Exploring the capability of evaluating technical solutions: A collaborative study focusing on teaching and learning in the primary technology classroom

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Abstract

The purpose of this study is to explore the capability of evaluating technical solutions in terms of fitness for purpose in the primary technology classroom. In the study we conceptualize pupils' ways of experiencing technical solutions in terms of what critical aspects are discerned. The analyzed data is drawn from a classroom study of technology education in a Swedish primary school. In this presentation we make an analysis of two technology lessons about technical solutions in grade 2 (pupils are 8-9 years old). We then analyze interactions between teacher-pupils, pupils and materials and tools. The results include pupils' different qualitative understandings of the specific content in terms of critical features discerned as well as how interactions in the classroom contribute to the collective development of technological knowledge.

Key words: Technology education, Technical solution, Fitness for purpose, Teaching, Learning, Variation theory

Introduction

The capability to evaluate technical solutions is highlighted by several authors as an important educational outcome within technology education (Barlex, 2011; Coles & Norman, 2005). It is considered essential as an analytical tool within design decision-making capabilities and for interpreting existing technological objects and systems. The importance of developing the capability concerned is well advocated in technology curriculum documents across the world. In the Swedish technology curriculum of 2011 (National Agency for Education, Sweden, 2011) the knowledge area named technological solutions is about making technology of everyday life transparent and comprehensible to pupils. Teaching in technology should give pupils the possibility to develop their ability to identify and analyze technological solutions based on their function, i.e. what they do, and fitness for purpose; in other words, how effective they support their intended functions. Another example is the New Zealand technology curriculum, which highlights evaluating technical solutions in terms of fitness for purpose that includes the physical nature, i.e. its physical realisation such as shape, size and structure etc., and function (Ministry of Education, New Zealand, 2007).

The limited amount of empirical research done on this area of technology education (Frederik, Sonneveld & de Vries, 2011) indicates that pupils have difficulties in evaluating technical solutions in terms of fitness for purpose (Compton & Compton, 2011). So, how can this type of knowing be described and what does it take to know it? This conference paper is based on a collaborative interventionist teacher-researcher study in primary education focusing on this specific capability. The aim of the study is to contribute to the understanding of what it means to be able to evaluate technical solutions in terms of fitness for purpose. Through an iterative classroom based study, we explore what is critical for pupils' learning and how it can be enhanced by the teaching methods used.

Background

Phenomenography is a qualitative research approach (Marton, 1981) grounded in a non-dualistic ontological position, depicting experience as an internal relationship between the individual and the world. A basic assumption is that people perceive, understand or experience a particular phenomenon in the world in a limited number of qualitatively different ways. These qualitatively different ways of experiencing are logically related to each other and usually formed as a hierarchical structure with rising complexity, since the basic idea is that certain ways of experiencing something are more powerful than others.

From describing different ways of experiencing something, phenomenography has evolved and qualitatively shifted focus to questions concerning the nature of the different ways of experiencing (Pang, 2003). These different ways of experiencing mainly arise because critical aspects of the phenomenon are discerned. According to variation theory, learning is seen as a change in the learners' ability to discern critical aspects (Marton, Runesson & Tsui, 2004). From this it follows that, in order to make learning possible, these critical aspects must be made possible to discern. To do so, the critical aspects must be experienced as dimensions of variation. Variation thus enables the pupils to experience aspects that are critical for a particular learning and the development of certain capabilities.

> 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 (Marton et al., 2004, p. 24).

The critical features (or aspects) are thus related to the specific content and linked to the pupils' experiences of the object of learning. The critical aspects are not the same as pupils' difficulties with the content taught; instead it is what pupils must be able to discern to experience the object of learning in a certain way. One can thus identify critical aspects from the difficulties pupils exhibit by analysing the differences between ways of experiencing a phenomenon in terms of critical aspects discerned. When the critical aspects have been identified, the teaching must be planned to make it possible for pupils to experience patterns of variation that highlight the critical aspects of the object of learning.

