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Learning specific content in technology education: learning study as a collaborative method in Swedish preschool class using hands-on material

Nina Kilbrink · Veronica Bjurulf · Ingela Blomberg · Anja Heidkamp · Ann-Christin Hollsten

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Abstract This article describes the process of a learning study conducted in technology education in a Swedish preschool class. The learning study method used in this study is a collaborative method, where researchers and teachers work together as a team concerning teaching and learning about a specific learning object. The object of learning in this study concerns strong constructions and framed structures. This article describes how this learning study was conducted and discusses reflections made during the process. Furthermore, we discuss how the learning study method could be implemented in technology education using hands-on material. Some of the results point to problems of delimiting an object of learning in technology education using hands-on material and the complexity in the relation between content and context in learning. The results also show benefits from the collaborative method where researchers and teachers work together with regards to specific learning content in the technology classroom.

Bjurulf is now employed by The Swedish National Agency for Education, Stockholm, but was at the time of data collection employed by Karlstad University.

N. Kilbrink (✉)
The Department of Educational Studies, Karlstad University, 651 88 Karlstad, Sweden
e-mail: nina.kilbrink@kau.se

N. Kilbrink · V. Bjurulf
The Department of Engineering and Physics, Karlstad University, Karlstad, Sweden
e-mail: veronica.bjurulf@kau.se

I. Blomberg · A. Heidkamp · A.-C. Hollsten
Älvstranden Bildningscentrum, 683 80 Hagfors, Sweden
e-mail: ingela.blomberg@skolor.hagfors.se

A. Heidkamp
e-mail: anja.heidkamp@hagfors.se

A.-C. Hollsten
e-mail: ann-christin.hollsten@skolor.hagfors.se

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Introduction

Previous research states that there is a need for research on how teachers teach and pupils learn different content in technology education (Bjurulf 2008; Jones et al. 2011; Ritz and Martin 2013; Sherman et al. 2010). Current research shows that a learning study is a vehicle to enhance pupils' learning in relation to different content (Lo 2009; Marton and Morris 2002; Marton and Tsui 2004). Furthermore, a new curriculum was implemented in Sweden during fall 2011, where technology, like other subjects, has long-term goals for the development of different abilities for the pupils to achieve during compulsory schooling (Skolverket 2011). In order to study teachers' teaching and pupils' learning in technology education, we therefore decided to conduct a learning study. The learning study method is a collaborative method, where teachers and researchers work together as a team (Björkholm 2013; Marton and Pang 2006). In this article, we write *the teacher-researcher team*, or just *the team* to refer to this group of teachers and researchers.

When conducting a learning study, the focus on pupils' learning is of central importance. How does the teaching facilitate, or prevent, the possibilities to learn? Through conducting the learning study, our intention was to (1) implement a learning goal in technology from the new syllabus implemented in Sweden during fall 2011; and (2) improve teaching and thereby enhancing the pupils' possibilities to learn a specific learning object. Moreover, both pupils' and teachers' knowledge, as well as the researchers' knowledge about the teaching, learning and understanding of the chosen learning object, were expected to improve during the learning process of working as a team in a learning study. A learning object can be divided into an indirect and a direct object of learning, where the indirect object of learning refers to a certain skill or ability and the direct object of learning refers to the learning content (Marton and Tsui 2004). The indirect object of learning we initially chose to focus on in this study was the ability to use strength in own constructions (bridges) and the direct object of learning was framed structure or truss structure as a strong construction design. The focus on these objects of learning was a result of reading the new steering document together as a team. Using hands-on material in relation to the learning object was also important to the team, since the teachers were used to working with hands-on materials in relation to technology education. Moreover, the chosen object of learning was a result of the teachers' earlier experiences of pupils' difficulties in building solid constructions in general, but also with the hands-on material *4Dframe* in particular. Therefore, the hands-on material we chose to focus on in this study was *4DFrame*, a teaching material that was invented in South Korea about 10 years ago (Hedkvist Manninen 2010). The material contains a variety of connectors and tubes, which are combined to make polygons, or other structures, and different kinds of models with moving parts, such as cars, airplanes, windmills and waterwheels (see for example Fig. 1).

In this article, we aim to describe and analyse experiences from a learning study, which was carried out in technology education in 2011, parallel with the implementation of the syllabus for technology education in Sweden, implemented in fall 2011. Teaching in Swedish preschool classes (6 year old pupils) follows the national curriculum, but the goals for the pupils to reach are not stated before class 1.

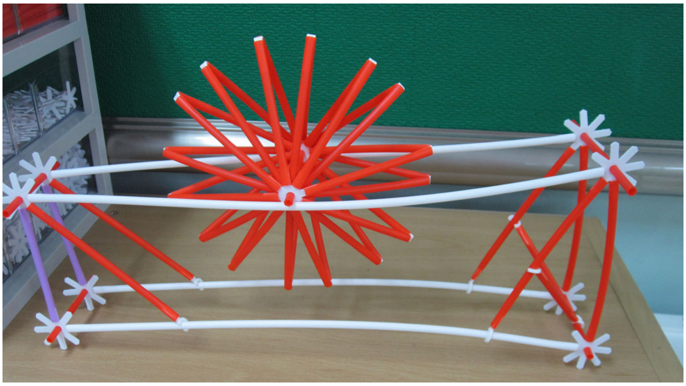

Fig. 1 *4DFrame* model

Learning studies

One overall purpose with the learning study approach is "to generate data that enable us to establish the relationship between teaching and learning" (Pang and Ling 2012), i.e. "to help teachers to help students learn the object of learning" (Ling and Marton 2012, p. 8). Lo (2009) gives an overview of the development of the learning study approach in Hong Kong from the late 1990s. The first learning studies were conducted in mathematics, Chinese language and English language, but cover most school subjects today at various levels of the school curriculum. Those learning studies show the significance of the specific classroom research model, which can be summarised as follows:

- The teacher learning takes place in their own practice, where the aim is to help the pupils to learn what is intended and "the learning study always takes the object of learning as the point of departure" (Lo, 2009 p. 177).
- Since the teachers work in close cooperation with researchers, and thereby work as researchers who generate knowledge about their own practice, "the theory–practice gap, which has led to the failure of many attempts to change classroom practice, disappears" (Lo, 2009 p. 177).

