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Learning environments applying digital learning tools to support argumentation skills in primary school: first insights into the project

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Based on a cooperative project between the Europe University Flensburg, the University of Koblenz-Landau and the University of Siegen (Germany) on the development of an open source electronic mathematical proof system (cf e-proof.weebly.com), a new project has evolved with a focus on primary education. The aim of this project is to support argumentation skills through the iconic and enactive visualization of reasoning processes. The focus is on supporting classical teaching and learning processes in primary education with digital learning environments. Grounded in the philosophy of pragmatism, Design Science research is performed for creating learning environments applying digital learning tools to support argumentation skills in primary school as artifacts. In this paper the first developed learning environment is presented and insights into the results of an empirical pilot study investigating the learning environment are given.

Keywords: Educational media, primary schools, argumentation.

Introduction

The demand of the Standing Conference of the Ministers of Education and Cultural Affairs of the Länder in the Federal Republic of Germany (KMK) is supposed to be addressed in this research project, that in dealing with the digitization of education the “primacy of the pedagogical” (KMK, 2016, p. 51) has to be followed and must be incorporated into educational concepts in which learning is in the foreground (KMK, 2016). Consequently, the potential of digital media for teaching can only unfold, if it is used in a meaningful and an educational reflected way. In this sense, a project on the development of learning environments applying digital learning tools to support argumentation skills in primary school is performed. The scope of this project is to identify opportunities and possibilities, as well as challenges and limitations of learning environments including digital media to support argumentation skills through the iconic and enactive visualization of reasoning processes and their influence on student learning. “In mathematics education, the teaching of reasoning skills plays a major role. These skills form the basis for proofs of mathematical statements and contexts dealt with in higher school-grades in different contexts. It is especially logical reasoning that supports the formation of understanding.” (Platz et al., 2017, p. 2). Wuttke (2005) performed a study, comparing different forms of educational communication in relation to their influence on the generation of knowledge and understanding among the pupils. This study has shown that it is in particular the argumentation in that a variety of connection possibilities to the students’ prior knowledge is provided through the exchange of different and well-founded perspectives, which therefore contributes particularly to understanding (cf. Budke & Meyer, 2015). In the present paper, a first draft version of a learning environment including an applet to be run on a hand-held device with internet-connection and touch-screen, e.g. a tablet PC, is presented. Design Science is performed for learning environment creation. The TPACK-Framework (cf. Koehler &

Mishra, 2009) is applied to analyze the developed learning environment and first insights into the results of an empirical pilot study investigating the learning environment are given.

Objectives

The aim of the overall project is to create learning environments to support argumentation skills through the iconic and enactive visualization of reasoning processes. A central media aspect is to make the handling with teaching and learning material computer-detectable and thus, to infer optimized learning environments. The focus is on supporting classical teaching and learning processes in primary education with both digital and non-digital learning environments.

The objectives of this paper are to

1. employ the TPACK-Framework (cf Koehler & Mishra, 2009) to analyze the developed first draft of a learning environment applying digital learning tools to support argumentation skills in primary school.
2. give an insight into the results of an empirical pilot study investigating the first draft learning environment.

Research Method

In order to optimize the learning environment, Design Science is applied. Design Science is grounded in the philosophy of pragmatism and creates artifacts which is something created by humans usually for a practical purpose. The learning environment applying digital learning tools to support argumentation skills in primary school is a method (artifact) (cf. March & Smith, 1995) to support pupils in gaining argumentation skills. Within the meaning of the Design Science Research Methodology Process according to Peffers et al. (2006), a problem was identified and an objective for a proposed solution was formulated (see sections “Introduction” and “Objectives”) for the first run of the process. Furthermore, an initial prototype was generated (see section “The developed Prototype and the TPACK-Framework”). For demonstration, the prototype (learning environment applying digital learning tools to support argumentation skills in primary school) was tested in an empirical pilot study (see section “The Empirical Pilot Study”) and first evaluation results are presented. The results are communicated among others through this paper. Through the first iteration of the process the prototype will be optimized.

