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# Exploring technical knowledge in the primary technology classroom

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## Abstract

*The aim of this article is to explore the use of categories and aspects of technical knowing which have been identified in specific contexts and related to specific learning objects to identify technical knowing and technical content in another teaching context. In this way, we want to contribute to the understanding of technical knowing within primary technology education, as well as to the development of analytical tools to help teachers in selecting and designing the content of technology teaching. Previous findings from two Learning Studies focusing on evaluating and constructing technical solutions were used to identify technical knowing in video material generated within a particular classroom practice (students aged 7-8 years old). The results suggest that the former categories and aspects can be used in different ways to identify and specify technical knowings related to technical content in the primary technology classroom.*

**Key words** Technology education, primary school, technical knowledge, technical content, construction, technical solutions

## Introduction

Teachers are required to design teaching activities that will make it possible for students to develop specific knowledge or, more precisely, 'knowings of specific knowns' (Carlgren, Ahlstrand, Björkholm & Nyberg, 2015). In order to do that, teachers need knowledge concerning these knowings. Such knowledge, about subject-specific understandings, skills and capabilities, which is often silent and implicit, is important when teachers design teaching that enables students to develop this knowledge. This kind of knowledge may be explored and (at least partly) articulated, and thereby become a tool for teachers to improve their teaching. For primary technology education, the task of designing teaching activities that allow students to develop technology-specific knowledge is more complicated as primary technology education, in contrast to many other school subjects, lacks a common base of experience of teaching and assessment (cf. Stein, Ginns & McDonald, 2007) because in the past technology teachers have largely focused on technology as an opportunity for students to experience practical work. Technology education has not, or only to a small extent, explicitly focused on something that the students are expected to learn (Siraj-Blatchford & MacLeod-Brudenell, 1999; Swedish Schools Inspectorate, 2014). Thus, a professional body of knowledge for planning teaching and evaluating student knowledge related to technology is still emerging (Jones & Moreland, 2003; Jones, Buntting & de Vries, 2013). The overall objective of this article is to contribute to the development of a professional body of knowledge on technical knowings for primary technology education.

A methodology for exploring what it means to know something specific is the classroom-based research approach called 'Learning Study' (cf. Lo & Marton, 2012; Marton & Pang, 2006, Pang & Lo, 2012). In a Learning Study, the focus is on a specific object of learning - that is, a capability concerning a specific content in a particular situation that the students are expected to develop - and on how teaching can enhance this development. This capability that the students are supposed to develop during a lesson, or a limited sequence of lessons, is usually chosen on the basis of something that is conceived of as being difficult to teach and learn. In a Learning Study, the object of learning is explored by a team of teachers in relation to a particular group of students. Critical aspects of the learning object are identified; these are what the students must discern in order to grasp the object of learning. Previous research on the generalizability of results from Learning Studies shows that it is possible that critical aspects, identified for well-defined objects of learning in a Learning Study, can be communicated to other teachers, and used as a resource in the work with other student groups concerning the same object of learning (Kullberg, 2012; Runesson & Gustafsson, 2012). Therefore, we can consider the results from Learning Studies as a way to contribute to the cumulative development of the meaning of the specific object of learning (Runesson & Gustafsson). This refinement of the meaning of the object of learning includes identifying more aspects, as well as nuancing and specifying the aspects identified, thus contributing to theory-building concerning the specific object of learning (Carlgren 2012; Carlgren et al., 2015).

This article takes a starting point in results from two previous Learning Studies in Swedish primary technology education focusing on two separate objects of learning concerning technical solutions. The findings consist of categories that qualitatively describe different ways of knowing in relation to the specific objects of learning, as well as aspects that primary students need to discern in order to develop the knowing (Björkholm, 2014; 2015). These results are thus expected to be useful for teachers in relation to teaching concerning the same objects of learning. But could the findings contribute to a more comprehensive understanding of technical knowing within primary technology education?