The learning studies have resulted in pupils' improved learning (Ling and Marton 2012). The learning studies have also contributed to the teachers' professional development and the learning of researchers (ibid.). Following the examples from Hong Kong, several learning studies in Sweden have focused on (the Swedish) language (Gustavsson 2008) and mathematics (Kullberg 2010; Runesson 1999; Wernberg 2009) in compulsory school, but also on biology (Vikström 2005) and technology education (Björkholm 2013) in compulsory school and on economics in higher education (Rovio-Johansson 1999). The results of these studies show similar results to Hong Kong, i.e. that the variation of the critical aspects plays a crucial part in whether the pupils learn what the teachers intended them to learn (Lo 2009; Marton and Morris 2002; Marton and Tsui 2004). The predominant studies concern mathematics and language, and thus the research overview points at the need to conduct more learning studies in other subjects, such as, for example, technology in Swedish compulsory school.

In the light of the results from the body of current learning studies, there is an assumption that teaching will improve and the pupils' possibilities to learn will thereby be enhanced when carrying a learning study through. Therefore, our intention in this article is not to examine if the teaching will be improved, but rather to examine in what way a learning study may be implemented in technology education, using hands-on material.

Technology education and hands-on

Technology as a school subject is often emphasised as being different from other subjects in its practical nature and is often associated with practical, problem solving, design and hands-on work (Bjurulf 2008; Kilbrink 2013; Lewis 2009; Middleton 2005; Sjöberg 2005). Middleton (2005) emphasises the possibility of working with meaningful tasks that have "a contingent relationship with the real world that is both inside and outside of the classroom" (2005, p 67). Furthermore, research on technology education emphasises context as important for technology education and technology education has a role in students' learning in solving real life problems (Bjurulf 2011; McCormick 2004; Middleton 2005). In line with how technology education often deals with practical, problem solving and hands-on work, we used a practical hands-on task for the pupils to solve in the learning study. Our study therefore differs from learning studies in other school subjects in the way we chose to use hands-on material in making a concrete construction as a part of the learning study.

The idea behind hands-on material in school is often based on a constructionist view of learning, and a focus on learning rather than teaching, and on how the learner actively constructs learning from experiences (Kafai and Resnick 1996; Papert 1995). However, pupils' learning is not always explicitly connected to the hands-on material. Kilbrink (2008) writes about pupils' experiences of learning objects when working with programmable robotics as hands-on material in school. The pupils' experiences in Kilbrink's study are that the lived learning object often concerns something other than the material itself, such as, for example, cooperation or other social aspects. She emphasises the importance of the conscious use of hands-on material in school if there is a specific goal in education. Therefore, the teacher has an important role in planning the education if the use of the material aims to contribute more than an entertaining variation in, for example, technology education.

The teachers in this study had used *4DFrame* in their teaching for about 2 years before this project started and have received training in the material and also been in charge providing of in-service training. All pupils had also been in contact with the material before the Learning Study. The chosen objects of learning was also a result of the teachers' earlier experiences of pupils' difficulties in building solid constructions in general, and with 4Dframe in particular.

Object of learning and variation theory

Pang and Ling (2012) emphasise two important elements in the learning study approach. The first is the distinct focus on the object of learning, and the second is variation theory as a tool in the learning study process. The focus on the object of learning means identifying what the pupils should learn and the critical aspects that they must discern in order to understand the intended object of learning. Variation theory (Marton and Tsui 2004) was used as a tool in the teacher–researcher collaboration in this study, when planning, conducting and analysing the research lessons. Therefore, we will briefly describe important elements from the variation theory here, which we used in the study.

According to variation theory the *critical features* of the learning object are important to focus on in teaching. Critical features refer to aspects of the learning object that are of importance in order to understand the object of learning (Bjurulf 2008; Marton and Tsui 2004). Marton and Tsui (2004) write that:

> The critical features have, at least in part, to be found empirically – for instance, through interviews with learners and through the analysis of what is happening in the classroom – and they also have to be found for every object of learning specifically, because the critical features are critical features of specific objects of learning. (p. 24)

Hence, the critical features could be different for each object of learning. They also vary between different groups of pupils (Bjurulf 2008). The critical features can be visualised in the learning situation by using different patterns of variation. Marton and Tsui (2004) mention four patterns of variation—contrast, generalisation, separation and fusion. *Contrast* means that in order to learn what something is, it must be contrasted to what it is not—for example, a triangle is not a square. *Generalisation* stands for clarifying different kinds, or varying appearances of the thing intended to be learned—there are for example different kinds of triangles. *Separation* is about lifting one critical feature at a time, and *fusion* is about lifting all critical features for an object of learning at the same time. The learner needs to be able to experience the variations simultaneously in order to discern the critical features.