The developed Prototype and the TPACK-Framework

Koehler and Mishra (2009) describe the TPACK (Technology, Pedagogy, And Content Knowledge) framework as a complex interaction between three sets of knowledge: content, pedagogy, and technology. The interaction of these sets of knowledge, both theoretically and in practice, generates the kind of flexible knowledge needed to successfully integrate technology into the classroom (Koehler & Mishra, 2009). In contrast to the original purpose the TPACK framework was designed for, i.e. to be used as an analytical framework for a teacher’s different types of knowledge, it is used in a broader way as a framework that refers to knowledge in general. Taking a closer look at the developed first draft of a learning environment applying digital learning tools to support argumentation skills in primary school, an interaction of technology, pedagogy and content knowledge becomes visible. In the following sections, the learning environment is analyzed

concerning the Pedagogical Content Knowledge (PCK), the Technological Content Knowledge (TCK) and the Technological Pedagogical Knowledge (TPK).

Pedagogical Content Knowledge (PCK): Mathematical Proofs in Primary School

The main task the pupils are concerned with in the empirical pilot study is the following¹:

Task: *If you add two odd numbers together, you always get an even number.
Is that correct? Give reasons!*²

With respect to the argumentation chain developed by Bezold (2009) by formulating the task in this way, the pupils have to question the special attributes and find reasons or respectively reasoning ideas to solve the task. Krummheuer and Fetzer (2005) hold the opinion that proofing in the strictly deductive sense is not yet possible in primary school, but substantial mathematical argumentation (cf Toulmin, 1958, p. 116) can be implemented. Due to Kothe (1979), primary school children have fun on problem solving with appropriate instructions. Here, proof need is: “I want to show the teacher or classmates that my approach is right” (Kothe, 1979, p. 276). The awakening of a need for proof in primary education requires long-term didactic planning to seek opportunities for local sensitization to mathematical thinking, (Kothe, 1979). Semadeni (1984), describes an action proof as “a simplified version of a recommended way in which children can convince themselves of the validity of a statement; in practice, an action proof will require some preliminary or additional exploration”, (Semadeni, 1984, p. 32). In this study, the preformal proof according to Blum and Kirsch (1991) is focused with the aim to find a way to include proofs in primary education: In accordance with the concept of action proofs (cf Semadeni, 1984), a preformal proof can be defined as a chain of formally represented conclusions which refer to valid, not formally represented conclusions which refer to valid, non-formal premises. In contrast to the definition of an action proof, inductive arguments (“etc.”) and indirect arguments (“imagine that ...” or “what would happen if ...”) should not be excluded in this context. The conclusions must be capable of being generalized directly from the concrete case. If formalized, they have to correspond to correct formal-mathematical arguments. To accept a preformal proof it is, however, not necessary for such a formalization to be actually effected or even recognizable. Occasionally, the consensus within the mathematical scientific community is quite sufficient. Preformal proofs have to be valid, rigorous proofs, (Blum & Kirsch, 1991). The concept of a preformal proof is comparable to the concept of the operative or “intuitional” (or “inhaltlich-anschaulich”) proof (“see-proof”), (cf. a.o. Wittmann, 2014, p. 226). To describe the differences and relationships between proof and argument, Pedemonte (2007) refers to Peirce and Polya:

¹The worksheet can be found at the following link: http://www.melanie-platz.com/ES_1/Task_even-and-odd.pdf. In contrast to e.g. Wittmann & Müller (2013a), the formulation of the task is meant to be more open to enable more variety in the solution methods, as the structure of double rows is not unconditionally necessary, when operating with pairs of tiles.

²An example on how a preformal proof for the **Task** above could look like is made available at the following link: http://www.melanie-platz.com/ES_1/Preformal-Proof_even-and-odd.png

the logical connection between statements in an argumentation differs from the logical connection in a proof. Each step of a proof can be described as a deductive step. But argumentation structure is unlikely to be a deductive structure; it can be composed of steps of different nature, such as abductive steps or inductive steps. (Pedemonte, 2007, p. 29)

Pedemonte (2007) derives, that a structural change is required for the construction of a deductive proof, that is from abductive or inductive steps to deductive steps. To enable a support of argumentation skills, the pupils worked together in groups of two, to foster communication between the pupils. Communication is important to gain argumentation competences, as one aspect pupils should learn is to respond appropriately to reasoning in interaction with others (Budke & Meyer, 2015).