The aim of this article is to explore how previous categories and aspects of technical knowing, which have been identified in specific contexts and related to specific learning objects, can be useful for identifying technical knowing and technical content in another teaching context. Technical knowings can only be studied in specific contexts concerning specific content. It seems reasonable, however, to assume there are generalizable aspects of these specific knowings, and that therefore they may function as usable analytical tools for identifying technical knowing in relation to partly different teaching content handled in the typical primary technology classroom.

## Perspective on technical knowledge

The Swedish compulsory technology subject was given a new direction in the curriculum reform in the early 1990s. From previously having been closely linked to the natural sciences, a distinct boundary was drawn between science and technology (SOU 1992:94). Technology was no longer seen as applied science, but as a field of knowledge of its own, involving a substantial element of practical experience and craftsmanship, thus representing knowledge traditions of another kind to subjects such as natural science and social science studies. Indicative of this approach is the name of the Swedish subject, *Teknik*, which has an identical meaning to the German *Technik*, as separated from *Teknologi* denoting the fusion of *Technik* and science. The English term *technology*, however, includes both these meanings (Hansen & Froelich, 1994; Schatzberg, 2006). The school subject Teknik is thus seen as representing technical knowledge traditions, different from the knowledge traditions of science, that are characterized by specific ways of developing knowledge, as well as specific contexts and practices in which the knowledge becomes meaningful.

A point of departure for us is that technical knowledge traditions are to a large extent characterized by unarticulated knowing-in-action (Schön, 1983), i.e. the knowledge is embedded in the actions. This way of seeing technical knowing comes close to Ryle's notion of 'knowing how' (Ryle, 1949). Technical knowing is seen as involving skills and understanding as integrated forms of knowledge, that is, mental skills and physical skills are not seen as separated.

### Technical knowledge explored in the two previous studies

This article takes the results from two previous Learning Studies as a point of departure. In the two studies, video-recorded pre- and post-tests were analysed using phenomenographic analysis (Marton, 1981; 1994), resulting in categories describing students' qualitatively different ways of experiencing the object of learning, that is, different ways of knowing, including tacit aspects of the knowing. The categories are logically related to each other and form a hierarchical structure of increasing complexity. The differences between the categories can be described in terms of what aspects of the object of learning are discerned and experienced simultaneously by students. In phenomenography, a distinction between referential and structural aspects of specific ways of knowing is made. The referential aspect refers to the particular meaning of the phenomenon, while the structural aspect represents the elements of the phenomenon that are discerned (Marton & Booth, 1997). In the two previous studies, the students' physical and verbal expressions were analysed phenomenographically, resulting in categories of different ways of knowing, as well as the aspects of the object of learning that must be discerned in order to learn.

#### *Evaluating and constructing technical solutions*

In the previous studies, two different objects of learning were focused on. In the first study, the capability to evaluate the fitness for purpose of technical solutions intended for opening and closing was explored. Within the field of technology education research as well as in curriculum documents, the capability of evaluating technical solutions is considered as an important educational outcome (Barlex, 2011; Coles & Norman, 2005). Previous research indicates, however, that students have difficulties linking physical and functional properties of a technical solution, and in relating this to the solution's fitness for purpose (Compton & Compton, 2013). The empirical material analysed comprised video-recorded interviews/conversations with children (49 students aged 7-8 years) focusing on familiar technical solutions for opening and closing (Björkholm, 2014). Table 1 summarizes the results of the phenomenographic analysis in terms of students' qualitatively different ways of knowing technical solutions' fitness for purpose. In addition, the structural aspects identified are presented.

