Teaching Modelling Using Digital Design Tools

Experiences of Swedish Secondary School Technology Teachers

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Modelling using digital design tools is a relatively new element in secondary technology education, though modelling using concrete material is common and has been practiced regularly. Many technology teachers now teach modelling using digital design tools, to meet the new criteria in the syllabus concerning problem solving and documentation using digital technology. However, there is a lack of knowledge concerning how technology teachers teach modelling using digital design tools and how they choose content and present it to the pupils. It is known, though, that teachers' experiences affect how they plan the lessons. Therefore, the aim of this study is to investigate technology teachers' experiences to gain more understanding in this particular area of technology education. Taking a phenomenographic approach, twelve semi-structured interviews with secondary technology teachers were conducted. The results show that teachers have different experiences teaching modelling using digital design tools, and four categories have emerged: 1) Handling the software and using simple geometries, 2) Using ready-made objects from databases, 3) Manufacturing via 3D-printers, and 4) Design and problem solving. The results indicate that teachers teach modelling using digital design tools with different aims; the intended object of learning differs. The results also indicate that teachers experience that they lack knowledge of teaching modelling using digital design tools and therefore have difficulties teaching in this area, which can affect the pupils' problem-solving skills. The results, described in this article, can be used as a basis for further discussion.

Keywords: Modelling, Digital design tools, technology education, secondary education, CAD, Phenomenography,

Introduction

Secondary technology education takes different forms in different countries, and syllabuses differ as well. However, modelling is an important feature in several syllabuses (Ministry of New Zealand, 2017; Department of education and skills, 2017; Skolverket, 2011) both as a means and as an end. Today, modelling using digital design tools is introduced in technology education partly as a response to new criteria in syllabuses, related to digital competence, but there is a lack of knowledge of teaching in this area. It is known though, that teachers' experiences affect the object of learning (Marton & Tsui, 2004; Mishra & Koehler, 2006). It is also known that Swedish technology teachers are uncertain in their professional practice regarding how they should interpret the syllabus, that the use of digital tools in technology education differs between schools, and that technology education tends to consist of *unreflected doing* (Skolinspektionen, 2014; Skolinspektionen, 2019). Therefore, teachers' experiences of teaching modelling using digital design tools in secondary technology education needs to be investigated and clarified.

Aim and research question

The aim of this ongoing study is to investigate the experiences of secondary school technology teachers when it comes to teaching modelling using digital design tools. There is a lack of knowledge concerning to what extent teachers teach in this area, what the intended object of learning is, and how it can be

taught, and the present study can enhance knowledge in this area. From this aim, following research question was formulated:

> How do secondary school technology teachers experience teaching modelling using digital design tools?

The phenomenon investigated in this study is *teaching modelling using digital design tools in secondary technology education* and the results presented are categories of teachers' experiences of this phenomenon.

Literature review

Children, young people, and adults all need to use digital technologies creatively while designing and solving technical problems, as a part of digital competence. Digital competence is needed to adjust to contemporary society which is digitalized and connected (Carlsson, 2014). One way of teaching digital competence in technology education is to let pupils design and solve problems in digital environments. The pupils can for instance design models using a digital design tool.

A model is a description or a representation of something, something real or something not yet realized, for instance a mental idea (Gilbert, Boulter & Elmer, 2000). The model is not an exact replica of its original. It has simplifications and hold compromises, depending on the use and purpose of the model. The model represents some explicit physical and functional features, and in that sense, models are dualistic; both physical and functional (Nia & de Vries, 2016).

Pupils (and professional engineers) can use models when working with problem solving, and the process of creating a model is here called modelling. Since models have both a physical and a functional feature, pupils need to learn both when modelling. Technology education is both practical and theoretical, pupils learn *in* technology, to assess and examine technology, and *about* technology, to handle and develop technology (Svensson, 2011; Kilbrink, 2013). Pupils engage in a technical activity while developing knowledge of a specific object of learning. The practical activities also deepen other aspects of technology for the pupils; methods of technology and developments of products and artifacts (Bjurulf, 2011). As mentioned above, modelling using digital design tools is one example of this dualistic education and previous research points to the importance of interweaving theoretical and practical tasks in technology education (Kilbrink, 2013). A common digital design tool in secondary technology education is CAD, computer aided design, where three-dimensional objects are created. From now on, the process of creating a model using digital design tools is called digital modelling.

