 91), is of prime importance for middle class parents who worry that "if their children do not participate in childhood tournaments they will fall behind in the tournament of life" (p. 8). While there is no conclusive evidence to show that participation in competitions actually augments their children's chance of admission to elite institutions, many parents believe this to be the case. Drawing on Bourdieu's (1973) concept of capital (or resources), Friedman (2013) coined the term "competitive kid capital" to describe the knowledge, skills, attitudes and values that affluent middle class parents believe their children need in order to be successful in one of the most competitive domains of American life—the labour market. Competitive kid capital suggests "internalizing the importance of winning, learning how to recover from a loss to win in the future, managing time pressure, performing in stressful environments, and feeling comfortable being judged by others in public" (p. 219). Gaining admission to an elite school is one of the "credentials checkpoints" (p. 227) one must pass through in order to attain economic capital (e.g., higher salaries) and certain types of symbolic capital (e.g., status and prestige). In higher education, Ivy League schools look for those "smart students" who also demonstrate ambition, versatility, and the willingness to take risks (p. xii). Whereas numerical grades signify academic achievement, ambition and a competitive attitude are not as easy to measure. For this reason, social capital (family and community networking) and symbolic capital (tangible rewards such as prizes, medals and trophies)—earned through participation in adult-organized activities—have become proxies for those highly valued, yet incommensurable character traits. Although she argued that preparation for the "reality of modern life" (p. 222) was important, Friedman questioned whether it was detrimental for young children to be focussed so much on winning—to the exclusion of intrinsic aspects of the activity.

From a pedagogical standpoint, the constraints of structural competitions—with "a win/lose framework" (Kohn, 1992, p. 4)—can be problematic. Relatively little educational research has been published concerning how competitions affect children's interest, motivation and learning in science and technology. In fact, Potvin and Hasni's (2014) recent review of 252 education research articles indexed in ERIC (2000 to 2012) included only four related to competitions. One can broaden the search to include some earlier studies in psychology and education. These suggest that contingent extrinsic rewards (e.g., competing for prizes, monetary rewards, status, outranking others, or taking joy in others' failures) 1) do not necessarily lead to deeper learning of concepts and skills (e.g., Craven & Hogan, 2008; Sadler, Coyle, & Schwartz, 2000), 2) tend to undermine the intrinsic worth and enjoyment of the activity (e.g., Deci, Betley, Kahle, Abrams, & Porac, 1981; Epstein, 1988; Greene & Lepper, 1974; Hibbard & Buhrmester, 2010; Ryan, Mims, & Koestner, 1983) thereby resulting in a decline in performance over time (Kohn, 1992), 3) negatively impact creativity (Amabile, 1982), 4) are likely to be counterproductive if students have no chance of success (e.g., Woolnough, 1994), and may even serve to reinforce existing stereotypes of engineers and scientists (Silver & Rushton, 2008). It is important to note here, that no sweeping conclusions hold true in all cases. As Epstein (1988) argued, the effects of competitions depended on "individual differences in achievement orientation" (p. 66). She found that low achievers did not like to compete as much as high achievers as they were more likely to experience "feelings of apprehension or anxiety" (p. 24)—particularly if their performance was ranked against their opponents (see also Epstein & Harackiewicz, 1992). In contrast, achievement-oriented individuals preferred competitive activities because they were perceived to provide objective feedback on their abilities and offered possibilities for improvement. The opportunity to make improvements was also an important feature in design competitions for middle school children, as Sadler, Coyle, and Schwartz (2000) observed:

> Although many design competitions pit one device against another in elimination competitions, we found that middle schoolers, taken as a whole, prefer to concentrate on improvement relative to their own starting point; they are not needful of others for comparison. Students are quite often satisfied with determining how well their new design works compared to its predecessor, with the test itself the sole arbiter. (pp. 109-110)

The collateral learning identified in these two studies suggest that competitions do have the potential to be educative in certain circumstances, provided the experiences contribute to, as John Dewey (1938/1997) put it, the most fundamental attitude of "desire to go on learning" (p. 48), and allow for continual "readjustment" and growth (1916, p. 611). However, competitive experiences can also be "mis-educative" (1938/1997, p. 25), if they produce undesirable effects such as increased anxiety, self-doubt, and cheating behaviours. Johnson and Johnson (1991) contended that over time, sports competitors can "become more committed to winning at any cost and less committed to values of fairness and justice" (p. 101). In H. Friedman's (2013) study, middle class parents reportedly engaged in deliberate deception and manipulation in order to win at any cost (see "gaming the system" pp. 170-173). As a team coach in engineering and robotics events, I have also witnessed inappropriate conduct by parents and coaches when disagreements arose. In general, many students seemed to enjoy the excitement and challenge of working under pressure, but for others, the experience generated public displays of anxiety, frustration, disappointment, hostility, jealousy, and anger—expressed as crying, fainting, shouting insults, cursing, refusing to share equipment, stealing other competitors' materials, and destroying projects when they did not win. I would argue that in these particular cases, the "win/lose framework" (Kohn, p. 4)—where "[w]inning is celebrated only by the winner. Losing results in feeling inadequate, jealous, and angry about one's failure" (Johnson & Johnson, 1991, p. 105)—was antithetical not only to moral growth, but to the entire project of "schooling for self- and social empowerment" (McLaren, 1995, p. 30).

The notion of fair play needs to be introduced as a just standard of practice to ensure "equitable or impartial treatment" (Allen, 2004, p. 497). In mainstream culture, it is generally assumed that schools offer a "level playing field" where those who are clever enough and work hard enough will reap the economic and social rewards that they "deserve". Running against this assumption is Bourdieu's concept of cultural capital that makes clear that "individuals in privileged social locations are advantaged in ways that are not a result of the intrinsic merit of their cultural experiences" (Lareau, 2011, p. 361). Participation in science and technology competitions requires funding, facilities, and the time of committed teachers willing to work with students outside of school hours in preparation for these extra-curricular events. It should not be surprising then, that a substantial number of teams comes from private schools and affluent communities (i.e., predominantly white middle- and upper-middle class). Sufficiently endowed with cultural capital, advantaged students can successfully compete. Conversely, under-funded schools (where technology facilities have been "moth-balled", for example) cannot provide students with the same learning opportunities or technical skill sets as the schools that do. So, before the contest even begins, the disadvantaged are disqualified.

Dewey's (1938/1997) early critique of mis-educative experiences underscored the critical importance of teachers' pedagogical work which draws on knowledge and understanding of constructivist philosophy, principles of problem-based learning (Torp & Sage, 2002), an appreciation of what is accessible, meaningful, appropriate according to the present capacity and needs of learners, and most importantly, "the total *social* set-up of the situations" (Dewey, p. 45). This responsibility, in contemporary society, would require the reorientation (or perhaps circumvention) of competitions in order to disrupt the reproduction of inequality. A few studies have suggested that alternative frameworks such as cooperative groupings and indirect competitive frameworks might encourage more girls (e.g., Jones, 1991; Owens & Barnes, 1982), women, international students, and some males (McGovern & Trytten, 2013) to participate in gaming tournaments and science fairs.

Conclusion

Findings in the education literature on the effects of competition on motivation, attitudes, creativity and learning are inconclusive—even contradictory. Understanding the ways in which competitions might be a beneficial pedagogic frame is no simple undertaking. Perhaps the wide range of differing reports gives one reason for questioning the certainty with which some claims are made about the educative value of competitions in schools. With Longino and Miner (1987), I would argue for a more nuanced understanding of competitive structures in education and society and our responses to them. These concerns are not new. More than a century ago, Dewey (1897) envisioned education as a "process of living" (in Archambault, 1964, p. 430) that would develop a human being's "capacity to live as a social member so that what he [sic] gets from living with others balances with what he [sic] contributes" (Dewey, 1916, pp. 609-610). Conspicuously absent from the competition literature are concerns for people to share in a balanced moral life, or principles of equity, social harmony, critical citizenship, and "decency and kindliness" (Dewey, 1938/1997, p. 34).