Table 1. Students' qualitatively different ways of knowing technical solutions' fitness for purpose, and the related structural aspects.

| Category and Description | | | Structural aspects |
|---|---|---|---|
| | Technical solutions' fitness for purpose | | |
| (A1) | Effectiveness for me | Own needs and situation are fulfilled | Own needs and related functions |
| (B1) | Effectiveness for others | Fulfilling functions based on others' needs and situations | Specific needs or situations of others |
| (C1) | Construction dependency | How efficiently aspects of the construction help to realize the function | Functional properties of materials<br>Form (size and folding)<br>Specific key components |
| (D1) | Technical efficiency | How efficiently commonly agreed technical solutions realize the function | Main and secondary functions linked to corresponding key components |

In the second study, the capability to construct a specific linkage mechanism allowing for transferring and transforming movement was examined. Construction of mechanisms is highlighted in curriculum documents, and is often part of the teaching content in the primary technology classroom. Young students, however, have difficulties in assembling parts to allow for transfer of movement when constructing (Chatoney, Delserieys & Martin, 2013). The empirical material that was analysed was video recordings of a total of 49 students aged 6-7 years constructing a linkage mechanism (Björkholm, 2015). Through the phenomenographic analysis, four qualitatively different categories emerged describing students' ways of experiencing/knowing and constructing a mechanism (Table 2). As in the first study, the categories describing the less complex ways of knowing are integrated in the more complex ways. The least complex category (A2) is about testing different components in order to realize the overall function. This way of knowing was the most common in the pre-test, since the students had great difficulty in constructing the mechanism. Testing components was thus a way to discover a solution for realizing the function. The more complex category (B2) describes an understanding comprising the existence of a machine without being able to discern it.

Table 2. Students' qualitatively different ways of knowing to construct a specific linkage mechanism, and the related structural aspects.

| | Category and Description | | Structural Aspects |
|---|---|---|---|
| | | Constructing the mechanism | |
| A2) | testing components | • Driving movement is directed at the same point as the resulting movement,<br>• components are tested to realize the function. | One joint |
| (B2) | making space for a machine | driving movement is directed at a different point than the resulting movement, thus creating space for both input and output as well as the mechanism for transferring movement. | Two joints |
| (C2) | controlling a machine | • components are attached in a fixed and a moving joint.<br>• distance between input and output is short and contains few intermediaries<br>• driving movement has the same direction as the resultant. | Moving joint and fixed joint |
| (D2) | building a machine | • A distinction between fixed and moving joint is made<br>• the moving joint is placed on the opposite side of the resulting movement. | Moving joint located on the opposite side of the resulting movement |

The more complex ways of knowing can be described as discerning the machine, and how its components interact in order to fulfil the different functions. The aspects that were identified as necessary to discern in order to make this knowing possible are related to different ways of joining the linkages, thus discerning the location and separation of moving and fixed joints.

Summarizing the main findings from the two studies, the first study identified technical knowing in terms of discerning specific functions related to different types of users and situations, the relation between function and construction, and how aspects of the construction such as the properties of materials, forms such as size and folding, and specific key components contribute to realizing functions. In the second study, technical knowing as a specified analysis of the construction in terms of location and separation of different types of joints in relation to specific functions was identified. The identified knowing was understood as increasing in complexity from directly affecting the intended outcome by physical contact with output components in the machine, to letting a machine and its components interact in order to realize the intended functions of transferring and transforming movement.

## Method

This section first presents the context of the research, followed by a description of the methods for data generation and analysis.

### *Specific teaching practice*

The basis for analysis is a series of technology teaching sessions that were part of a larger project concerning the Swedish children's author Lennart Hellsing. The overall purpose of this project, as formulated by the teachers, was to integrate the subjects Technology and Swedish, and to foster collaboration between the two participating classes. Although the aim of the task given to the students was not confined to developing a specific technical knowing among the students, there was an ambition to give students the opportunity to develop skills in relation to 'construction, tools and security'. The technology sessions lasted for two full consecutive school days, and involved four teachers and two classes, one in grade 1 (students aged seven years) and one in grade 2 (aged eight years) with a total of 53 students. The students were divided into four mixed groups and placed in separate classrooms with a teacher. One of these groups (16 students) was the main focus of this study. The students of this group were asked to collaboratively construct a model of a town, the Lake Town, which is described in words and pictures in the book *Krakel Spektakel* (Hellsing, 1959).