The learning object has two aspects: the specific and the general aspect. Marton and Tsui (2004) also distinguish between three different learning objects—the *intended*, the *enacted* and the *lived* object of learning. The intended object of learning is about what the teachers are aiming for the pupils to learn during a learning situation, i.e. what is *supposed* to be learned. However, in the learning situation, it is not always possible to learn what is supposed to be learned, because it is not made visible in the learning situation. Therefore, what the students encounter in the learning situation is the enacted object of learning, which deals with what is *possible* to learn about the learning object, during the learning situation. The third object of learning—the lived object of learning—is about what is actually learned, the learning outcome. In learning situations, these three learning objects can differ, because of different experiences and expectations. However, one aim of a learning study is that the intended, the enacted and the lived object of learning close in on each other, and the students' actual learning outcomes become closer to what the teacher had planned for. The learning study approach follows the steps typical of an action research process, but always with a specific focus on "How can the object of learning 'X' be taught so that students can see 'X' in the way intended?" (Pang and Ling 2012, p. 593). The different steps we have conducted are as follows:

- defining the learning object
- finding out the pupils' experiences of the learning object
- designing the research lesson(s) of the learning object
- teaching the research lesson(s)
- evaluating the research lesson(s) and identifying the pupils' learning problems
- adjusting the research lesson(s) based on the results (compare e g Marton and Ling 2007).

These steps, i.e. the learning study cycle, may be repeated in as many groups of pupils as necessary in order for the teachers to find out the necessary conditions for the pupils' discernment of the critical features of the learning object.

Previous research has also discussed how to delimit learning objects and how it can be problematic in different areas and in relation to different kinds of learning objects (Dahlin 2007; Mossberg Schüllerqvist and Olin-Scheller 2011; van Bommel 2012). Dahlin writes that different subjects could have different hidden curricula, which can influence how an object of learning can be delimited, without losing important aspects of the subject thought:

> /…/if the learning object focused on is too narrowly delimited; that is, if the researchers do not consider the possible presence of a hidden curriculum of the subject taught. The notion of finding and transmitting the most ''powerful'' way of understanding a particular learning object may then actually lose some of its substance. What is powerful is, after all, relative to context and purpose. (Dahlin 2007, p. 343)

Therefore, we aimed to keep what was important to the team, in relation to technology education at school, and therefore chose to relate to the nature of technology education, as practical, problem solving and hands-on. Since context is emphasised in relation to technology education, we also discussed learning as a result of interplay between human and world, which is emphasised in the phenomenology of the life-world theory (Bengtsson 2005; Heidegger 1927/2004; Merleau-Ponty 1962/2002). Therefore, the variation theory as learning theory is complemented with a life-world perspective in this study (compare Bjurulf 2008; Kilbrink 2013).

Mossberg Schüllerqvist and Olin-Scheller (2011) write that earlier learning studies often focused on mathematics, but when applied to the area of reading and understanding fiction, there were other conditions. For instance, there was a need to distinguish between more aspects of the learning object than were made by Marton and Tsui (2004). Mossberg Shüllerqvist and Ohlin-Scheller write for example that one way to handle their area is to consider the reading and understanding of fiction as a superior learning goal, but in teaching, teachers and pupils need to deconstruct this learning goal into smaller units or aspects, such as reading strategies, understanding different concepts or being able to relate to the time when the fiction was supposed to take place.

Leaning study in preschool class technology education

The learning study reported here was conducted in three cycles, from October 2011 to February 2012. Different pupils from the preschool class participated in the different cycles. Each cycle lasted between about 2 and 4 weeks for the different groups of pupils, but there was also an ongoing discussion between teachers and researchers during the entire process. The same teacher taught all three research lessons, since she was the only one used to teaching at the preschool class level in the team. Data for this study was collected through audio- and video-taped research lessons as well as pre- and post-tests. The pre- and post-test involved the pupils building models of bridges of the hands-on material *4DFrame*, sitting together in a classroom. The construction task was followed by individual interviews in the pre- and post-test, where the pupils were able to elaborate their thoughts behind the constructions they made and discuss different technology concepts, relating to strength, solidness, different shapes and framed structures. The empirical material collected in the project also consists of photos of the constructions the pupils made, documents from the planning of the teaching made by the teacher group, and audio recorded discussions between teachers and researchers concerning the learning study cycles. All parents of the pupils in the study were informed about the project, and the parents of all the participating children gave their written consent to participation. The research ethics defined by the Swedish Research Council were followed in the project (Vetenskapsrådet 2002) and no names of the pupils will be revealed in the report from the learning studies and no children's faces were visible in the pictures reported in research publications.

In this article, we do not aim to analyse each lesson or to describe the critical features of the learning objects as such, which is one important aim when carrying out a learning study. In this article, the focus is rather on describing the working process in the learning study, when implementing it in a team of researchers and teachers in technology education using hands-on material, illustrated with examples from the empirical material. The first cycle of the learning study is described in more detail, in order to show the different steps in the method. This first cycle included seven pupils.

In the team, the teachers had the role of planning and conducting the learning studies using variation theory and the researchers had the role of collaborating and supervising this process. In the first two cycles in the preschool class, the researchers carried out the interviews that, together with the construction task, constituted the pre- and post-test, but thereafter the teachers themselves videotaped and carried out the interviews, as well as videotaped the lesson.

In the following sections, we briefly describe how the learning study was conducted, and the analysis made in the teacher–researcher team during and after the learning study process. The first cycle is presented in more detail, and thereafter we focus on describing the major changes made between the different cycles. Thereafter, we discuss the whole process, how a learning study can be conducted in the technology classroom using hands-on material and what potentials and problems can be seen in this study.