In general, the research has tended to look for factors that contribute to "winning" and on the "high achievers" who, in the main, are already members of the dominant social class, while little work has been done in the field to examine the impact of competition on the majority of students who do not reach the top, or whose participation has been barred altogether. The existing research leads me to believe that competitive activities may never be an effective or appropriate method for attracting a more diverse population of learners into STEM-related fields of study as long as the social structures and market place values that prevent certain groups from participating fully remain unchallenged. And while

I agree that innovative approaches to teaching and learning in science, design and technology are needed, I would also argue for critical vigilance to keep issues of equity, diversity, and social justice at the fore. As some scholars have suggested, STEM education in general and engineering-type competitions in particular serve only to reproduce "the status quo educational practices that have monopolized the landscape for a century" (Sanders, 2009, p. 21). I therefore join with others who have argued that an economic rationale for policy and practice in technology education *must not* be the only point of reference. With the number of national and international robotics and other engineering-oriented student competitions increasing every year (Holmquist, 2014; Robinson, 2013; Wankat, 2005), this is a critical issue that merits further debate. I call upon those committed to ideals of fairness and inclusivity to advocate for a curriculum reform agenda that places young people and their learning at the heart of education.

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Pupil's perceptions of design & technology education in England and Wales: emergent findings

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Abstract

The curriculum for Design and Technology in secondary schools in England and Wales has been under review. With policy makers questioning not only the position the subject occupies within the curriculum, but also the value Design and Technology holds. As a result, Design and Technology's future, as a subject, is uncertain. Set against a background of policy and curriculum change, this paper presents the findings of a research study designed to elicit the perceptions of, and gain an insight into the way Key Stage 3 pupils (11 - 14 years) view Design and Technology. Utilising the concept of the original PATT Tool (Raat & de Vries, 1986), and building upon the work of previous studies undertaken nationally or globally (de Vries, 1988; de Klerk Wolters, 1989; Bame & Dugger, 1993; Volk & Yip 1999; Van Rensburg, Ankiewicz & Myburgh, 1999; Ankiewicz & Van Rensburg 2001; Becker & Maunsaiyat 2002; Chikasanda, Williams, Otrel-Cass & Jones, 2011; Gaotlhobogwe, 2010; Ardies, De Maeyer & Gijbels, 2012, 2013), the fundamental aim of the research at inception was to investigate the perceptions of pupils with respect to their understanding of what is technology education. Although simplistic in origin, the findings presented illustrate that this is far from the case. Framed epistemologically within a social practice lens (Suchman, Blomberg, Orr & Trigg, 1999), the research tool used was a questionnaire comprising of a series of open and closed questions. Administered by teachers who recorded both electronically and in hard copy, the sample was drawn randomly via those choosing to respond. Responses were gathered from 173 schools throughout England and Wales with data being collected over an eight month period commencing in July 2012. Analysis of the data elicited a number of key findings which are presented here. Although exclusively based on the perspective of school pupils in England and Wales, it is anticipated that the findings will provide both stimulus and a starting point for researchers working under similar curriculum constraints or revisions. Given the nature of the curriculum changes which have occurred, the research team intend to develop the tool further and expand it to include pupils in the post compulsory age bracket (16 - 18years) and the primary education age bracket.

Keywords

Pupils attitudes, design & technology, perceptions

Introduction

It is important to understand the context from which the study emerged. The authors of this paper were brought together due to a curriculum debate around Design and Technology in England and Wales. (Gove, 2011).

Since the first National Curriculum for England and Wales was published (DCSF, 1989) there have been a number of changes (DfE, 1995; DfEE, 1999; DfES, 2004; QCA, 2007) but drafts of the new curriculum (DfE, 2013) led many within the subject (DATA, 2011) to believe that policy makers were questioning not the curriculum position of the subject but the value and importance assigned to it.

When delivered effectively, the subject engages children and promotes their ability to understand key knowledge sets associated with other subjects, through practical application of theoretical concepts (Sage, 1996). This vision has not always been fully realised, and for too long in a significant number of schools in England and Wales the pedagogical focus of Design and Technology lessons has been product completion (Miller & McGimpsey, 2011). This focus has led to stakeholders being consumed in the drive to create a finished outcome. As a result there has seemingly been limited opportunity for the learner to reflect, and provide them with the potential to generate meaningful constructs (Piaget, 1953).

This, it could be argued is a failing of Design and Technology, which has not gone unnoticed (Ofsted, 2008, 2011, 2013) and has undoubtedly impacted negatively upon the subject. It could also be perceived that Design and Technology is of limited in value and of a lower status (Sayers, Morley & Barnes, 2007).

So how could those researching and supporting Design and Technology best respond? There was clearly a need for evidence to show that the subject is valued by stakeholders. For the authors, one of the key stakeholder groups was pupils. It was decided to use the PATT tool (de Vries, 1988) to provide a starting point to develop a body of evidence from pupils with respect to their understanding of what technology means to them.

Research methodology and methods

This is a mixed methods (Creswell, 2011) study, with the primary research method being an online survey. The ontological and epistemological stance of the researchers, however, leans towards an interpretive approach (Lincoln, Lynham & Guba, 2011), recognising the multiple realities, experiences and understanding of the participants (pupils) regarding their experience of Design and Technology education (Guba, 1981).

The intention of the team was to explore the beliefs of the participants through their experience of learning in Design and Technology, within a social practice framework, recognising the interconnectedness of individuals, and their learning activities in terms of designed and made products (Reckwitz, 2002).

The team were conscious of their own assumptions and beliefs in the value of the subject. The intention of this study was to examine personal expectations and correlate this with previously reported attitudes elicited through prior studies involving the use of the PATT tool.

Ardies et al. (2012, 2013) tested and evaluated the original PATT survey developed by de Vries (1988) and significantly reduced its length. Given their experience, this 'reconstructed' PATT instrument seemed a logical choice for the current study. Their reconstructed instrument had been tested for validity with a significant sample (n=3039) who's findings have been reported within the Design and Technology community.

Predominantly, the responses sought were quantitative, however the survey design facilitated additional qualitative feedback. The data was gathered over a period of eight months, analysis of which was undertaken by the team who are all engaged in Initial Teacher Education (ITE) and as such the ontological position is one of a firm belief in the benefits of Design and Technology education.

Research sample

The selection of participants in this pilot was by convenience sampling (Cohen, Manion & Morrison, 2005), with the survey being deployed through practitioner networks in England and Wales. As a non-probability sample of the population of Key Stage 3 pupils, in this pilot, the study does not claim to be representative of the wider body of pupils, rather to identify a 'snapshot' of pupils' beliefs, experiences and aspirations at a time of flux in the subject. The questionnaire was introduced to pupils by their teacher.

In total, responses were gathered from participants from 173 different educational settings situated throughout England and Wales, yielding 561 individual responses. The questionnaire was designed for completion by pupils within the predefined age group. As such the terminology and reading age necessary to access the questions and hence provide an appropriate response was carefully considered. The questionnaire comprised of short and concise questions, which were based upon, and developed from, the work of Ardies et al. (2012, 2013).

Ethical considerations

The team adopted the guidelines of the British Educational Research Association (BERA, 2011) in designing the study and conducting the data collection. The purpose and scope of the study was clarified to ensure that all stakeholders were in a position to give informed consent to their individual participation in this study.

Presentation of findings

There have been a number of studies considering gender within Design and Technology and the debate about gender within the subject continues (Bell, Hughes & Owen-Jackson, 2013) so the team sought to establish the gender of the respondents. This is something that has been retained from previous versions of the PATT tool including the revised version (Ardies et al., 2012; 2013). Results illustrate an almost equal split between male (48%) and female (52%) respondents.