Evaluating technical solutions

Technical functions are closely linked to human intentions and activities. In the user context, it is mainly the object's function in relation to the realization of the goal or purpose that is important, whereas the physical nature of the object is of minor importance. From an engineering perspective, however, the function of a technical object is mainly related to its physical nature, since it realizes or performs the function (de Vries, 2005; Kroes, 2002). A main task of engineer's is to design, develop and produce physical objects or systems that can achieve specific functions. These functions are often described in terms of criteria that the designed object must meet. The results in terms of technical solutions can be varied and some fulfill the function better than others. In the same way, some materials are better suited than others for use in a particular object in order to fulfill the function. Knowledge of functions as well as knowledge of the relationship between function and physical nature thus have evaluative elements, since knowledge of functions of objects is not about what they do, but rather what they ought to do (Jones, Buntting & de Vries, 2011).

Although there is limited access to research on pupils' understanding of technical solutions (Frederik, Sonneveld & de Vries, 2011), results indicate that pupils in both primary and secondary education have difficulties in understanding the link between physical nature and function, as well as the fitness for purpose (Compton & Compton, 2011). Oboho & Bolton (1991) studied how pupils in the 11-16 age range judged whether an artifact designed was a "good" or "bad" design. The younger pupils tended to respond more in terms of function than physical structure, stating what they could do with artifacts in a concrete operational way. The thinking appeared to go on towards structural terms with increasing pupil age, implicating that structure possibly is an understanding of function in a more comprehensive manner. Cajas (2001) highlights the need of research on how young children learn about functional properties of materials and states that young children have problems in distinguishing the properties of the object from the properties of the material from which the object is made. A contribution to the field is a study by Chatoney (2008), observing pupils, aged 6-7, and their development of knowledge about materials during activities comprising designing and making a toy. The analysis was based on the relationships between material and object, and teacher-pupil interactions. Results show that knowledge about materials has a central position in this kind of activity. The knowledge is introduced in the beginning of the activity, as soon as the functions are defined, and it is viable throughout the entire process.

In summary, research on this specific content within technology education indicates that it involves certain difficulties for pupils. Linking function and physical aspects seems to be hard for pupils as well as evaluating technical solutions' fitness for purpose in general. What one has to know in order to be able to evaluate the fitness for purpose of technical solutions' is, however, not self-evident. This study explores the meaning of this specific knowing by investigating what is critical for pupils' learning. By designing teaching activities that make it possible to discern these critical aspects, systematic teaching-learning strategies can be developed.

Method

The study was carried out as a learning study (Marton & Pang, 2006; Pang & Ling, 2011), which could be considered as a further development of the Japanese lesson study (Fernandez, Cannon & Chokshi, 2003; Lewis, 2000) or a hybrid of a design experiment (Brown, 1992) and a lesson study (Marton & Pang, 2006). The rationale for using this model is its focus on a specific object of learning, i.e. what the pupils are supposed to learn, and on the related teaching-learning process as it is practiced in the classroom. The model has a collaborative approach, in which teachers' professional knowledge is crucial in identifying pupils' learning difficulties and what it takes to know something. What is critical for learning something specific is explored through a systematic and iterative process (Marton & Ling, 2007).

Teaching context

The study was conducted with four teachers in primary school during a period of six months. Two classes in grade 1 and 2 (pupils aged 7-8 years) participated in the study. There were 23 pupils (grade 1) and 26 pupils (grade 2) in the participating classes. Based on teachers' experiences regarding pupils' difficulties in problem solving, the researcher and teachers agreed to choose the object of learning "to evaluate technical solutions in terms of fitness for purpose”. In order to further set the limits of the object of learning, an opening-closing function was selected.

The design, implementation and preliminary analysis of the pre-test have been presented briefly (Björkholm, 2011). The analysis of the pre-test resulted in four qualitatively different categories, describing pupils’ experiencing of the phenomenon, technical solutions’ fitness for purpose. These were “effective for me in a specific situation”, “effective for others in different contexts”, “technical efficiency”, and “relevant technical standard solution”.

Based on the qualitative differences between these categories, dimensions were discovered and analyzed resulting in the following identified critical aspects:

a/ user and context

b/ material, form and components

c/ key component interaction

These critical aspects formed the starting point when planning the lessons. Variation theory was used as a tool when planning, opening up dimensions of variation, in order to make the intended learning possible. All lessons included a classroom discussion and a problem solving task given to pupil pairs. In order to focus the structure’s significance for fulfilling the function, different kinds of solutions with an opening/closing function, like zippers, hinges, screw caps, were compared and examined. Different types of materials, such as plastic, metal etc., their areas of use and properties were emphasized in the first two lessons. Materials were chosen since it was the primary aspect mentioned by pupils’ when talking about the physical nature in the pre-test. The two categories indicating the least complex understandings of the phenomenon focused on the user dimension. In order to open up dimensions focusing on the design context, materials could thus be considered as an appropriate link between user and design contexts.