The work in the student group was led by the teacher Anna, (pseudonym). She had been teaching primary technology for about 15 years, and had undergone fairly extensive training in technology (30 credits). The teaching session started with teacher-led collaborative planning of the town to be built, and one student was asked to simultaneously make a sketch based on the class proposals of what the planned town should look like. The sketch contained a central square with a fountain, houses and shops located along a shopping street etc. (Figure 1).

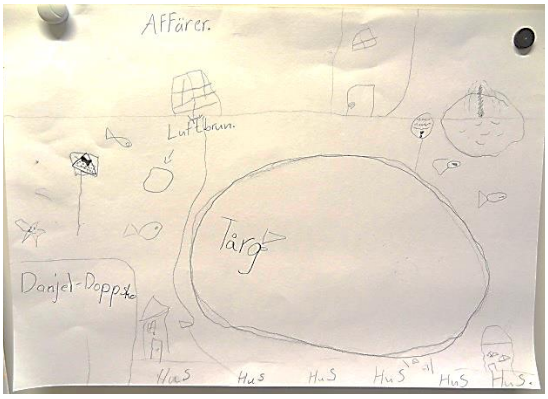


Figure 1. The sketch representing the Lake Town.

After each subgroup of four to five students had been assigned a specific task, such as making houses, people or vehicles, the students started to paint the base plate and to make models. The construction materials that the students were offered mostly consisted of cardboard in the form of packages of various kinds that the students had brought from home, and general art supplies commonly found in schools. Throughout the town modelling process, students worked independently within their groups without much support from the teacher. The teacher offered help when cutting or sawing due to safety concerns, and also suggested additional objects to make. The second day began with a discussion of what needed to be done in order to complete the town model. The final model of the Lake Town is shown in Figure 2. At the end of the second day, all student groups came together in order to exhibit their final models. This wide-ranging practical task could be seen to also comprise the Swedish school subjects Art and Crafts.

Figure 2. The final model of the Lake Town.

*Data generation and analysis*

The data were mainly collected by video recording students' working processes in the classroom. The student group (16 students) worked on constructing the imaginative town model based on the text and illustrations in the children's book. A hand-held camera was used to record the students' construction processes to varying degrees. Within the subgroups, students constructed individually in silence but also interacted with other students and with the teacher to a certain extent. The video data comprised 120 minutes of film displaying student activity. In addition, data were collected through field notes from the two days' work in the classroom, photographs of students' models, and from an audio-taped interview with the teacher, Anna, a week before the start of the technology sessions.

The video material was transcribed verbatim. In the transcript, students' bodily actions in relation to artefacts, as well as verbal and physical expressions such as gestures and mimicking were also noted. The analysis started by identifying the technical content in the teaching sessions in relation to the Swedish national technology syllabus (National Agency for Education, Sweden, 2011). In the continuing analysis, the previously identified categories of technical knowing were interpreted and used in a more generalized way in order to identify instances of technical knowing in the teaching sessions. These instances were then analysed in order to further specify the meaning of technical knowing and the technical content involved. In the students' verbal and physical expressions of technical knowing, their difficulties manifested when constructing were also taken into consideration when identifying technical knowing. In other words, the previous categories were tried out in relation to the new empirical data, and this data helped to further specify the identified technical knowing related to the technical content handled in the teaching sessions.

## Findings

The presentation of the findings first describes the technical knowing identified and technical content in relation to the evaluation of technical solutions, followed by the findings related to the construction of technical solutions.

## *Evaluation of technical solutions*

Representing a town on the basis of a book

The overall purpose of the construction can be understood in relation to the students' task of building a town model, based on the story and the illustrations in the children's book. The model was planned to be presented to other students and teachers at the end of the technology sessions. The potential recipients of the town model thus included the students themselves, as well as other students and teachers. The evaluation of the fitness for purpose can be seen in relation to the town model's representing function, even though this was made explicit mostly in the planning phase. By making a common sketch, the model to be built was planned and discussed in the classroom setting. During this process, the teacher gave instructions to the whole student group named 'the city planning office' on how to sketch houses and streets from a bird's eye perspective, referring to students' experiences of reading maps during orienteering activities within physical education. In the following excerpt, the sketch is finished, and a group of students are about to start painting the base plate on which the town model will be mounted.