The first cycle of the learning study in the preschool class

The learning study followed the different steps described above and the following section describes the realisation of the first learning study cycle in the preschool class. The indirect object of learning in this study was the ability to use strength in own constructions (bridges) and the indirect object of learning was framed (truss) structures. Since the students work a lot with fairy-tales in the preschool class, it was decided to frame the learning object within the old folk tale about The Three Billy Goats Gruff.[1] The pre-test involved the pupils individually building a bridge of *4DFrame* for the goats and to try the strength by hanging a weight on the bridge (see Fig. 3) as well as to participate in an interview. Before the pre-test, the teacher read the story about The Three Billy Goats Gruff to the pupils and ended the story when the goats had walked over a bridge to graze on a meadow with green grass. She showed the children small toy goats (see Fig. 2).

The teacher also told the pupils that there had been an accident, the bridge that the three goats had to walk over to come back to their home had broken, and invited the pupils to help the goats by, individually, building a bridge made of the 4Dframe material. The pupils were not told to use any specific design methods, i.e. a framed structure, in their constructions, but could use the material however they wished. Furthermore, the pupils were not taught about framed structures before the pre-test. The information the pupils got for the pre-test was solely to build a bridge that was solid for the goats to walk on, without breaking the bridge.

[1] We used a Swedish version of this folk tale printed in a book by Adolfsson and Friberger (2008).

Fig. 2 The toy goats, the weight and the story book

When all pupils had finished their bridges, individual interviews about their constructions were conducted. These interviews aimed at revealing pupils' conceptions about the chosen learning object. Consequently, in the pre-test we asked the pupils questions about their use of geometrical objects and if they knew what a framed structure is and they tested the solidity of the bridge with a weight (see Fig. 3).

In the pre-test, some of the pupils got ideas for their bridges by comparing to other bridges, for example by "*watching a bridge through the window*" from the class room, by watching how the other pupils built their bridges or by thinking of "*a small bridge at home, that dad has built*". When comparing to real bridges, the pupils referred to what was visible, and not to how the bridges were constructed to be stable. Some pupils were also concerned about appearance, for example, which colour, or focused on the goats, i.e. building a roof for them not to get wet if it was raining, or making constructions where the goats would not fall down in between the tubes in the building material. When analysing the interviews, we found that the pupils had difficulties in discerning the geometrical objects as crucial for strength. Therefore, the difference between a triangle and a quadrilateral was chosen as a critical feature to focus on in the research lesson, which was taught 3 weeks after the pre-test.

During the research lesson, the teacher built a framed structure (triangle) and a square of 4DFrame. She also contrasted the strength of the two geometrical objects in two different ways, by:

1. moving the tubes back and forth—the tubes at the framed structure hardly moved, but the tubes in the square did
2. hanging a weight that showed that the framed structure did not change shape, whereas the square did.

The teacher encouraged the pupils to stand on the floor with their legs wide open. Thereby a framed structure was formed of the legs and the floor, and the arms at their hips created two more framed structures:

> *Let us pretend that the wind blows.* (They blow with their mouths.) *And now you try to keep your balance and that is working great when you are standing like this.*

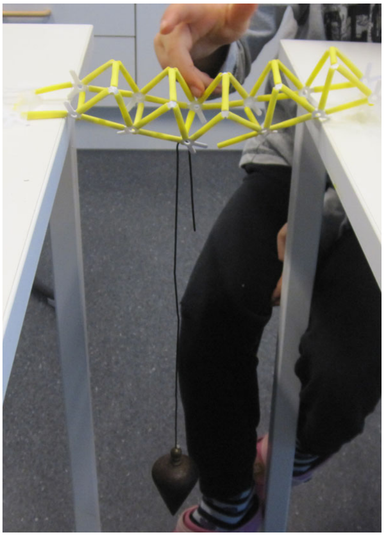

Fig. 3 The solidity of the bridges was tested by a weight

Maybe we are in a boat, and the boat is rolling back and forth, but we are able to keep the balance.

Thereafter, the teacher contrasted the framed structure with a linear form. She did this by asking the pupils to put their legs together:

If we are standing like this (she put her legs together) *and letting the arms hang downward, and then the wind blows and the boat is rolling.* (The teacher and the pupils tipped over, some of the pupils even fell on the floor.)

Directly after the research lesson, the pupils were asked to build a new bridge followed by an interview. One of the pupils was absent at this occasion, so there were six pupils. When looking at the bridges it was obvious that the pupils made variants of their first bridges (see Fig. 4), rather than applying the experiences from the research lesson about framed structure. Notwithstanding, their first bridges were not simultaneously available until they had finished their second one.

In the interviews, the pupils explained their thoughts about their second bridge as follows:

I built such a bridge last time too, I built in a similar way. (Pupil 2, P2)
I wanted to build like last time. (P4)

Those excerpts show that the pupils had their first bridge in mind, when they built the second one. There were also examples of ad hoc constructions, as the following excerpts show:

I just took some connecters. (P3)
I don't know why it became as it did. (P5)

One of the pupils said that I just thought, "*I wanted to build like this*" (P1) and another one explained that the new bridge had sides and a roof, since "*it* [the bridge] *becomes more solid because of the side and the roof*" (P6). P6 also associates size to stability. The pupil compares his construction to big and small sticks and says "*If you have a stick like this*

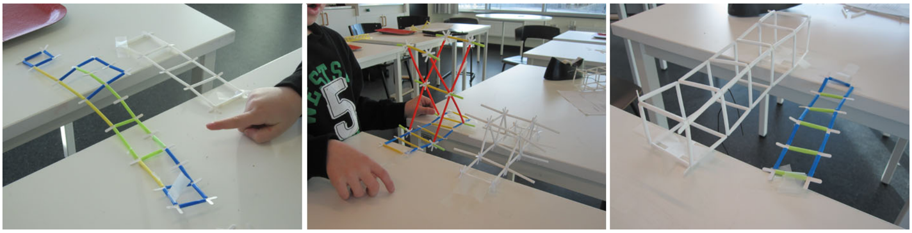

Fig. 4 Colored bridges from pre-test and white bridges from the post-test

[small one]*, then the stick breaks and that's small. This* [bridge] *is not small*". P6 also tells that triangles are smaller than squares, and since he has drawn the conclusion that he needs to build a big bridge in order to make it stable, he also chose to use squares rather than triangles.

