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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; Ginestí, 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.

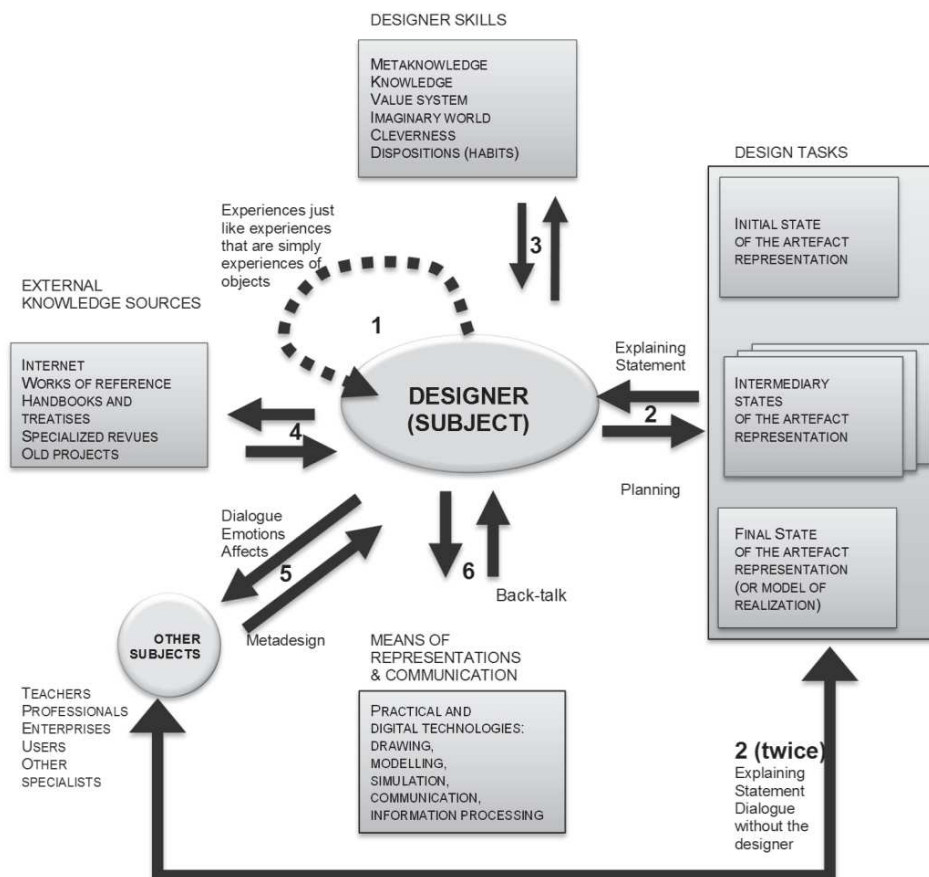


Figure 1. The interactions' complex.

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.