Teacher: The base plate is here (takes a large sheet of cardboard and puts it on the table).

A: [to Students B and C] Hey, a tip. Take some [inaudible] [holding the arms upwards]. Then you glue and put it like this [points to the base], a rectangle.

B: Yes, but shouldn't we build upwards?

C: Shit, what a big town we will make!

B: (turns towards the teacher) But shouldn't we build upwards (stretching the arms upwards)?

Teacher: Yes, you should build upwards.

This example shows how Student B seeks confirmation of how to make the town, focusing on the translation from the two-dimensional sketch to the three-dimensional model. Student C comments on the scale difference between the sketch and the model. Throughout the construction process, the sketch of the town is not referred to explicitly. Likewise, some students start by drawing a sketch of their planned construction, but they do not refer to their sketch when constructing nor when evaluating the completed model. In the next excerpt, the teacher speaks to the student group regarding this topic.

Teacher: I think we are short of houses, my friends. More houses.

/../

Teacher: We lack houses. This was supposed to be a shopping street, we agreed together. A very simple way, Sarah [brings a gable top carton of milk and shows how the gable top can form the roof].

Here, we see how the teacher reminds the students to build the town model according to the collectively planned town, and ensures that the houses will be built when hinting to the pupil Sarah how to make a house in a very simple way. During the construction process, students evaluate their technical solutions in various ways. On the one hand, they evaluate their constructions in relation to the book illustration which the students have access to during the project, and to which they also refer on a few occasions. On the other hand, it seems that the students evaluate their solutions on the basis of their ideas of what the objects look like in real life. There is, however, a tension between the two types of representation, since the imaginative book illustrations do not seek to resemble real objects.

*Choosing materials based on functional properties*

The primary ways in which students evaluate their technical solutions while constructing include various aspects of the construction. Materials are selected and evaluated based on functional properties in order to realize the overall purpose of representing a town. The materials mainly chosen for construction are various types of paper materials such as cardboard and corrugated board, but also textiles and metal in the form of steel wire. This way of evaluating materials can be seen to relate to the category C1 focusing on different aspects of the construction in order to realize the desired function.

*Adding secondary functions*

During the sessions, the intended functions of the different constructions are rarely made explicit. However, in the following excerpt showing the interaction between Student C and the teacher, the function is focused upon.

C: The well is finished [holding up a model].

Teacher: Ah, is that the air well? Great!

C: It came off.

Teacher: Oh, that's not a big problem. But you should paint it in some way, right?

C: Yes, I will, later.

Teacher: Hmm, is that some kind of place where one can go to, where several people are sucking air from the same well? I was thinking like this, if you did like this, a number of people can get air from the same well [takes an additional 'tube' of pipe cleaner and holds it close to the attached one].

C: Hmm.

Teacher: Or, what did you think?

C [starts to attach an additional pipe cleaner into the existing one, like a tube with multiple branches.]

In this excerpt, shows how the teacher helps Student C to add and thus discern an extra function of the construction. This sub-function allows more people to get air, and can be seen as a further development of the model's main function.

*Evaluating stable structures*

Actions related to evaluation of the stability of structures were also identified in the video material. Students' construction of simple house models of cardboard and corrugated board met in most cases the functions of being both solid and stable. In the following example, however, an unstable house model is to be placed on the base plate.

H: [Comes and sits down at the base plate which is placed on the floor at the front of the classroom, H is holding a house model.]

Look, if you put it like this. [Tries to put the house on the base plate, but the model tips over].

One needs some support then. [Looks at J who has come and sat down next to H].