Study design

The teachers-researcher group planned the first lesson based on the critical aspects identified in the pre-test. After the lesson had been conducted, it was analyzed by the researcher. At the subsequent teachers-researcher meeting the analysis was discussed and based on these results, changes in lesson design were proposed. Thereafter, a further three cycles with lesson planning, teaching and revising the lesson, were conducted.

Data was generated by audio recording the six teacher-researcher sessions, each of which was approximately two hours long. Each of the four lessons was video recorded and lasted for approximately 60 minutes. Texts, drawings and models produced by pupils during lessons were collected or documented by photo.

Analysis

All generated data was transcribed verbatim. The lessons were analyzed using variation theory as an analytical tool. Pupils’ understanding of the object of learning during the lessons in terms of linguistic and bodily expressions was analyzed focusing on identifying difficulties in pupils’ learning. These difficulties were then analyzed in order to understand and identify aspects of the object of learning not discerned by the pupils concerned. Since discerning these dimensions could be seen as essential for making the specific learning possible, they were identified as critical aspects. The preliminary results concerning critical aspects were discussed with the participating teachers using selected video sequences, and possible ways of understanding pupils' learning difficulties were discussed.

Results

This article investigates what it means to be able to evaluate technical solutions concerning \`opening-closing´ in terms of fitness for purpose, based on the critical aspects identified during the research process in relation to pupils' difficulties in learning this specific content in the technology classroom. The analyses of the lessons suggest the following additional critical aspects:

- Materials separated from objects
- Main function and secondary functions related to key components

Materials separated from objects

When discussing different types of materials and their uses, some pupils had difficulties in distinguishing between the material and the object made of the material. In the following example, the material cardboard is discussed.

Teacher: /../ Cardboard, what can you use it for then? Erika?

Erika: If you want to send big things to someone, you can pack it, so it won't break

Teacher: Smart. Jens, what do you think?

Jens: Pizza, pizza boxes

Teacher: Oh yes, to put the pizza in, when bringing it home

Ralf: You mean packages

Teacher: Packages, you think. Yes, yes. Måns?

Måns: Shoe boxes, all kinds of boxes

Ralf: Then it is still packages

Teacher: Yeah, right. Olle?

Olle: You can have boxes, boxes, simply. Moving boxes, they are usually made of cardboard. If they are made of wood, then they are very difficult to handle and they can be prickly and hard and a lot heavier than cardboard, but cardboard is anyway quite strong to put heavy things in

Teacher: It is good to use cardboard, a different material, you think

Nina: There are boxes in here

Teacher: Oh well, have you seen any?

Nina: Over there (pointing)

Teacher: Yes, we use a lot of cardboard boxes over there. Yeah, you know, talking about boxes /../

Discerning the material as separated from objects made of the material, can be considered critical for the understanding of materials' significance for realizing the function. As seen in the above example some pupils just discern the object, when talking about cardboard. Without discerning the specific material, these pupils will not be able to evaluate this aspect of the technical solution. Thus, this aspect is identified as a critical aspect.

When the critical aspect is raised in the classroom discussion, the teacher gives the pupils opportunity to discern a variation of possible meanings of cardboard. The comments by the pupil Ralf give pupils opportunities to experience varying appearances of “package”. Olle also contributes to the collective knowledge production in the class through his comment on the appropriateness of different materials from the user’s view based on the properties of the materials, when comparing boxes made of wood and cardboard.

Main function and secondary functions related to key components

During lessons, some of the pupils had difficulties in distinguishing the main function opening-closing from the secondary function unlocking-locking. This problem is illustrated in the following example, when talking about a glass jar and its opening and closing function.

Teacher: What is it that makes this possible to open and close (opens and closes a jar with a hinged lid)? Is it this thing (the locking mechanism)? Or is it (opens it with the hinge)? What do you say, Molly? You don’t know?

Molly: It is perhaps this thing that fits into the hole (pointing to the rubber ring)

Ellen: But it is just to, to prevent the glass, if you happen to drop it

Markus: Or to make it tight

Teacher: Aha

Marcus: It is a weird hinge

Rickard: Yes, exactly /../

Teacher: It is some kind of hinge, some of you think

August: Hooks!