Learning to design in CAD requires different kinds of knowledge; knowledge that concerns handling the software, the commands and menus, what commands are available, and when to use them; and also knowledge of how to build your design, in what ways you can make solids and surfaces, and how easy it is to change and choose between different modelling strategies (Chester, 2007). A pupil about to solve a problem in CAD needs both types of knowledge described above. If one type of knowledge is underdeveloped, it will affect the pupils' ability to solve the task (Buckley, Seery, & Canty, 2018). Many pupils get stuck learning the commands of the software and they tend to use their cognitive ability to learn the software, instead of using their ability to find different solutions to the problem. This is problematic, since pupils develop their problem-solving skills poorly (Chester, 2007; Leisney & Brandt-Pomares, 2015).

Today, some schools also have access to a 3D-printer. The 3D-printer can print a physical object, digitally designed, in plastic. It can be helpful to use a physical model when teaching the iterative cycle of modelling and design processes (Novak &Wisdom, 2018). The iterative cycle moves between ideas, sketches, and functioning tests, but there is a lack of research of how 3D-printers are used in relation to

this process in technology education. However, Smith, Iversen & Hjort (2015) conducted a study where the results point to insufficient knowledge among both teachers and pupils concerning the design process. As a result, they avoid designing complex and more advanced objects in favor of more simple objects, like key tabs and name tags. Teachers experience problems with the transition from simple to complex models, and they have problems teaching procedural knowledge and encourage the pupils to explore and try things on their own (Smith et al., 2015).

Methodology

To meet the aim of this study, a phenomenographic approach (Marton, 1981; Marton & Booth, 1997) was found suitable for investigating how a group of teachers understand and teach a specific area where the content can be a mix of concepts, abilities and processes. Data was collected through twelve semi-structured interviews and the participants were chosen strategically to be representative of Swedish technology teachers in secondary education. In Sweden, about half of the in-service technology teachers lack formal teacher education for teaching the technology subject (Skolverket, 2019). Three of the interviewed teachers, have a teacher education, but lack diplomas of certification for teaching the technology subject. The interviewees, seven females and five males, have been in practice between 1 and 19 years. The interviews were digitally recorded and thereafter transcribed. The transcribed interviews were read several times to establish a holistic view and to find units of description without any preconceived perceptions. The units where then compared and contrasted against each other and an outcome space of categories was formed, based on the data.

Results

This section starts with a description of the outcome space and the four resulting categories. The categories are hierarchical and qualitatively different:

1) Handling the software and using simple geometries
2) Using ready-made objects from databases
3) Manufacturing via 3D-printers
4) Design and problem solving

Each category is presented with a general description of the teachers' purpose with their teaching. The presentation continues with a more detailed description occasionally followed by excerpts, the logical relations between the categories, and the hierarchical structure.

Handling the software

The aim of the teaching described in this category, according to the teachers' utterances, is to show the pupils that there are digital design tools that are used professionally by engineers and others.

The interviewed teachers explain that they introduce this area through digital modelling at a very basic level. They say that pupils need to acquire general digital competence, such as creating accounts and passwords for the software used, and they need to learn how to open and save files. Then, the teachers teach simple commands and functions of the software in question, the design tool that will be used to create the model. Sometimes the teacher shows what he or she is doing by connecting a projector to his or her computer in the classroom, and the pupils follow the teacher's instructions and copy what the teacher is doing. An alternative is to use Youtube tutorials, and let the pupils copy and emulate what the Youtube clip shows. The teachers explain that the digital models that pupils create using digital design tools are simple and have distinct geometric shapes. Jewellery or name tags are common objects for beginners. What is produced is not important, according to the interviewed teachers, since the object of learning is to learn how to handle the software. One teacher describes teaching as based on the idea that the pupils have to be allowed to ”play around” in the digital design tool.