When analysing the research lesson and the post-test, we noticed that the way in which the pupils had connected the *4DFrame* material was often more important in the test than what geometrical objects they had used. Sometimes an expected stable construction broke, because they had not put the pieces together properly. In the post-test, we saw that the pupils related more to how they had built the first bridges (the pre-test), rather than what had happened in the research lesson. In the interviews, there were also examples where pupils drew parallels to other bridges or phenomena they knew about. These parallels did not obviously improve their understanding of the learning object.

We also noticed that the teacher avoided frequently using the words "framed structure" and other important terms during the lesson, because she was "afraid" of influencing the results in the post-test, but this made it difficult for the pupils to make the connection between what was supposed to be learned during the lesson and what was tested in the post-test.

Changes made for the second cycle

With the point of departure being the experiences from the first cycle of the learning study, some changes were made in carrying through the second cycle. The group of pupils participating in this second cycle consisted of 8 pupils from the preschool class.

In the teacher–researcher team discussions concerning the second cycle, there was confusion about what the lived object of learning became in the first cycle and how to handle the object of learning in the second cycle. The team discussed whether there was a need to focus on connecting tubes and connectors in the learning object, and leave the learning object we initially aimed for—framed structures—for a future study, or if it was possible to include the connecting of the tubes and connectors into the learning object without making it too wide and complicated to analyse. The team decided to include it in the second cycle. The team decided to adjust the learning object in the second cycle to concern *compounding for strength* and the direct object of learning was *simple strong constructions*.

The team tried to eliminate the problem the pupils had connecting the material, so that the pupils could focus on the learning object. Therefore, the pupils were more clearly informed about how we were going to test their bridges with a weight and that to hold the weight it was really important to connect the pieces together.

In the pre-test, we changed some of the interview questions from the first cycle, to include how to build stable constructions with 4Dframe. We also asked about how the different connectors and tubes could influence the solidness of the constructions. In the interviews in the pre-test of the second cycle, similar to the first cycle, some pupils focused on appearance in their constructions, like colours of the tubes and different patterns, rather than on how they shaped their constructions. As with the first lesson, we chose to focus on the difference between a triangle and a quadrilateral in the research lesson, but also to emphasise the importance of connecting the material properly.

Another change that was made for the second cycle was that the *use of terms* concerning the learning object, like *compounding* and *stability*, was clearly made by the teacher in the lesson. Examples of stable and unstable bridges were also shown in the lesson, in order to contrast stable and unstable constructions. She showed bridges that other pupils had built previously, and told if they broke or not when testing them. Furthermore, weak points were highlighted. This resulted in one of the pupils in this cycle trying to build a similar bridge in the post-test, similar to one of the bridges shown as a stable bridge in the research lesson.

In the post-test in the second cycle, some pupils said that strength is about putting pieces together properly and one pupil told about the triangle as a solid construction. As with the pre-test, there was still a focus on how the bridges looked, but some pupils actually used triangles in their constructions after the second research lesson, in order to make their constructions solid. Hence, in the second cycle there were slightly more improvements made concerning the pupils' understanding of the learning object between the pre- and post-test, compared to the first cycle of the learning study.

Changes made for the third cycle

Initially, we had planned for two learning study cycles in the preschool class, since the time it took to carry out those cycles corresponded to what time was available to the team to work with this learning study. However, the experiences from the previous two cycles made the teacher in the preschool class want to try a third cycle. The teacher in the preschool class conducted and filmed this cycle on her own, but in discussion with the rest of the team. In this cycle, 5 new pupils from the preschool class participated.

The framed structure as the direct object of learning was reintroduced, but in connection to compounding and stability. The preparation for the research lesson with the pupils was changed. The pupils were given much clearer and concise instructions, there was less emphasis on the fairy-tale of the Three Billy Goats Gruff in the third lesson and the teacher did not bring any small toy goats. This was made in order to put focus on the object of learning and what the teacher said during the lesson, rather than seeing if the toy goats could walk on the bridge without falling down. Instead of the focus on the fairy-tale, the teacher showed pictures of bridges with framed structures visible. The teacher had prepared different shapes built by the *4DFrame* material and during the lesson the pupils could touch and feel the shapes and see which were the most stable. The teacher and pupils built framed structures together during the research lesson. Together, they also watched a bridge that they could see through the window. Thereby the pupils had both the possibility to compare (contrast) different shapes and see different kinds of framed structures in different constructions (generalisation). In the last group, there were some pupils who did not have Swedish as their mother tongue, which made it important for the teacher to focus more on using the body by touching and feeling and also visualising the learning object.

The teacher felt more secure in the role of teaching in the third cycle and was more comfortable in the learning study method, being video recorded and discussing the learning content, than she was in the first two lessons. She was also very clear that the pupils were supposed to use framed structure in a bridge for the Billy Goats Gruff in the post-test. This instruction was not given as clearly in the two previous cycles, because the team was afraid of influencing the post-test too much. In the previous test, the pupils did not connect the content from the lesson to their own constructions, so this instruction was important for the pupils.