Teacher: That doesn’t look like anything we have seen before

August: Hooks, hooks, they are hooks

Teacher: Like hooks, see? Exactly, and this, what does it do, then (shows the locking mechanism)?

Molly: It closes the jar

Markus: Locks

Teacher: It perhaps locks the jar. It opens and closes like this (shows how the lid opens and closes with the hinge). And this one locks (shows the locking device). Ok

Different parts of the jar and their functions are examined through the collective discussion. To separate the locking from the closing function, the teacher focuses on the parts linked to the different functions. The pupil Markus is distinguishing between the closing and locking function, the teacher responds by showing the different parts and their corresponding functions. The pupils have thus possibilities to simultaneously discern the closing and locking function linked to different parts of the jar. In the discussion additional parts of the jar are examined and more secondary functions come up. Alternative functions of the rubber ring around the jar opening, as protection and tightening is mentioned. A further dimension of the physical nature linked to opening and closing function is highlighted in the example. The pupils talk about weird hinges looking like hooks. The pupils are given the opportunity to discern a hinge, a standard technical solution used for opening and closing, and compare it to other hinges they have seen before. They may in this way get the opportunity to experience an additional variation of types of hinges.

Discussion

In this study some critical aspects of the object of learning to evaluate technical solutions in terms of fitness for purpose, were identified during the learning study process. These critical aspects could be considered as further dimensions necessary to discern in order to develop this specific knowing. When a critical aspect is raised in the lessons, the teacher and pupils together construct the space of learning and what is possible to experience during lessons. A variation of answers and examples mentioned by the teacher and pupils, could lead to a deeper and more complex understanding of what it is to be learned. However, even if a critical aspect is made possible to experience in a lesson, it does not imply that all pupils learn.

The critical aspect concerning the distinction between the material and the object could be understood in relation to earlier research (Cajas, 2001) indicating that young children have problems in distinguishing properties of the objects from the properties of the material. During the learning process, discussion and design decision making seem to be vital in making 7-8 year-old pupils aware of concepts of materials and functions and how to evaluate technical solutions. Giving pupils opportunities experiencing the critical aspects through discussion, design decision making and involvement in the task, allow them to explore technical solutions in terms of material, components, main and secondary functions from the engineering view as well as from the user perspective. The importance of these factors for knowledge production in primary technology education is well highlighted by Chatoney (2008). Compton & Compton (2011) suggest the content needs to be introduced across more than one level and broken down into smaller ideas, in order to enable pupils' learning of technical solutions' fitness for purpose. An alternative way of interpreting pupils' difficulties and how to enable learning is in terms of critical aspects necessary to discern and to design teaching that give pupils opportunities to experience variation through classroom discussions and design activities that are linked to pupils' real problems and needs.

The question of how results from a learning study can be of use for other teachers and contribute to the collective knowledge base of the teaching profession has been discussed lately (Carlgren, 2010). A study by Kullberg (2010) indicates that it is possible to communicate the findings, in terms of critical aspects, from one learning study to other teachers and that the findings concerning pupils' learning may be valid even for other pupils and for different contexts. Learning study aims to have implications for teachers and teaching, what Nuthall (2004) refers to as pragmatic validity. Larsson (2009) suggests a variant of generalization in qualitative research, based on the perspective of the user of the research. Communicated patterns produced by research can be recognized in new cases and in that way the user of research get tools for identifying patterns in the everyday world.

This kind of reasoning could hopefully be applied in the field of learning study. The findings from this study may be used by teachers in their own teaching context, looking for the critical aspects identified and using them for structuring the content of teaching in order to support pupils in experiencing technical solutions in more complex ways.

In a recent article reviewing the development of technology education over the last two decades, Jones et al. (2011) call for an increasing focus on classroom-based research in order to develop understanding of how pupils learn in technology and how teaching can enhance pupils learning. They state that such work can make great contributions in terms of methodologies that are theoretically and empirically based. The involvement of teachers as research partners is well highlighted as a way to break down some barriers between the academic field and practice. The findings of this study will hopefully contribute to the understanding of pupils' learning in technology and how teaching can enhance learning, as well as in terms of an empirically and theoretically based methodology that takes its starting point in the classroom and benefits of teachers' professional knowledge.

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