> …they [the pupils] should see that you can sketch in a digital mode, and not just in a classical manner. […] That they [the pupils] have seen it. The purpose is that. So they can try it out. (Teacher 12)

> And in TinkerCAD [digital design tool], how you turn different objects around, so you get… this is a cone, but now it is turned upside down. It is still a cone. […] same thing but upside down. (Teacher 2)

When pupils create these simple objects, they use basic geometries from the software toolbar and combine them into their own simple objects.

Using simple geometries and ready-made models

In this category, besides the pupils' knowledge of the software, the interviewed teachers say that pupils can use ready-made objects collected from databases and libraries connected to the software. The aim of the teaching is to create an interest in digital modelling among the pupils.

According to the interviewed teachers, by fetching ready-made objects pupils get opportunities to work with inspiring objects, without so much knowledge of modelling using digital design tools. The pupils also get opportunities to see what is possible to create and design digitally. The interviewed teachers express that pupils discover the difficulties involved in making advanced objects on their own, but the teachers still want to show the pupils the possibilities of the digital design tool and that most object in fact are based on basic geometrical forms.

Manufacturing via 3D-printers

The experiences from category 1 and 2 are represented in and form a basis for this category. However, the teachers with experiences in this category also experience the 3D-printer as a way of showing the pupils a modern manufacturing method. The aim of teaching modelling using digital design tools is to expose the printed physical model as a means in the product development process, since 3D-printing is a fast way to produce a physical model. But the physical printed model can also be an end. In those cases, it is not necessarily the pupils themselves who have designed the objects. The pupils are allowed to fetch and print ready-made objects from digital libraries and databases as in category 2.

In the interviews, the teachers point out that it is important that the pupils understand the principles of how a 3D-printer works, that it fabricates objects one layer at a time and that it cannot start printing from surfaces that are not supported from below. They explain this through telling the pupils about props and supports and showing them printed models which have not been supported so that the thermoplastics, the filament, are suspended midair.

> I have explained [to the pupils] that it [the 3D-printer] cannot start printing in the air. If so, the threads will be hanging. (Teacher 3).

The pupils are not always given the opportunity to print their objects, since the focus is on the 3D-printing method itself. Printing the objects is time-consuming in a school context, and according to the interviewed teachers, problems tend to occur when pupils are allowed to use the printer by themselves, which is why this is usually not allowed. The object of learning, then, is simply to make the pupils understand the principles of creating printed objects.

According to the teachers, putting knowledge into practice is an important aspect of digital modelling, and a way to document the process. Documentation is also about letting the pupils create digital sketches of their objects which may then be used for construction in other subjects, such as crafts.

Design and problem solving

When pupils are designing and solving problems, the interviewed teachers express that category 1, 2, and 3 are represented, although to various extents. Teachers with experiences in this category explain that the aim of modelling using digital design tools is to allow the pupils to work with product

development and problem solving, and to inspire them to pursue a future career in technology. They also want to develop pupils' spatial skills and teach them to use software to design strategically. Teaching is often adapted to each individual, and the teachers experience that a great deal of the pupils' work is done on their own terms. The pupils are allowed to explore the software independently, and freely select an object to be designed.

The teachers taking part in the study say that they teach strategies of digital modelling, and how the pupils can effectively create digital objects that allow for adjustments and changes. The teachers explain that, in this type of teaching, the students have to learn more commands in the software, and they practice working with different planes and depths as well as various axes in a three-dimensional coordinate system. The interviewed teachers also point out that strategic design is challenging for the pupils and that the pupils find it difficult to understand how to create objects by removing surfaces and solids instead of building something. For instance, one teacher describes how pupils are given the task to design a house, and the teacher wants the pupils to start out from a cuboid and then cut out smaller cuboids to create rooms, windows, and doors.