The team then sought to determine the geographical location of respondents, as they wanted to ensure that the study only considered those affected by the then proposed curriculum changes.

The data shows, over 50% of the respondents live in the North West of England. Over 27% were located in the Midlands with the smallest recorded percentages being attributed to respondents living in the Isle of Man and Wales. This underpins the team's belief that this work should be viewed as a pilot due to a lack of proportional representation.

Next the team sought to establish the age of the pupils taking part in the study (Figure 1). In England and Wales pupils are taught in year groups which equate to their chronological age. Year 7 Pupils are aged 11-12 years, Year 8 Pupils are aged 12-13 years and Year 9 Pupils are aged 13-14 years.

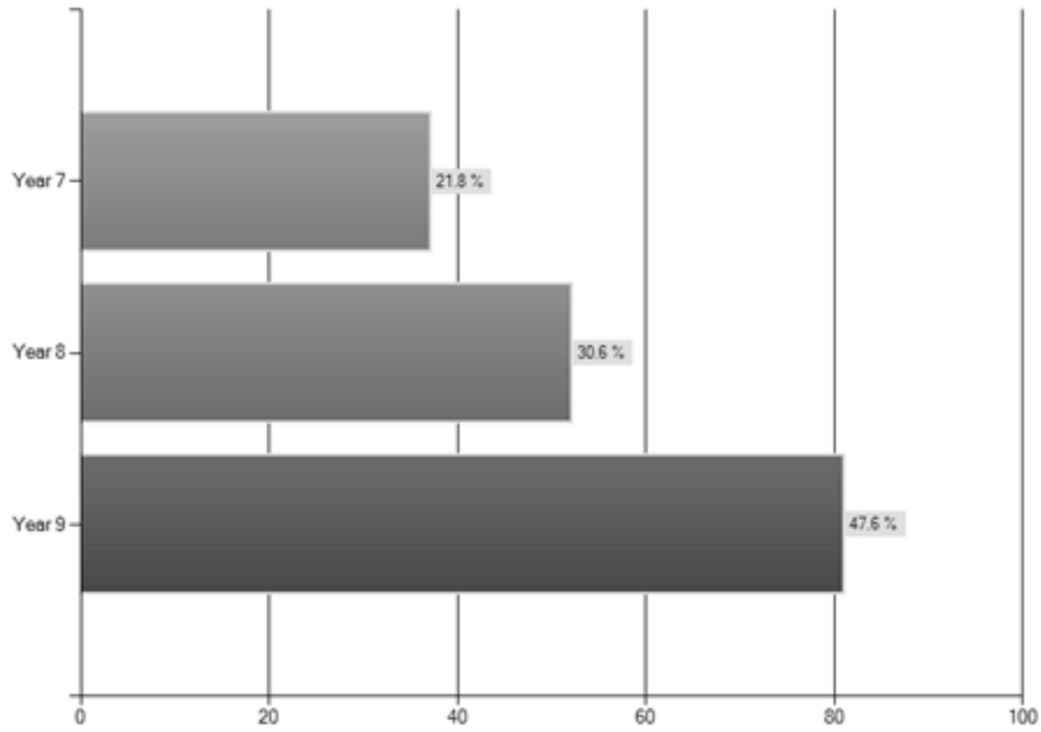

Figure 1. Graphical representation of age groupings of respondant cohort

Typically during Year 9 pupils in England and Wales undergo a selection process to elect which subjects leading to the award of the General Certificate of Secondary Education (GCSE) they will study. So those in Year 9 should have formulated valid opinions about Design and Technology having already studied it for a minimum of two years.

To contextulise the study, the team sought to establish the level of interest the children had in relation to Design and Technology (Figure 2). In excess of 70% of respondants indicated an interest.

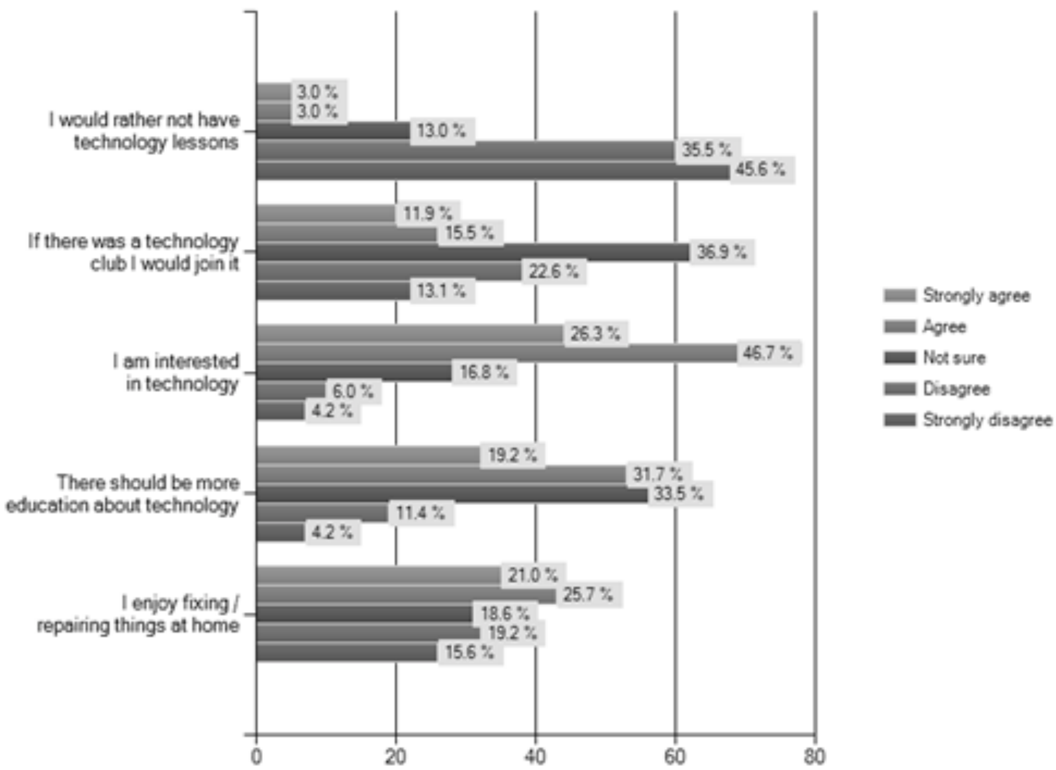

Figure 2. Pupil's interest in technology

The team then used the tool to establish pupil's individual attitudes towards technology (Figure 3). Overwhelmingly, respondents indicated that they perceive technological activity to be of interest in both career based options and personal, leisure based options.