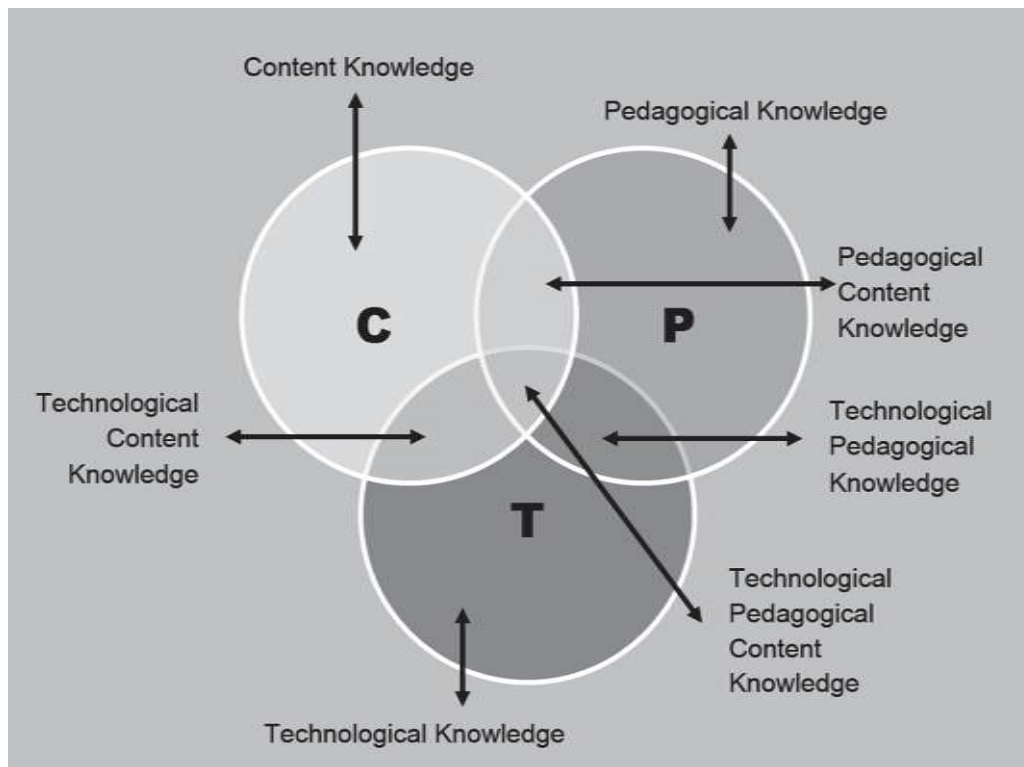


Figure 2. Technological pedagogical content knowledge and its knowledge components. (Koehler & Mishra, 2009).

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.

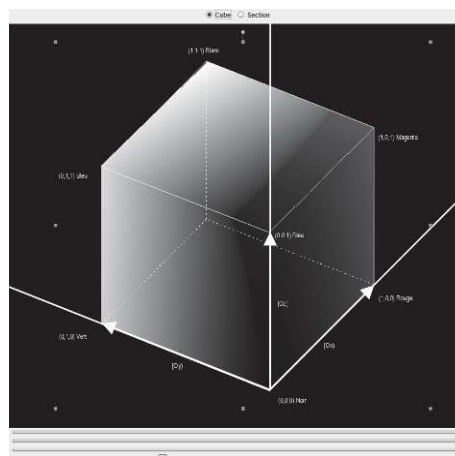


Figure 3. Chromatic cube.

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).

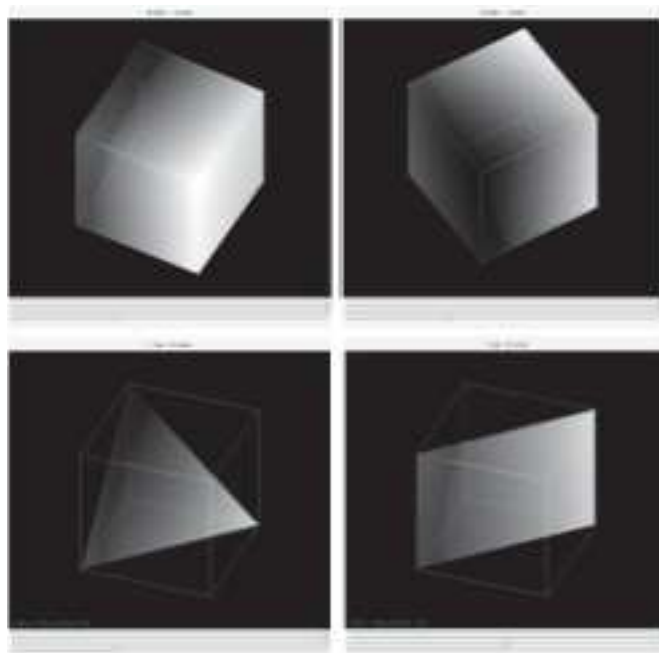


Figure 4. Different geometrical shapes.

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). Their 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**

	<b>File 1 Chromatic cube</b>	<b>File 2 Bézier curves</b>	<b>File 3 Black &amp; White Spreadsheet (pixels)</b>	<b>Didactical planning: complex interactions’ components and theoretical background</b>	<b>Teachers</b>	<b>Students</b>
CK	Millions of colours within a geometrical volume	Photos and layers with Bézier curves	Photos	<b>External resources at all the digital screens (theatres, TV, Pads, Smartphones, etc.) : ‘magical artefacts’</b>	Math & AA: Yes	Yes
PK	Analysis of space objects	Connection of two curves	Functions of reference Equations	<b>Planning of mathematics knowledge</b>	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, ...)	<b>Software to handle as representation &amp; communication instruments</b>	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	<b>Explanation of parts of the pictures we see on all the screens: ‘operative images’</b>	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	<b>Different and superimposed tasks to master the representations with mathematical tools</b>	Math & AA: Yes	No
TPK	Useful properties of parallel perspectives	Analysis of an architectural component	Discovery and handling of pictures’ grey scale	<b>Understanding of artefacts’ mechanisms (pictures, structures, drawings, etc.)</b>	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	<b>All the available digital tools to explore and to design the complicated reality and its representations: a new ‘drawing space’</b>	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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