> … and they will design a house, it is a completely different way of thinking. In Google SketchUp [digital design tool] you drag in a box or a cuboid. And that box, well there you remove the kitchen. To make a kitchen, you need to take off something. (Teacher 8)

The teachers also say that they themselves find it difficult to explain design strategies to the pupils. Yet another problem is to make the pupils understand that all the parts have to be linked to constitute a unit, for instance the letters that make up the text of a key tab. If the parts are not linked, a 3D-printer will not be able to print the object, even if it looks correct on the screen.

> There are so many steps when you model an object. So there cannot be a gap between the legs of the chair and the chair. Or the key tab, it happens often, the letters are wrong, they are nor attached to the tab. (Teacher 8)

Problem solving is experienced as a question of modelling an object in accordance with set goals and specifications. Will the object have the correct measurements (has the right scale been used?) and will the desired function be achieved (will the door in the room open the right way?)? These two aspects of design, the physical aspect and the functional aspect, are not distinguished when the teachers describe the pupils' efforts to model an object digitally.

In category 3 and 4, one purpose of the teaching is to let the pupils work with the iterative process of problem solving. Problem solving is not a linear process but moves back and forth between different stages. Modelling is one stage of this process, although modelling itself is iterative. The teaching, according to the interviewed teachers, focuses on pupils doing and redoing, changing, adjusting, and trying out different alternatives and options. While working with digital modelling, the pupils experience the iterative process of problem solving. When results are not as expected, pupils are encouraged to find solutions on their own or together with their peers. This is partially a result of the teachers' experiences of insufficient knowledge in the area of strategic digital modelling.

Discussion and conclusions

The results from this ongoing study provide knowledge about four different categories of experience, with different objectives and different content. The results show that technology teachers in secondary education experience teaching modelling using digital design tools in four qualitatively different ways. Teaching ranges from simple to more complex, and the object of learning ranges from pupils only learning how to handle the software to also comprising the product development process and strategic digital design. Teachers' pedagogical aims also differ between the four categories, from a more general wish to demonstrate a digital design tool, to a desire to inspire pupils to pursue a future career in

technology. In the more advanced category, design and problem solving, the pupils are also experienced as working to solve problems. A problem here is that many pupils get stuck trying to handle the software (Chester, 2007; Leisney & Brandt-Pomares, 2015). The teachers also experience that they themselves lack knowledge of strategic digital design (a similar result was presented by Smith et al., 2015), and consequently the pupils may not be able to proceed with their digital designs and solutions to problems.

The fact that teachers are uncertain about digital modelling results in simple tasks with little guidance, and pupils are given great freedom to select design and content. Teachers say that they feel relatively confident about handling the software and knowing what commands can be used, but less confident about constructing objects and how they can convey that knowledge to the pupils. The teachers report that they are not always able to explain to pupils how to think when designing, how to plan the construction of their object. Pupils sometimes have to be assistants in relation to each other and help their peers when the teacher does not have sufficient knowledge. This does not necessarily mean inferior learning for the pupils, or that it is undesirable for pupils to help each other – quite the opposite. There is research that indicates that learning may be enhanced when pupils collaborate (Wiliam, 2013).

3D-printing is experienced as supporting the pupils' potential to learn about product development and problem solving, but according to the interviewed teachers the pupils do not learn how to handle the actual printer. Instead they are given the opportunity through working with digital modelling and 3D-printing to understand the iterative cycle of the product development process. Digital modelling as it is experienced in categories three and four is an example of theoretical and practical knowledge being interwoven in teaching. The teachers also have distinct aims for their teaching in all four categories, and digital modelling can be seen as *reflected doing*. However, the four categories indicate that it is not clear what content this teaching has or should have in compulsory school and this can be further studied. Further, focusing on teachers' experiences gives no insight into the pupils' learning. This shortcoming can be elaborated upon in future studies.

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