J: Yes, but you should glue it there. If it is glued, then it will (inaudible), right?

Student H expresses the need for some supporting structure as a way to overcome the problem of instability, but Student J suggests the model should be glued to the base. This latter solution can be considered as functional since it easily solves the immediate problem. This situation could, however, provide an opportunity to develop knowing in relation to constructing stable structures.

*Summarizing the technical knowing and content concerning evaluation of technical solutions*

Table 3 summarizes the technical knowing and content identified in the video-documented technology sessions in relation to the results from the first study focusing on the evaluation of technical solutions. Two of the former four categories were recognized in the video material. The first category, 'Effectiveness for me', was not identified in the new data material since the students' task did not involve this knowing explicitly. Instead, the representing function was focused on, including perspectives of both me and others. The representing function was realized by making a sketch of the town, as well as making a model. These were evaluated in relation to the story and illustrations of the book. Relating the sketch to the model was also identified as technical knowing in the teaching sessions.

Table 3. Specifications of technical knowing and technical content in the technology teaching sessions concerning evaluation of technical solutions.

| Previous categories | | Aspects concerning evaluation of technical solutions | Technology teaching sessions<br>Evaluation of technical solutions |
|---|---|---|---|
| (A1) | Effectiveness for me | Own needs and related functions | - |
| (B1) | Effectiveness for others | Specific needs or situations of others | Realizing function of representation:<br>- as a sketch<br>- as a model<br>Relate sketch to model |
| (C1) | Construction dependency | Functional properties of materials<br>Form<br>Specific key components<br>Main and secondary functions linked to corresponding components | Choosing materials based on functional properties<br>Building stable structures<br>Adding components related to secondary functions |
| (D1) | Technical efficiency | Common technical solutions and the interaction between key components of the construction | – |

In addition, technical knowing and technical content was identified in terms of evaluating the material to use when constructing, based on its functional properties. The stability of structures was evaluated and tested by the students during the sessions, they also added components related to additional functions. Technical knowing in terms of evaluating the efficiency of common technical solutions and the interaction between components (D1) was not identified in the video material. The previous categories of technical knowing and technical content concerning evaluation of technical solutions have been specified in the new teaching context.

*Construction of technical solutions*

Processing materials

Actions that can be identified in the video material focus on selecting and using tools for cutting in relation to different materials. During the project this knowing is primarily expressed relative to hard paper materials such as cardboard and corrugated board. The knowing includes the selection of appropriate tools, which include scissors, knife and saw, as well as using the tools in an appropriate and safe way. For security reasons, the students are not allowed to use the knife for cutting the hard material. Instead they come up to the teacher and directed the teacher's cutting, as illustrated in the following excerpt.

> [Student B is holding a cardboard box, cutting the box along the line of the fold of the cover, and is progressing slowly. B makes a face expressing difficulty when cutting with the small pair of scissors. B changes side and starts cutting from the other end. It is rather slow, so she changes side again. B looks around several times, letting the scissors go. She takes the box and goes to the teacher's table where there is a knife.]
>
> B: [turns to the teacher] Anna, can you cut here? [Points to the folding line.]

Here Student B tries cutting the hard paper material with the small scissors from different positions. After having experienced the difficulties using the scissors for cutting, they are replaced by a knife. The use of appropriate tools for cutting different types of materials can be seen as a type of initial knowing in terms of processing and shaping of material.

*Joining materials*

In the process of construction, students are also, to a great extent, testing different ways of joining material to fulfil the intended function. In the following excerpt, Student D tries to join two pieces of corrugated cardboard.

> D takes a piece of corrugated cardboard and puts it in the stapler, then removes it. He folds the piece of cardboard in half and, puts it in the stapler to test whether stapling will work. He presses with both hands but the staple does not go through both layers, so he removes the staple from the piece of cardboard. He goes away to put the staple in the trash, comes back and starts to tear off pieces of tape from a roll of tape in a tape holder. He starts taping, and attaches a piece of tape over the opening of the cardboard ends. He turns the piece of cardboard, looks through the opening, tears off another piece of tape and then puts one piece on each side of the first piece of tape.