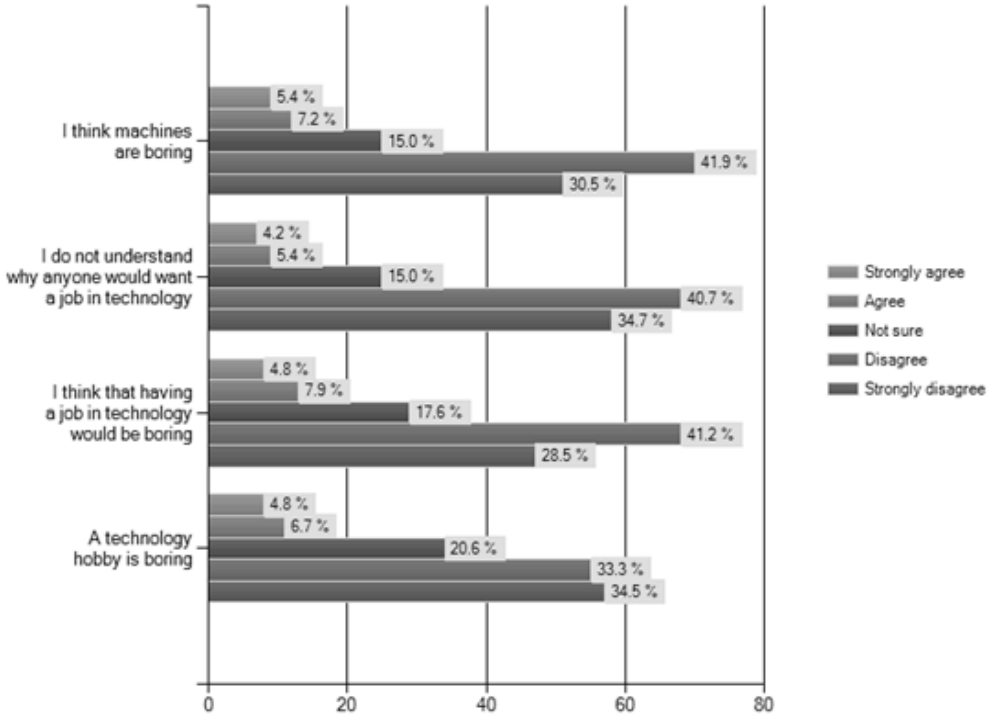

Figure 3. Pupil's attitudes towards technology

The survey then returned to engendered questions; pupils were then asked to respond to a varitey of questions with a gender bias, for example; "*Girls know more about technology than boys*" with 33% reporting uncertainly at this idea (n=185). A similar response rate determined that "*boys are more capable of doing technological jobs than girls*" with 32% either strongly agreeing (17%) or agreeing with this (15%).

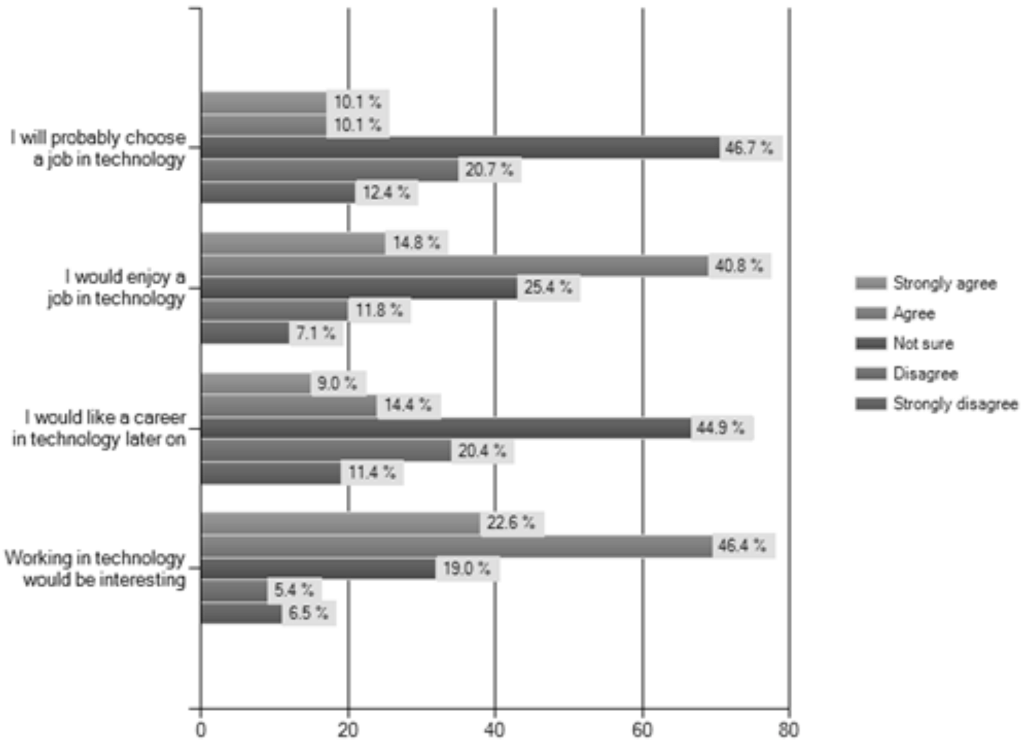

Figure 4. Pupil's career aspirations

Figure 4 highlights a contrast in the perceptions of pupils with more than 55% saying they would enjoy a technology job and 69% saying that it would be interesting, yet only 20% reported that they would choose a job in technology, rising slightly to 23% if they considered their options later.

This illudes to the importance of accurate advice relating to careers and employment highlighting the options and pathways that are open to pupils should they choose to pursue technology.

Having considered career options, the next question determined that all respondants were able to consider the importance of technology in their own personal lives and the wider global context. This was echoed in their belief that lessons in Design and Technology were important.

Pupils were then asked to respond to the statement; '*I think technology is easy*' 36% of pupils responded indicating they were unsure. When asked do you need to be good at mathematics or Science to study Design and Technology? 28% agreed. Only 20% considered they had to be clever to study Design and Technology, only 14% considered they needed to be talented. This suggests that participants in this study believe Design and Technology is an 'easy' subject.

To conclude, the team wanted to illicit further responses if pupils wished to comment, 28% did so. To clarify commentary, responses were grouped according to similarities they exhibited. This yielded the areas/themes shown in Table 1.

Table 1. Response groupings

Response groupings
Those expressing a general interest and/or enjoyment of one area of Design and Technology
Those expressing a deeper interest/and or enjoyment of Design and Technology
Those expressing comments relating specifically to gender issues in Design and Technology
Those who were concerned/desired a 'making' only curriculum
Those who recognised the importance of technology in a wider context

Drawn from these, set against and within the context of the overall data, some interesting findings begin to emerge.

Expressing an interest in a technological career:

The majority of pupils expressed an interest in the subject, and technological hobbies, welcoming a career in the subject as they perceived it to be interesting. Responses lead the team to believe that teachers should work to capitalise on this and promote links beyond the seemingly self-imposed subject boundaries inherent in Design and Technology. Possibly through the use of Science, Technology, Engineering and Maths (STEM).

An easy option:

Data indicated that pupils perceive technology to be easy, so by inference respondents must consider themselves not to be talented or clever. This is in line with findings from the initial study (Raat & de Vries, 1986).

Given huge technological advances over the past decade (Manyika, Chui, Bughin, Dobbs, Bisson& Marrs, 2013), disregarding the idea that the majority of respondents to the questionnaire are indeed talented or clever and assuming a mix of ability in the same cohort, this leads to the conclusion that curriculum tasks are insufficiently challenging.

Gender:

The results indicate that gender is not a barrier to undertaking a technological career and this comment drawn from the survey raises an interesting point.

> "I enjoy doing cooking and sewing more than metal and electronics but I think some people are very sexist towards girls about what they wanna do!"

This highlights that there is still some work to be undertaken to ensure gender equality in areas of the subject at the very least.

Conclusion

From the data it is clear that the majority of respondents in this study enjoyed Design and Technology and they felt motivated to engage in it, mindful that it would likely play some role in their future plans or careers.

However the data illustrates there are significant challenges ahead of the subject if it is to emerge from the curriculum review and become a subject important to the future industrial and technological aspirations of the nation (DATA, 2011). Not only does this relate to policy makers (Paton, 2013) but the findings presented here highlight that it also relates to the pupils studying it.

Teachers of the subject and those in the wider Design and Technology community have a lot of work to do in terms of educating pupils about the wider implication of the subject and the potential impact it has upon their futures by means of career choices.

Respondents in this study found the subject too easy which suggests work is required to ensure tasks set are of sufficient complexity and challenge to ensure engagement of those undertaking them. This corroborates the thoughts of the head of the schools inspectorate who has contacted all schools in England and Wales highlighting that all future inspections will have a strong focus on stretching the most able pupils (Wilshaw, 2013).

This pilot study also highlights that there is much work to undertake in the field of career guidance, this cannot be left to a single individual body of people (eg. teachers) to affect change. Turning to gender; data collated through this study indicates that there was no significant belief by pupils that one gender had more technological ability than another.