Technological Content Knowledge (TCK): reversible tiles as representation

The reversible tile applet is a prototype of a freely available JavaScript-applet developed by the author of this paper, which allows the virtual laying of (reversible) tiles. The applet is available at <http://www.melanie-platz.com/WPA/>. Tiles are a fundamental means of representation in primary education (cf. Wittmann, 2014). Based on the categorization of Krauthausen (2018), the tiles are used in the function of working material and illustrations as argumentation and proving tool. Wittmann (2014), states that this material is from its origin not didactic, but of epistemological nature. The preformal proof stimulated by the *Task* mentioned above is not grafted from the outside, but deeply connected with the nature of numbers. Around 600 BC, Pythagoras and his students discovered and proved universal number-theoretic patterns when laying stones (Wittmann, 2014; Wittmann & Müller, 2013b). “It can be said without exaggeration that stones (tiles) form the cradle of number theory” (Wittmann & Müller, 2013b, p. 142).

Technological Pedagogical Knowledge (TPK): The reversible tile applet

The developed applet is especially suitable for digital devices with touchscreen display (e.g. tablet PCs), which allow a control through touch gestures with the fingers. The tiles in the app are created similar to the analogue tiles. Because of the two-dimensionality of the screen, the tiles are also two-dimensional and cannot be lifted up, as it is the case with the analogue tiles. In the case of the present study, the tool is used in the sense of activist learning as an illustrative tool and to be given to the learners as tool of their own mathematical activity (cf. Krauthausen, 2018). In order to ensure a certain openness of the use of the applet, no structuring aids are given. The applet can thus be used in the function as a medium of argumentation and proof. Referring to the SAMR-Model (Puentedura, 2010), the first step of enhancement can be covered with the developed applet in the learning environment, which is substitution of the analogue material. The second step of enhancement, augmentation (technology acts as a direct tool substitute, with functional improvement), can be rudimentary covered. One advantage of the reversible tile app is that the organizational handling is more suitable for everyday use (to be quickly provided or put away in an orderly manner) than with analogue tiles, as single tiles cannot disappear within the app.

The Empirical Pilot Study

In the framework of a school visit in May 2018 at the Maths Lab “MatheWerkstatt” at the University of Siegen (Germany), a fourth-grade school class of a local regular school containing 23 pupils took part in the empirical pilot study. The school class was separated into groups of six or respectively five pupils who worked at different learning stations during their two hours stay at the university. For the learning station three tablets were made available where pupils worked in groups of two using one tablet per group and discussing their ideas and results. In each of the four cases, one group of two pupils of the three groups of pupils was videographed and the tablet screen was screencasted, both with audio recording. This possibility of the screencast is an advantage of the technology use, because the touch-gestures performed by the pupils coming with their oral argumentation can be captured. Each group worked for 20 minutes at the learning station. The recorded material was transcribed and sections were extracted, where information on the argumentation process and on the User Experience (UX) could be discerned. From these sections, video vignettes were extracted and the argumentation process was represented in a model as it is described below (see Figure 1).

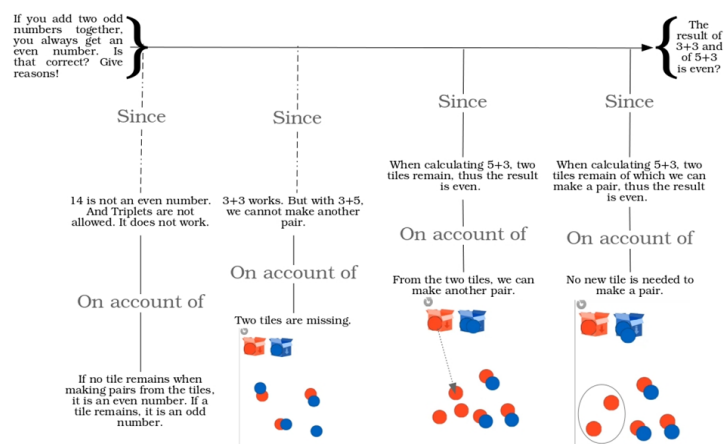


Figure 1: Exemplary representation of an argumentation process in the pilot study; the diagram can be read like a timeline from left to right; the dashed lines mark refutation trials of the assertion; screenshots with markings visualize the action of the pupils while speaking