Student D is testing different types of connection methods, such as the use of fastening with a stapler and with tape to join the pieces of cardboard. The type of joint that D seeks to make is a so-called permanent joint, which implies the creation of a strong and rigid structure that cannot be taken apart without breaking it. Making this kind of joint is the most common way of joining pieces of material identified in the video material. The joining includes parts consisting of the same or different types of materials. This knowing is about using appropriate ways of permanent joining with different materials, in this case cardboard, paper, metal, and plastic. Besides using tape, and fastening with a stapler, the students also use sticky tack and hot melt adhesives. The joining can thus also be related to appropriate and safe use of different types of tools such as a stapler and a glue gun. In the video material the construction of a different type of joint is also identified, which is shown in the next excerpt. Students E, F and G, who have been given the task of constructing people, are standing together around a table with different types of construction materials.

E: I'm going to make eyeglasses by using these two [holding two pipe cleaners].

/../

E: A red head.

[Takes a red cotton pulp ball, puts on 'glasses' made from a pipe cleaner, takes the remaining part of the pipe cleaner with the right hand and extends it around the 'head', looks at it, turns the cotton pulp ball, holds the end of the pipe cleaner to the other side of the frames. He asks for the scissors, takes them, cuts off the unused piece, loosening it from the cotton ball and assembles the glasses.]

F: I'll go to get a better pair of scissors. [Returns after a short while.]

E: [to F and G] Look, I did it like this. [Smiles and holds up the cotton pulp ball with the attached glasses, turning the cotton ball several times.]

G: Oh gosh, that's great.

[F looks and nods towards E.]

G: I also want to do like that.

/../

[G forms glasses in the same way as E, then puts the finished glasses around the cotton ball.]

Here we can see how Student G expresses a positive evaluation of the way Student E has made a joint, and that Student G later imitates this way of constructing. This joint is different from the most common type since it is a flexible joint, which means that the structure can be taken apart. In this way, the individual components of the construction can be processed in detail by iteratively joining and testing the realization of the function. One difficulty that the students encounter in several situations during the technology sessions concerns the attaching of something that has a small contact surface. For example, to attach the end of a pipe cleaner to a larger surface to make a strong joint. The students glue on the tip of the pipe cleaner, but fail to attach it to the surface in a way that it can stand upright without falling over. The students mostly cannot find a way to solve this problem. At one point, however, the knowing related to how to attach successfully was documented.

K is sitting at the base plate on the floor, holding a model of a person with legs made of pipe cleaners. K glues with the glue gun on the model's feet, which consist of relatively long right-angled folded end parts of the pipe cleaners, and then tries to fix the model so it stands on the base plate.

This excerpt shows that by enlarging the contact surfaces Student K makes strong joints when gluing. In the next example, this problem is highlighted in the interaction between Student M and the teacher.

M I can attach the tree now. [Showing a tree model with a trunk made of a pipe cleaner.]

[The teacher discusses with the student for a while that the trunk should probably be made a little thicker in order to stand up.]

The teacher suggests to Student M a possible way to attach the tree to the base plate. Without the interaction, the students probably would not have been able to solve this problem, since most students gave up after having failed to make the structures stable.

*Summarizing the technical knowing and content concerning construction*

In Table 4, the findings concerning construction of technical solutions are summarized. In the video material, students' actions in relation to processing and joining materials were frequently present. Selecting and using tools for cutting, and joining materials were identified as categories of technical knowing and content (X and Y) in the construction of the town model.