In this third cycle, almost every pupil used triangles in their bridges in the post-test, and the bridges were more stable in the post-test than in the pre-test. The teacher helped the pupils to connect or to see that the pupils had connected the tubes and connectors in the *4DFrame* material properly, so that this problem was eliminated when the bridges were tested. Nevertheless, some pupils still focused on how to connect the material, rather than focussing on the shapes used in their constructions to establish if their construction was stable or not.

There were still many questions after the second cycle and after conducting this study, the team felt that three cycles were necessary in order to learn the learning study method, but also to narrow down the learning object and to focus on this in the research lesson. In the third cycle, most of the pupils actually used framed structures (triangles) in their constructions of bridges. Instead of teaching the specific object of learning in a complex context, the team concluded that the research lesson needed to be a part of a larger teaching block, where the learning object is a part of wholeness. However, in the specific research lesson, the critical features of the learning object appeared more clearly when it was stripped from context that confused the pupils.

Discussion

Since this research was conducted as a collaborative project between teachers and researchers in teaching a specific content in technology education using hands-on material in a learning study, there are results concerning both the learning content and the learning study method in this context. The discussion is divided into four sections, concerning different themes of importance in relation to conducting a learning study in technology education using hands-on material. The four themes are:

- The learning content and context
- The definition of a learning object
- The use of hands-on material
- The collaborative method

The learning content and context in technology education

The learning content was highlighted in this learning study in technology education. Since context is often emphasised in technology education (Bjurulf 2011; McCormick 2004; Middleton 2005), the team also aimed at putting the object of learning into a meaningful context for the pupils in teaching in this study. However, there was a change in the way we related the content to context.

Some researchers argue that what is learned in one context cannot be transferred to another (Hagberg and Hultén 2005; McCormick 2004), but there are also reports on how pupils can connect what they do with hands-on material to other areas or how pupils relate their technology learning from one area to another (Kilbrink 2008, 2013). In Kilbrink

(2008), pupils working with hands-on material in compulsory school could relate their learning with the lego-robotics to other contexts, but this is not to be taken for granted, and could be facilitated by help from the teachers. In the first cycle of the first learning study in the preschool class, there were examples in the interviews where pupils drew parallels to other bridges or phenomena they knew about when talking about their own constructions of bridges. This is similar to results presented in Kilbrink (2008). However, these parallels did not obviously improve the understanding of the learning object in this study. One pupil, for example, associated size to stability because of previous experiences of sticks, and chose to use squares rather than triangles, because squares are bigger than triangles. Haglund and Jeppsson (2012) write that there is a risk that when pupils use self-generated analogies in science education, these analogies can mislead the pupils in their understanding, which is obviously the case in the example mentioned here. Another pupil in the first cycle of the learning study in the preschool class compared her construction to her experiences of a bridge she knew from home, focusing on how it looked and not how it was constructed to be stable. Relating to pupils' experiences from outside school in technology teaching is suggested by Kilbrink (2013), but Kilbrink also emphasises the importance of discussing those experiences in the classroom, in order to learn from them. This would likely have been helpful for those pupils in this study too, in order to understand the object of learning.

In technology education, common learning contents are *problem solving* and *design* (Lewis 2009; Middleton 2005). In our study, we did not focus on problem solving or design as objects of learning, but we used a task where the pupils were supposed to design a construction to solve a problem. Therefore, there are some results that relate to Hope's (2007) study of children making design tasks. Hope writes that teachers' thinking styles can be different from children's. In our first cycle of the learning study with the preschool pupils, where the pupils were supposed to build a *stable* bridge for the Three Billy Goats Gruff, using the *4DFrame* material, some of the pupils were so focused on building a bridge, where the toy goats could actually walk without falling in between the building tubes, or getting wet if it was raining, that they left out the actual task *to build a stable bridge*. Our conclusion was that our attempt to create a whole context, with a story where a stable bridge was needed, made the children make different associations than what we had expected, or wanted them to do. Our problem in this example could be similar to the one Hope describes in her study, where the "problem for the younger children in my sample was that I was unwittingly playing with the grey area between fantasy and reality" (Hope 2007, p. 39). Some of the pupils did not really know when to stop pretending. They therefore did not use any of the information about shapes for stable constructions that were given in the lesson, but focused on building bridges without holes in them.

Furthermore, the pupils in this study had problems discerning the object of learning from the context. They also did not connect the research lesson to their own construction tasks in the post-tests, in the first cycles. The teachers tried to eliminate this problem by being very explicit about the connection and helping the children making this connection—more and more for every cycle conducted in the learning study.

The definition of a learning object

One important task when conducting a learning study is to define a learning object to focus on. During the process, we noticed that we had problems defining a realistic learning object in the technology classroom. Since context often is emphasised in technology education (Bjurulf 2011; McCormick 2004; Middleton 2005), the team aimed at putting the object of learning into a meaningful context for the pupils in this study, by initially framing it with a fairy-tale and thereby relating to their experiences and how they were used to working in the preschool class. Previous research emphasised the importance of a meaningful context, however, our study indicates that a specific object of learning can disappear for the pupils in a complex context. We discussed in the team whether it would be possible to choose a specific learning object for more specific focus in lessons as a part of larger teaching blocks, where the wholeness and the meaningfulness can be kept in the larger teaching block. Aspects that can be problematic for the pupils to understand could be chosen for those lessons, and other parts could keep the closeness to context and reality. This is something that could be examined in further studies on how to implement learning studies into technology education.