It seems that pupils find that it's too easy and you don't have to be talented or clever to be good at technology, this is maybe why the first proposed draft of the new curriculum seemed to have a post war 'make do and mend' approach to the subject (DfE, 2013) offering little in the way of a creative outcome, devoid of opportunities for challenge and innovation.

There is no doubt that if we, as a Design and Technology community, wish to disengage with the modernisation of our subject, and we do not articulate the benifits and positive impact our subject has, and we only seek to contain the middle achievers in classes without stretching and challenging the most able, then we will continue to see responses like those presented here.

Next steps

The team propose to undertake the following:

- Extending the work undertaken here by undertaking a larger scale piece of work being more representative of the geographic nature of pupil demographics in England and Wales,
- Undertaking an almost identical study since the new curriculum has been firmly embedded in all schools to determine if this new content has had an impact on pupils perceptions,
- Undertaking a pilot within the Primary education sector to see if the ideas formulated and articulated by the age range considered here are formed by the time pupils leave primary school, or if they are shaped and moulded by their secondary education experiences.

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STEM – Calculate & controls robots: hands-on mathematics and technology

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Abstract

The growing realization of the benefits to individual students and to state economies, of providing science learners with opportunities to expand their knowledge, skills and experience of knowledge-based technological design has led to seeking instructional strategies to facilitate the transition from traditional school settings to project based learning environments. This paper refers to engaging high school robotics and computer-science majors in challenging design projects which seek to activate and implement the often inert formal content knowledge within the context of designing and constructing systems dealing with real world engineering challenges in robotics. this paper suggest that visualization of the problem space and guided exploration of its spatial relationships can promote the elicitation of relevant formal knowledge and lead to creative solution design. These methods are described in the context of designing and programming robot navigation and in the context of developing remote distance sensors.

Keywords

Project based learning, visualization, spatial relationships, guidance, robot navigation, inert knowledge

Introduction

There is wide agreement that the science and technology education should develop learner abilities for problem solving, independent critical thinking, creative and inventive skills and productive team work (Chung & Chow, 2004; Gijbels, Dochy, Van den Bossche & Segers, 2005). Project-based science and technology learning provides a natural environment for achieving such goals, thus enabling the shift from traditional, teacher centered instruction towards meaningful, student centered learning (Harpaz, 2005; Resnick, 1987; Zohar,1997). The recently published New Generation Science Standards has embraced these insights, and includes an explicit focus on Engineering Design ("on behalf of the twenty-six states", 2013).

Many programs promoting project-based-learning in the context of engineering design for high school students, have been initiated in different countries during the past decade (n. d. "Engineering Projects in Community Service"; "Engineering Design via Community Service Projects"). Many of these programs are based in institutions of higher education. This may be due to the realization that engineering is vital for national economies and that high school students should be encouraged to join departments of engineering in colleges and universities. Robotics courses naturally fall into this category of instructional activities. Some high school curricula include Robotics as a study domain (Altin, 2012).

Abundant evidence has been gathered showing that students involved in electronics and robotics projects display high motivation to confront complex tasks and show originality and creativity (Barlex, 1994; Barak, & Zadok, 2009).

Study participants and context

This paper refers to engaging high school students challenging design projects which seek to activate and implement the often inert theoretical content knowledge (Bereiter, & Scardamalia, 1985) within the context of designing and constructing systems dealing with real world engineering challenges.

The study took place within a robotics course offered to high-school pupils who came once a week for half a school year (15 weeks) to the robotics lab. The robotics program was considered an extension of science and technology studies in the school, and a teacher from each school followed the pupils' participation in the course. The course format, however, was significantly changed in the second year, as discussed later in this paper.

The challenges of project based learning

Traditional k-12 education provides very few opportunities for learners to develop attitudes, skills and knowledge which are necessary for confronting technological problems and succeeding in project-based learning. Thus, even high ability learners lack the habits of mind and the practical skills for designing a technological system and progressing towards producing a working artifact (Cuban, 1990). There is a growing realization that learning and creative thinking are complex processes. The linear project design prescriptions commonly found in the engineering and technology literature, are poor approximations of the ways these processes unfold in reality, or of the work methods of experts (Barak, & Doppelt, 2009). To this one needs to add the realization that problem-solving and thinking skills are context-bound. Thus, very little transfer can be expected between problems in different domains (Perkins & Salomon, 1989). Swartz & Perkins (1990) stress that learners need direct instruction regarding the cognitive skills required for problem solving in a specific domain. We should not expect that formal knowledge acquired in physics or geometry lessons will be automatically invoked in the context of programming robotic motion. It is the instructors' responsibility to involve the learners in activities intended to elicit relevant formal knowledge.

Visualization as a problem-solving strategy for technological projects

Visualization is one of the powerful strategies for problem solving in general, and creative technological problem solving, in particular. Visualization involves transforming a physical situation or event into an explicit verbal or graphical representation, in a form that helps define the problem and promotes progress to one or more solutions (Tseng & Yang, 2011). We intend to show how exploring and explicating spatial relationships can be instrumental in understanding a technological problem and designing creative solutions Welch, Barlex, & Lim 2000).

Spatial ability is a collection of specific skills related to the ability to receive, mentally process and spatially present information (Olkun, 2003). Spatial thinking includes the following stages in visual information processing: 1. Visual perception of object having spatial properties. 2. Mental rotation. 3. Physical or visual representation of spatial information - Visualization. In the following we shall refer to "spatial relationships" as the manner in which spatial properties are related to each other.

Spatial abilities are considered particularly relevant for learning mathematics, science and technology at school and a vital condition for vocational education and engineering careers (Linn & Peterson 1985; Velichová, 2002). Researchers believe that spatial abilities can be developed through drill and experience (Tseng & Yang 2011). Educators have suggested advanced technological environments for developing spatial abilities in the fields such as mathematics, science, engineering and medicine (Lohman 1988; His, Linn & Bell, 1997).

Visual spatial abilities are often framed within the domain of 3D perception (Ruthven, Hennessy & Deaney 2008; Gorska, 2005). However, basic plane geometry offers a rich arena for developing an understanding of spatial relationships. Experiential visual perception allows children to identify circles and triangles, but visual experience by itself is unlikely to lead to the formulation of the many relationships that exist between lines and angles. Formal instruction in mathematics and geometry is responsible for teaching some basic spatial relationships such as Pythagoras' theorem; sum of the internal angles in a triangle; ratio of the circle circumference to its radius; ratio between the sides of similar triangles; ratio of the sides of a right angle triangle; definitions of geometric loci. Likewise, formal instruction in physics is responsible for teaching basic relationships related to motion, light propagation and electrical properties. All this formal knowledge is usually represented in concise "formulas", which high school students use extensively in text book problem solving. The challenge for project instructors is activating this stored knowledge in the context of designing technological problem solutions.

Exploring spatial relationships: the case of Lego Robot navigation

The Lego robot EV3 advances using two wheels which are powered by separate motors. The motors can be programmed to rotate at different rates in a forward or reverse direction. The robot's motion is determined by programming instructions related to traveled distance and the rotation rate of the driving motors, as well as by signals received from activated sensors.

The system records the total rotation angle of each motor. Programming the robot motion and calculating distances, necessitates an explicit understanding of the spatial relationships related to circles and the physical relationships between translation and rotation. Novice robot programmers tend to adopt a "try it and see" trial and error strategy, to achieve their goals. Robot project instructors can use the following sequence to promote deeper thinking about the relationship between the motion of the wheels and that of the entire robot.

Advancing in a straight line

When a circle rotates around the point of contact with a line, the centre advances a distance equal to the circumference for each completed rotation. This is called "rolling without slipping" (Fig. 1).