To investigate and understand preformal proof and argumentation processes, a diagrammatic representation is developed and evaluated. This is in line with van Gelder (2005) who represents the opinion, that a diagrammatic representation of complex argumentation was developed, because

everyone knows that complex structure is generally more easily understood and conveyed in visual or diagrammatic form [...]. Interested in argument but dissatisfied with the tools offered by the logical tradition, Toulmin developed a simple diagrammatic template intended to help clarify the nature of everyday reasoning. (van Gelder, 2005, p. 4)

Nevertheless, Toulmin himself applied his layout to mathematics: as an example, Theaetetus’s proof that there are exactly five platonic solids is visualized in Toulmin et al. (1979). Aberdein (2005) concerns with the application of Toulmin’s layout to multi-step proofs. Pedemonte (2007) uses Toulmin’s model as a methodological tool to compare proof and argument. “This model can be used to detect and analyse the structure of an argumentation supporting a conjecture (abduction,

induction, etc.) and the structure of its proof” (Pedemonte, 2007, p. 23). Reid et al. (2011) investigate the potentials of the refutation of arguments visualized in an adapted model of Toulmin’s layout. The ideas of Reid et al. (2011) are similar to the representation of arguments of Miller (1986). Miller (1986) works with structure trees in order to analytically grasp argumentation processes. A combination of these models is applied to represent the argumentation processes in the pilot study, see Figure 1. Furthermore, in orientation to a framework developed by Barendregt and Bekker (2003), the User Experience of the children while working within the learning environment, was investigated.

Results

With regard to the User Experience, the applet itself seems to be intuitive and the pupils did not have problems in using the applet. No introduction on how to control the applet was needed. One pupil of the test group did not like to work with tiles, as this was found “childish being already in grade four”. The argument of the pupil was, that they had already learned to calculate until one million and tiles were only needed to calculate in grade one. From the conversation with the pupils, it seems likely, that the task was not really understood, i.e. no real need for proof (Kothe, 1979) was awakened. In the example visualized in Figure 1, it seems like the pupils did not understand the reason for making pairs of the tiles. This can be inferred from the interpretation of the pupils’ actions visualized in the screenshot of the third backing, when the pupils added new red tiles to build pairs instead of making pairs of the red tiles representing the number 5 which they already got out. As the need for proof did not seem to be awakened, it is not possible to reconstruct a structural change for the construction of a deductive proof (Pedemonte, 2007) from the conversation of the pupils.

Discussion

The prototype (learning environment applying digital learning tools to support argumentation skills in primary school) was analyzed via the TPACK-Framework and tested in an empirical pilot study and needs to be optimized through the first iteration of the Design Science Process. Due to Kothe (1979), the awakening of a need for proof in primary education requires long-term didactic planning to seek opportunities for local sensitization to mathematical thinking. This is supposed to be reached with an optimized prototype of the learning environment. One important issue for an optimization is to give the pupils more time and instruction, to initiate an understanding of why a proof is needed. Due to Kothe (1979), primary school children have fun problem solving with appropriate instructions. Here, proof need is: “I want to show the teacher or classmates that my approach is right”, (Kothe, 1979, p. 276). To support this creation of proof need, a new prototype should incorporate the theory of discovery learning (cf. Winter, 1989). Discovery learning is based on the idea that knowledge acquisition and progress and the ability to work in problem solving skills happens “by own active action and recourse to the already existing cognitive structure, but usually stimulated and thus made possible by external impulses” (Winter, 1989, p. 3). Furthermore, a central media aspect shall be to make the handling with teaching and learning material computer-detectable and thus, to derive optimized learning environments. One research field is the investigation of “gestures” made by the pupils on a touch screen with relation to semiotics (cf. Peirce, 1931-1935). Huth (2013) states that gestures in particular, can at least temporarily take over

the function of possibly unavailable or not possible inscriptions. Such “gestures” can be made detectable with the help of digital media, and automated evaluation and help selection are supposed to be provided. With implementation of these functionalities, the first step of transformation according to the SAMR-Model (Puentedura, 2010) can be reached, which is modification, i.e. the technology allows for significant task redesign and enables other possibilities to handle heterogeneity in a school class.

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