The team also aimed for teaching in line with how they were used to working with technology education at school and included hands-on material in the learning study. The use of hands-on material in order to learn something other than handling the material complicated the process of defining the learning object. In the second cycle of the learning study, we even changed the learning object to concern the material. Nevertheless, our aim was not to learn about the material, but to use the hands-on material to learn about framed structures as solid constructions, in line with how the teachers were used to working with hands-on material in technology education. Therefore, we changed the learning object back to concern framed structure after the second cycle, but tried to eliminate the problems the pupils had connecting the material, by helping them. Thereby, the focus could be moved from the problems the pupils had connecting the material to the actual learning object.

As mentioned above, previous research has discussed how to delimit learning objects and how it can be problematic in different areas and in relation to different kinds of learning objects (Dahlin 2007; Mossberg Schüllerqvist and Olin-Scheller 2011; van Bommel 2012). Mossberg Schüllerqvist and Olin-Scheller (2011) write, for example, that one way to handle the area of reading fiction is to consider the reading and understanding of fiction as a superior learning goal, but in teaching teachers and pupils, there is a need to deconstruct this learning goal into smaller units or aspects. Similarly, in our study on technology education, a superior learning goal could have been *constructions and understanding of strong constructions*, which could have been divided into different smaller units. The units could, for example, be about learning to handle the construction material, to discern a solid construction, to recognise different shapes and to use framed structure as a solid construction.

In our study, it was also complicated to define the critical features of the learning object—framed structure—since a lot of problems that appeared in the pre-tests concerned other learning objects that obstructed the view of the intended object of learning. If we had used a less delimited learning object or a superior goal (Dahlin 2007; Mossberg Schüllerqvist and Olin-Scheller 2011), such as strength, those features would all have been relevant and easier to relate to a context in technology education.

In this study, our learning object was too complicated for the preschool children to grasp, when the learning was situated in a context. This was compounded by the fact that the planning of the learning study was made by a team where the participants had a lot of combined experience in teaching in different ways, but nevertheless had problems identifying a well-defined learning object for the study. This way of working is apparently a new way of thinking about teaching and learning in technology education. Furthermore, the teaching in Swedish preschool classes follows the national curriculum, but the aims for the pupils to reach are not stated before class 1. This means that neither the teacher nor the pupils in the preschool class in this study were used to teaching or being taught in a goal-oriented way as in this learning study, which may have influenced the results and the problem of defining and focusing on a specific learning object in this study.

The use of hands-on material

One aim in this study was to examine in what way a learning study might be implemented in technology education, *using hands-on material*. In our learning study, the intended object of learning was not the use of the hands-on material itself; rather, the material was used in order to help the students understand something else: the framed structure. However, the handling of the material often became the object of learning. Important knowledge obtained in this study is thereby that the hands-on material added a dimension that prevented the understanding of framed structure. In addition, the results from the post-test of the first cycle depended on the ways the pupils had connected the building material, rather than on what shapes they used. Therefore, we saw that it was not possible for them to reach an understanding of the intended object of learning before they could handle the material. Thus, the handling of the hands-on material obstructed the view of the learning object for the pupils. In Kilbrink (2008), pupils' experiences were that the lived learning object often concerned something other than the material, for example, the working method, cooperation or other social aspects. In contrast to Kilbrink's study, the material became the object of learning in this study. Still, a similarity between the two studies is that there is a vague focus on learning objects related to technology education that can be learned *by using* hands-on material.

As mentioned above, the idea behind the use of hands-on materials at school is often a constructionist view of learning, and a focus on learning rather than teaching, and on how the learner actively constructs learning from experiences (Kafai and Resnick 1996; Papert 1995). The results from this study imply that if there is a specific learning object for the students to learn, this process must be supported by the teacher and focus cannot be put solely on either teaching or learning, but on both teaching and learning in a learning situation.

The unsupported building task in the pre-test was problematic in our study. As mentioned above, it was obvious that the pupils preferred to make variants of their first bridges, rather than apply the experiences from the research lesson about framed structure to the post-test in the first cycle. This occurred in spite of the fact that their first bridges were not simultaneously available until they had finished their second one. Maybe the knowledge from the pre-test became embodied (Merleau-Ponty 1962/2002) when the pupils were working with the hands-on material, and the lesson did not focus on letting the pupils using their bodies in learning in the same way as the tests were arranged. Therefore, another finding from the first cycle in the first learning study was that the practical oriented task obstructed the view of the specific learning object. In the following learning study cycles, we tried to handle this problem by being more specific about the object of learning in teaching. The practical experiences in the pre-test would have needed to be complemented with knowledge about the practical experience (compare Kilbrink 2013). However, the team was afraid of "destroying" the tests in the learning study method in the first cycle, if too obviously relating to them in the research lesson, which made it too complicated for the pupils to connect the content from the lesson to the tests. Hence, one of our most important findings was that the pupils did not make this connection between the tests (building tasks and interviews) and the research lesson (focusing on the object of learning), without help from the teacher.

Reflections made in the team after the three cycles in the preschool class was that it was very complex to delimit an object of learning in relation to practical hands-on work, since this work includes many different aspects. Furthermore, clear instructions and a level of confidence in handling the construction material was of importance, in order to be able to use the material for learning about something other than the material itself, such as strength and framed structures. A third reflection was that other different hands-on material could have been used, in order to use generalisation as pattern of variation more clearly. Then the pupils could have built solid constructions of different hands-on material and compared them. This could be a way of showing different kinds of framed structures, using the generalisation as pattern of variation (Marton and Tsui 2004). We would therefore have been able to move the focus from the *4DFrame* material to the types of constructions and shapes used in the construction. However, a risk is that the building material itself becomes the critical feature and not the shapes used in the construction. For example, the pupils could compare which hands-on material is most solid, and not which kinds of constructions. This can be further examined in future studies.