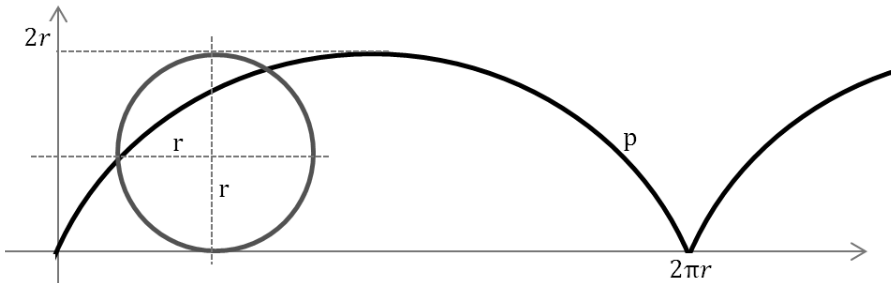
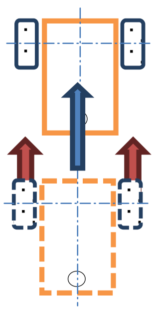


Figure 1. Visualization of a wheel rotating and advancing

To achieve motion along a straight path, both motors must rotate at the same rate. To calculate the traversed distance, the reading of the motor angle counter is read and the value is fed into the appropriate cell, divided by 360 and multiplied by the wheel circumference ($2\pi r$).

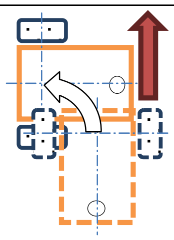
		Rotation angle	Wheel circumference (cm)	Distance covered
Both wheels		$\Theta°$	2πx2.8	$\Theta\frac{7\pi}{360}=\Theta\times 0.061$

Calculation of the robot movement straight drive

The instructional sequence starts with students observing the straight line motion of a pre-programmed robot. The next step is a graphical visualization of the motion of a wheel and a formal expression of the relation between the rotation angle and the distance traveled. After the students copy the instructor's program into their robots, and write a procedure for displaying the distance - they realize that the actual path differs from the theoretical calculation due to friction and other imperfections.

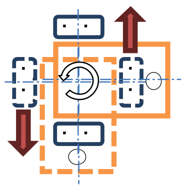
Changing direction - making a 90° turn

Robot navigation requires changing direction and turning corners. There are two options for achieving a 90° turn: 1. Using one stopped wheel as a pivot, and the distance between the wheels as the radius.

		Distance covered	Rotation angle
Outer wheel		$2\pi R4$	$360\cdot 0.5\cdot\pi\cdot R2\cdot\pi\cdot r=90\cdot Rr=90\cdot 122.8=385.7140$
Inner wheel		0	0 motor stopped

Calculation of the distance between the wheels as the radius

Turning around an axis midway between wheel centers, by rotating one wheel in a forward direction and the other in a backward direction, at the same rates.

		Distance covered	Rotation angle
Both wheels		$2\pi R4$	$360\cdot 0.5\cdot\pi\cdot R2\cdot\pi\cdot r=90\cdot R3.5=90\cdot 62.8=192.8570$

Visualizing the spatial relationships in pivoting around the robot center

The instructional sequence starts with the students manipulating the robot wheels, trying to achieve a turning motion. Students suggest the idea of making the wheels rotate in opposite directions, based on videos they have seen of the way tanks achieve turning motion. The students implement their understanding of straight motion and turns by programming the robot to travel along the sides of a square. This implementation leads to an increased awareness of the gap between theory and reality, and the need for the use of sensors to control robot navigation.

Navigating a circular path

Robot navigation often requires planning a path that avoids collisions with obstacles, thus requiring deviation from a straight line. Due to the robot breadth, the inner and outer wheels traverse arcs of different radii. The difference in radii equals the distance between wheel centers (Fig. 2).

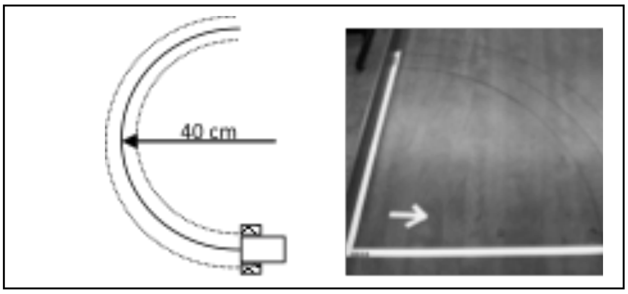
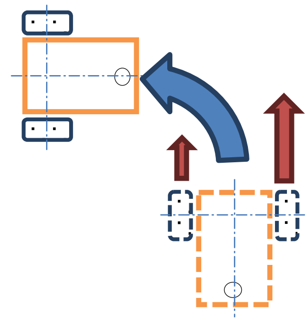


Figure 2. Visualization of the different paths taken by the wheels and robot center

Assuming the wheels roll without slipping, each full rotation advances the wheel center by the wheel circumference. Since the wheels have equal radii, the inner wheel should complete fewer rotations than the outer wheel, as the robot advances along the curve. Thus, the rotation rates of the wheels need to be coordinated according to the difference in the length of the inner and outer arcs.

For example, the distance between a Lego robot's wheel centers is 17.0 cm, and the radius of each wheel is 3.5 cm. For the robot to follow a semi-circular path with a median radius of 40 cm, an outer radius of 48.5 cm and an inner radius of 31.5 cm, the following spatial relationship will need to be established:

		Distance covered	Rotation angle	Motor power ratio
				
Inner wheel		$2\pi\times31.52$	$360\cdot\pi\cdot31.52\cdot\pi\cdot2.8=1671.420$	$31.548.5=0.6495$
Outer wheel		$2\pi\times48.52$	$360\cdot\pi\cdot48.52\cdot\pi\cdot2.8=1671.420$	

Calculation of the robot movement request

Finding the diameter of an outlined circle

Figure 3 shows the circle circumference outlined by a painted black line. The robot's light sensor recognizes the circle's outline. The robot starts out from a random point on the circle's edge and moves into the circle in a random direction. How should the robot be programmed to obtain the circle diameter?

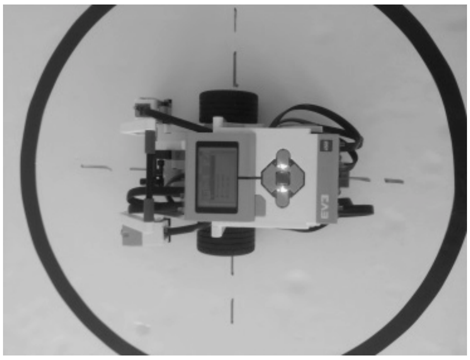


Figure 3. The robot about to travel into the outlined circle

The suggested solution invokes the spatial relationship between the diameter and inscribed angle

The robot moves into the circle and measures the distance between the first and second points on the circumference - side a. (Fig. 5).

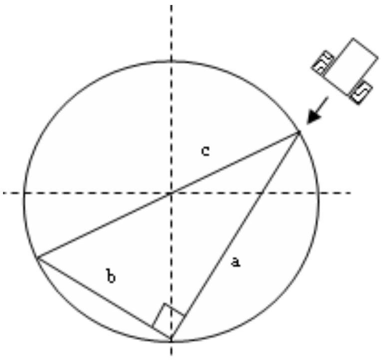


Figure 4. Visualizing the spatial relationship between the diameter and the inscribed angle resting on it.

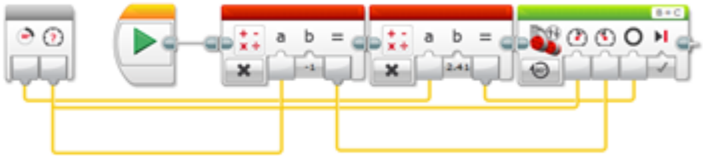


Figure 5. Programming the robot to make a 90 degree turn around its center.

The robot makes a 90 degree turn inside the circle.