Table 4. Additions to technical knowing and technical content in the technology teaching sessions concerning construction of technical solutions.

| Previous categories and aspects | | Construction of technical solutions | Technology teaching sessions | | Construction of technical solutions |
|---|---|---|---|---|---|
| | | | (X) | Processing materials: | Selecting and using tools for cutting different materials |
| | | | (Y) | Joining materials: | Making permanent joints in different types of material |
| | | | | | How making permanent joints is related to size of contact surface |
| | | | | | Making flexible joints |
| (A2) | Testing components | One joint | | | - |
| (B2) | Making space for a machine | Two joints | | | - |
| (C2) | Controlling a machine | Moving joint and fixed joint | | | - |
| (D2) | Building a machine | Moving joint located on the opposite side of the resulting movement | | | - |

The construction process mainly focused on getting the parts to stand upright and fastened to make rigid structures. The technical solutions were thus of a different type than those constructed in the previous study concerning mechanisms. The ways of constructing in the teaching sessions could be seen as more basic than in the previous study. One can assume that constructing in terms of rigid structures and attachments is a prerequisite for the construction of solutions allowing for movement. The former categories could, therefore, not be used to specify technical knowing and technical content. Instead, the categories X and Y identified in the video material are added to the former categories. In this way, adding categories of less complex ways of construction contribute to the understanding of technical knowing and technical content concerning construction.

## Discussion

This article has explored the usefulness of previously identified categories and aspects of technical knowing related to specific objects of learning (Björkholm, 2014; 2015) for identifying technical knowing in a new empirical material focusing on somewhat different contents within the primary technology classroom. The analyses show that the former categories could be used in different ways in relation to the empirical material. The categories from the first study could be used to specify technical knowing and technical content concerning evaluation of technical solutions in the new teaching practice. The specifications dealt with evaluating functionality related to sketches, models, materials and stability. Considering the second study, new categories were identified in the video material which could be added to the former categories. In this way, categories of less complex ways of constructing contributed to the extension of technical knowing and technical content concerning construction of technical solutions. Construction in terms of processing and assembling materials to make rigid structures and attachments could be seen as basic technical knowing and as content, from which to proceed to construct mechanisms.

The technical knowing identified in the technology sessions could be related to the content in terms of materials, stable structures, modelling and sketching formulated in the current Swedish technology syllabus (National Agency for Education, Sweden 2011). However, the syllabus gives only limited guidance on the detail of knowing related to constructing, sketching and modelling. The categories of technical knowing identified in the teaching sessions give some information on what the knowing involves. However, the new categories of technical knowing and content regarding construction need to be explored further. The identified knowing and content related to constructing with materials can be seen as closely linked to central aspects of the Swedish subject *sloyd* which concerns craft skills related to the materials wood, metal and textiles. A question is, therefore, whether the content identified can really be considered as technology content. In the Swedish technology syllabus, the technology content is explicitly linked to certain specific engineering areas, such as mechanical engineering, building construction, control and regulatory systems, and product development. In this study, the teaching sessions focused on a different engineering area, city planning. This content could be seen as relevant to technology education in that models and sketches have important functions, and can also be linked to technological systems, a topic highlighted in the Swedish syllabus as well as in the technology education research literature (e.g. de Vries, 2005).

Teachers in primary school are expected to design teaching, select the content and plan activities in a way that enables students to develop technical knowing in relation to technical content. This requires knowledge of what these knowings imply (Carlgren et al., 2015). In the article, a few characteristics of technical knowing have been identified in primary education. These features can be used as tools for teachers, helping them to identify and analyse technical knowing related to technical content in the technology classroom. We believe that these initial tools are important contributions to the development of the teachers' body of professional knowledge concerning primary technology education (Jones & Moreland, 2003; Jones et al., 2013).

Finally, based on the analysis of students' ways of evaluating and constructing during the technology sessions and the knowing and content identified and specified in relation to previous case studies, the findings can be treated as potential objects of learning to be used and further explored in primary technology teaching practice. These could be seen as subject-specific knowings and contents to be implemented in technology teaching. Technical knowing cannot be studied in general, since it always concerns some specific content. Studying technical knowing thus always concerns specific objects of learning. However, by studying knowing of specific objects of learning, knowledge is generated concerning knowing in a more general sense.

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