The collaborative method

The collaborative learning study method was a new way of working for all project participants. The structured process and the use of variation theory was a helpful tool in our working process. The team got more and more secure in their collaboration and watching each other teach during the learning study process. The teacher teaching in the preschool class also mentioned in the group discussion that she became more secure in her own role as a teacher during the process, which shows that the learning study process was a way of working that was enriching for the participants in their professions. The analyses of the data material and the discussions we had in the team have contributed to a great extent when it comes to examining our own teaching. The pupils' results in the post-test in the first learning study cycle showed that there were no obvious connections between the lesson and the building task for the pupils. However, this evolved during the learning study cycles in this study, which supports the idea of repeating the learning study cycle as a way of "helping teachers to help students learn the object of learning" (Ling and Marton 2012, p. 8).

In this learning study, we succeeded in improving the results concerning the framed structures during the learning study cycles, but we ended up giving the pupils the answers very directly. This might be useful in relation to topics that are problematic for the pupils to grasp, while complicated aspects can be clearly lifted forward in a systematic way. However, the team discussed that in relation to technology learning in general, it is important to keep some relation to context, in order to make learning meaningful for the pupils and to keep the holistic nature of technology (compare Kilbrink 2013; McCormick 2004; Middleton 2005).

The view of learning used in this study, where critical features of an object of learning are studied (variation theory) and where the focus is on pupils' experiences of being in the world (phenomenology of the life-world) made us choose to do interviews in the pre-and post-tests. In the interviews, we had the possibility to explore the pupils' experiences further, more than would have been possible in a written test where pupils' knowledge of the object of learning would have been tested more with focus on single facts. As mentioned above, some children focused on building a bridge without holes in it, so that the goats could balance without falling down to the holes in their bridge models. Without interviewing the children when testing their bridges in the pre- and post-tests, we would not have obtained this information. We could have simply interpreted it as the pupils not learning about framed structures and solidness from the lesson, rather than understanding that, from their point of view, it really was a thought-out solution. In relation to conducting a learning study in technology, the interview is needed to complement the construction task as pre- and post-test, as it allows the pupils to explain their models.

In the first cycles, we also noticed that the teacher was “afraid” of frequently using the words “framed structure” and other important terms during the lesson, in order to influence the results in the post-test, but this made it impossible for the pupils to make the connection between what was supposed to be learned during the lesson and what was tested in the post-test. More and more we realised that it is not possible to be too clear about the learning object, which was visible in the teachers’ planning for the final lesson in this study, where they emphasised the importance of being overly explicit about framed structures.

In this study, there were also many different learning objects for the team to learn during the process of conducting a learning study, including working with a well-defined learning content, delimiting the object of learning, using a learning theory in practice, working with a new syllabus and more, which made this study a learning process on many levels. Not only was the pupils’ learning studied, the learning process in teaching and doing research in cooperation between teachers and researchers was also constantly reflected upon.

Conclusion

In this article, the process of working in a learning study with hands-on material in a preschool class in technology education has been presented. Earlier research shows that learning studies have resulted in pupils’ improved learning, contributed to the teachers’ professional development and the learning of researchers (Ling and Marton 2012). In this study, we saw similar results, but focused in this study on problematising the process of conducting learning studies in technology education using a hands-on material. The results from this study show that this process relates to many different areas, which can be summarised as relating to the *learning content and context, definition of a learning object*, *use of hands-on material* and the *collaborative method.*

The relation between the *learning content and context* in technology education is double according to the results in this study. The context emphasised in earlier studies on technology education can prevent the pupils from seeing important aspects of the learning content. Furthermore, our study also indicates that the unsupported practical-oriented task obstructs the view of a specific learning object, since the pupils made variants of their first bridges, rather than applying the experiences from the research lesson about framed structure in the first learning study cycle. In the following learning study cycles, the support from the teachers was clearer, and then the specific learning object also became more apparent. Moreover, *the definition of a learning object* in technology education using hands-on material could be problematic. When something very special, a specific learning object, is supposed to be learned, this should be made with a clear focus without a lot of context to relate to, according to the results from this study. However, it is important to keep some relation to context, in order to make learning meaningful for the pupils and to keep the holistic nature of technology. Aspects that are problematic for the pupils to grasp could be chosen for specific lessons, but thereafter, the teachers have the important role of connecting the specific learning to a realistic context for the pupils. The teacher also seems to have an important role when the learning goal is very specific, in order to clarify critical features of the learning object. In relation to *the use of a hands-on material* when learning a specific content in technology education, the pupils first need to learn to handle the hands-on material itself. According to the results in this study, the handling of the hands-on material will otherwise obstruct the view of the learning object.

In this study, both pupils' and teachers' knowledge as well as the researchers knowledge about teaching, learning and understanding the chosen learning object were expected to improve during the learning process of working as a team in a learning study. The learning study method was helpful in this process. Discussing the teaching and learning in relation to a specific content chosen with the point of departure in variation theory made the team see aspects of teaching that were not visible before, and the teaching as well as the consciousness about teaching a specific learning object improved during the process. Using interviews as pre- and post-tests in relation to their constructions was important to understand the strategies behind the pupils' choices in building. These strategies were not always visible to the team in the pupils' constructions. In the interviews, the pupils could also explore their knowledge about shapes and solidity, even if this knowledge did not appear in their construction. Through the combination of a construction-task and interviews, we could identify critical features to focus on in the research lessons.

Consequently, the collaborative learning study method was a helpful tool in relation to working with specific content in technology education. However, more research is needed in order to study how to delimit objects of learning in technology education and how the use of hands-on material can influence learning of specific contents.

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