The robot reverses out of the circle, and then advances until it detects the circle outline. The program shown in Fig. 5 is now repeated and this time it measures the distance of side b.

The length of the hypothenuse is calculated using Pythagoras's theorem. Finally, the result is displayed.

The decision to construct a sequence for the "90 degree turn", rather than employ the available dark green block, was intended to promote better of the spatial relationship between circle radius and rate of rotation for different wheels..

Discussion and conclusion

There is wide agreement throughout the science education community that science learners of all ages should be provided with opportunities to experience and practice the art and craft of engineering design. This can best be achieved by project-based learning, which can be carried out within the school curriculum or as extra-curricular elective programs, often hosted by the education or engineering departments of institutions of higher education.

In this paper we have focused on the technique of guiding students by exploring and explicating spatial relationships that can be found within their project space. High school science learners acquired a store of formulas in their science and math school lessons. Many of these formulas describe spatial relationships within systems. Students are accustomed to activate this stored knowledge in the context of end-of-chapter problem solving. We have provided several examples of the ways in which this stored and often "inert knowledge", can be activated by discussions, static and dynamic visualization and structured guidance.

The transition from traditional, teacher centered, text book based instruction to challenging problem solving and technological design is non-trivial, even for high ability science learners. Students must be provided with mental and technical tools and sufficient guidance to help them succeed in the unfamiliar learning environment. Students also need to become aware of the differences that exist between theoretical models and material reality. For example, the focus of a lens is not a mathematical point and the robot's wheels are not perfect circles. This is achieved by comparing experimental results with expected theoretical values, and refining the engineering design to compensate for these effects.

The activities we have described represent a small sample of activities that have been implemented in our work with high school science majors over the past decade. Initial testing indicated the absence of cognitive bridges between theoretical math and physics knowledge vs. material reality. We have collected ample evidence that exploring spatial relationships in real life problem contexts promoted the creation of such bridges. Students' new insights were expressed in the working models they created, solving a variety of seemingly different technological problems by implementing core ideas. For example, the triangulation method for remote distance measurement described in section IV in this paper, has been implemented in systems of transportation (collision avoidance and smart road signs), security (intruder detection and location) and assisting visually impaired persons.

Experience has taught us that achieving the desired transformation of the students' mental world view does not occur spontaneously. It requires an instructional design of revisiting the analysis of spatial relationships in a variety of contexts, using suitable pedagogical tools.

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How is time experienced during work-based training? Perspectives of trainee engineers and their tutors

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Abstract

Work-based engineering training articulates different contexts, i.e. in the companies and at university, and specifically articulates different times, i.e. time of production and that of training. Studies on the training of engineers have mainly looked at the management of time, seen as a constraint or a resource. In this communication, we investigate the time experienced by trainee engineers (TE) and their engineer tutors (ET) in the work-based training contexts. We mainly focus on the link between the training time and that of the construction of knowledge and professional competences. Eleven pairs of TE/ET were interviewed and two complementary levels of analysis of their discourse were articulated, i.e. a lexical analysis and a thematic analysis. The lived times conceptions, or temporalities, of TE and ET are characterized and some implications for the training of engineers in work-based programs are proposed. This study mainly shows that ET and TE express their temporalities by evoking the elements of the didactic dynamic that play out in business, seen as a training space, but they also do so in the expectation of different outcomes, respectively outcomes related to production and training.

Keywords

Didactics, engineers, time, work-based training, knowledge Introduction

This paper is based on a research about the temporal contexts of trainee engineers (TE) and their engineer tutors (ET) in the work-based training of engineers[1]. In such a program, the TE alternate between successive periods in different social spaces (business and university) that are, *a priori*, distinct, in terms of their organisation, actors, economic functions, etc. Their professional training involves the reconstruction of this succession as a coherent group of actions involving training and learning. The main preoccupation of this paper is thus the characterisation of the temporal contexts by the TE and the ET according to two organisational timeframes which are assumed to be articulated: the production time within the business and the training time at university. The aim is specifically to investigate the link between the training time and the construction of knowledge and professional competences.

[1] Engineering training – CFA Ingénieurs 2000

Studies on time in professional university training, specifically on the training of engineers, have mainly looked at the management of time seen as a constraint or a resource (Swart, Lombard and de Jager, 2010; Anderson *et al.,* 2011). Time in training contexts remains a blind spot, in particular in the studies mentioned in many research reviews on work-based training (Clénet and Demol, 2002; Couturier, 2011; Landry, 2002; Zaid, 2013) and those who have contributed to different special issues of the *Éducation Permanente* [2] journal.

Nonetheless, few empirical studies highlight the link between the time during which professionals or engineers exercise their profession, or are trained, and the construction of knowledge and professional competences (Gainsburg, Rodriguez-Luesma and Bailey, 2010; Kolari, Savander-Ranne and Viskari, 2008; Mayen and Olry, 2012; Roquet *et al.*, 2013; Savoie-Zajc, 2001). Mayen and Olry (2012) state that it would be possible to establish the relations between an adaptation of the rhythms of moving between business and university, and the effects in terms of the integration of trainees, as well as the development of their learning and integration, according to the following mode of reasoning: "the more the trainee has entered into the normal flux of work and the more he/she has been engaged in the ordinary tasks of the work structure, the more his/her professional insertion is likely as he/she will have acquired and occupied the functions just like any other employee" (p. 51-52).

The relevance of temporal contexts as a means of characterising the didactic dynamic of work-based training

The didactic perspective views the business as a place in which learning is structured by a didactic dynamic (Loewenberg and Forzani, 2007; Zaid and Lebeaume, 2012). This is a dynamic whose main elements are: an organisational framework (training, production), actors, engineering tasks, content and sociotechnical networks (Callon, 1991). Understanding the tasks of the actors, their interactions, the content and its construction within the sociotechnical networks involves understanding the elements of a dynamic, in the mechanical sense of the term, that is to say a process which proceeds by actions, movements, trajectories, positions, inertia, etc. The didactic dynamic can be understood by characterising the temporal context of the actors (in particular the TE and ET).

The temporal context is underpinned by the idea of a plurality of *temporalities*, that is to say a plurality of autonomous constructions of social time and specific means of being-in-time (*être-dans-le-temps*) (Chesneaux, 2004). With reference in particular to the works of Zerubavel (1981), McGrath and Kelly (1986) and Adam (1995) on the manner in which time is experienced in organisations, work situations and ordinary, collective or individual life, it is possible to distinguish two temporalities which imply two levels of analysis of work-based training time: the organisational level corresponds to the prescribed time, and the transactional level corresponds to the experienced time. These temporalities can be characterised via two main properties (Zerubavel, 1981):

- The *construction* of time by the actor: all of the notions mobilised by an actor in order to narrate his/her temporality: space, movement, change, transformation, etc.;
- The *structure* of time as constructed by the actor is defined via four characteristics: the *sequence* which provides information regarding the implementation order of the event; the *length*; the temporal *localisation* which defines when an event occurs and, finally, the *rhythm*, which provides information regarding the frequency of the event.

Investigating the lived time, as a subjective and intersubjective experience (McGrath and Kelly, 1986), thus involves questioning the construction and the structure of the temporality of the actor under the influence and in interaction with the organisational temporality. This interaction may be studied by mobilising the metaphor of resonance[3]. It allows us to approach the modification of an endogenous rhythm under the effect of an exogenous rhythm (McGrath and Kelly, 1985; Zerubavel, 1981 and Giddens, 2005). When it is applied to work-based training, this metaphor enables us to put forward that

[2] Special issues of *Éducation Permanente* on work-based training: 115, 163, 172, 190 and 193 (website of the review: http://www.education-permanente.fr/).

[3] Similar to the mechanical phenomenon of resonance between vibrating blades and an exterior source of vibration.

training time, which prescribes sequences of presence at university and in business[4], influences the endogenous time of construction of knowledge and professional competences by the trainee engineers.

In what follows, two questions are fundamental: which temporalities are constructed by the TE and ET with regard to the organisational temporalities of training and production? What do the temporalities constructed by the actors say about the learning and training of TE in the sequences which take place in business?

Method

The study looks at a work-based engineer training program within the *Centre de Formation par Apprentissage Ingénieurs 2000* in France. This is an organisation which undertakes the coordination and animation of a network of universities and businesses bringing together different industrial and service sectors. Each trainee is accompanied by an academic tutor and an ET. The TE is a paid employee of the business during the three years of the training program, which is divided between the engineering school and business according to the following organisational temporality (figure 1):

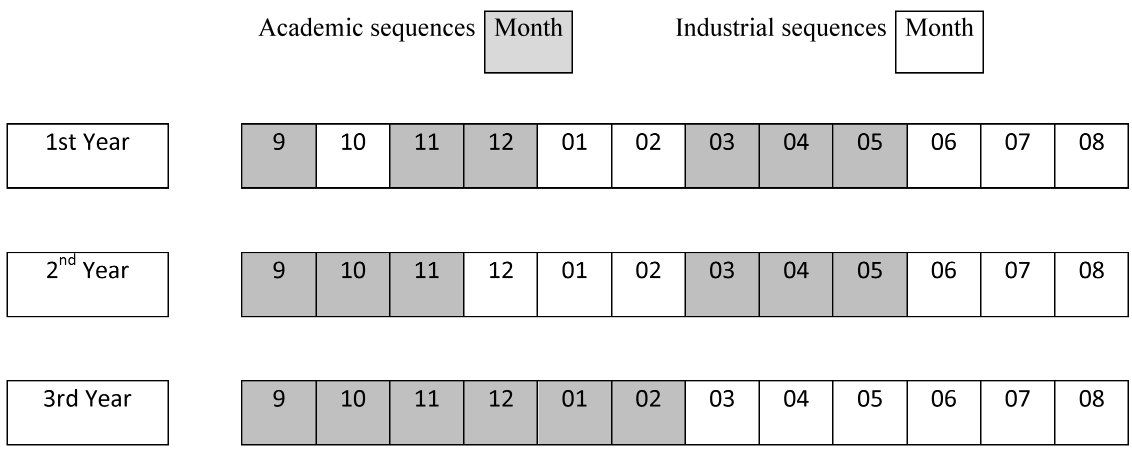

Figure 1. Temporality of the training program

The study was carried out using semi-structured interviews. 11 pairs of TE/ET were interviewed during the week of the end-of-year examinations and each interview lasted between 45 and 60 minutes. The questions were structured around the following themes:

- Temporality of the training and production temporality within the business
- Training activities of the trainee within the business and the progression of the tasks
- Role of the engineer tutor
- Temporality of learning within the business
- Articulation of the temporalities of training in the business and at the engineering school

Two complementary levels of analysis were articulated. Firstly, in order to explore the meaning of the discourse of the trainee engineers and their tutors with respect to the question of the temporal contexts within the business, we carried out a lexical analysis (Reinert, 2001) using the Iramuteq[5] software package.

We also undertook a thematic analysis of discourse of the ET and TE (Bardin, 1979; Blanchet and Gotman, 2007) in order to document the components of the temporal conception: namely constructions and structure. This analysis allows us to specifically clarify in which way the work-based training may or may not encourage the integration of the production temporality by the TE.

[4] With sequences of one month in business and one month at university in first year; sequences of three months in business and three months at university in second year and, finally, sequences of six months in business and six months at university in third year.

[5] Http://www.iramuteq.org/.

Construction and structure of the temporalities of the ET and TE

ET and TE experience the sequences in business according to two different constructions of temporality. While ET experience the temporality of the integration of TE within the project and production time, TE experience the temporality of the acquisition of knowledge and attitudes inherent in becoming an engineer. For ET, the organisational temporality of the training, which fixes the sequences of presence within the business, is a constraint.

> "ET: So during the first year each month we couldn't give him anything, no responsibility. We could only give him short-term responsibilities. So we could only put him in charge in the long run."

The structures of the temporalities evoked by ET highlights three factors of tension between, on the one hand, lengths, localizations and rhythms of presence within the business and, on the other hand, those with respect to the sequences of production: factors linked to time which is external to the business (determined by the client's requirements or other external constraints), factors linked to time which is internal to the business (specific to the production process) and factors linked to the time of tutoring.

> "ET: For us, if we were to talk in terms of seasonality, it would be based on contracts. So the contracts, they come in, more or less the same thing depending on the units (…); the progression is always the same, so it's the seasonality, I guess that we'd talk in terms of contracts".
>
> "ET: And so the other problem is that there is a mismatch between the two chronologies: the chronology of the contract and the time during which the student arrives during his training".

ET and TE express their temporalities by evoking the elements of the didactic dynamic that plays out in business, seen as a training space, but they also do so in the expectation of different outcomes, respectively outcomes related to production and training. The temporal analysis reveals a didactic dynamic centred on interwoven content and of different orders. We thus highlight the scientific, technical and professional content, reconstructed by the TE, as well as the content which is more related to the personal conscience of the trainee and his/her own perception, such as the feeling of being useful in the business or the realisation of having 'passed a milestone'; but this is a content whose appropriation is necessary in order to construct other, more tangible content, and to progress in the training. Moreover, we noted that this content is constructed by actors according to irregular, unstable and extremely local temporal structures present in each individual business, possibly even in each service within the business.

"TE: Over the course of the same cycle, yes, yes I didn't move, it was just a change of service as my tutor modified what I was in charge of but at the end of the first year I drew up an organigram for example of my link, I really tried to identify, I am here and then by the end of the first year, at the end of the three-month sequence, I started to feel useful, I would say in the service but also in the department. Em yeah, from there on, he was behind me a lot less, I became autonomous, it really wasn't about training, it was work that involved accompanying and guiding"

The discourses of ET and TE highlight, finally, that the *resonance* between the temporalities of the TE and the organisational temporalities depend on the choice of the structure of the organisational temporality of the training (length, localisation, and rhythm) and is not reduced to a choice of the lengths of stay within the business.

Discussion and conclusion

This study shows that ET and TE express their temporalities by evoking the elements of the didactic dynamic that play out in business, seen as a training space, but they also do so in the expectation of different outcomes, respectively outcomes related to production and training. The analysis of didactic time that we propose here contributes to a deepening of the research on temporal profiles of the content which appears in the practices of engineers or in their training, with the aim of looking at the temporal profile of their activities (Zaid, 2013; Filliettaz and Saint-Georges, 2006; Gainsbourg et al. 2010). It should be noted, however, that only the discourses of the TE and their ET are taken into account here, which constitues one of the limits of this paper..

This research has implications for the training of engineers in work-based programs. The first is that there is no ideal temporality, rather a temporality that articulates between length, localisation and rhythm of the industrial and academic sequences in coherence with the cultural, experience-related and social acquisitions of each training program. Consequently, irrespective of the temporality chosen, the decisive elements are the measures taken to deal with, in particular, the presence/absence dilemma within the business: *training ET in the management of the training time and its articulation with the production temporality*; cordoning off time during the academic sequences to allow the trainee to prepare, continue or finalise work from the company; adapting to the evolution of the engineering profession, to TE who are more and more familiar with information technologies, acculturated to flexibility and choice and with increasingly diverse prior training. The second implication concerns the construction of the progressivity of the TE's learning. Different forms of progressivity can be proposed based on the elements of the didactic dynamic as axes of progress: from technical knowledge to management knowledge; from internal sociotechnical networks to clients and sub-contractors; from tasks with few issues to tasks with major implications for the company; from the ET participating in the tasks of the TE to an expert who is recognized by his/her peers in a class of tasks, etc.

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