A project about *materials* as subject content within technology education

Susanne Engström, Eva Björkholm, Per Norström

KTH Royal Institute of Technology, Sweden

Abstract

Within technology education in compulsory school in Sweden, materials are part of the core contents. What kinds of materials, and which characteristics that should be highlighted is open to interpretation. The study includes three sub-studies: 1/ An analysis of classroom activities during two lessons about materials in primary school, 2/ A Delphi study (Osborne et al. 2003) with experts on materials to gather their thoughts about materials in elementary technology education, and 3/ A review of text books. The purpose of this study is to put light on the field of materials as a content area by investigating what aspects of materials are highlighted in the three contexts. Two teaching sessions were video recorded. The data analysis focused on the content highlighted by teachers and students. Results suggest that the teachers and students highlight different aspects of materials. Nine experts participated in the first round of the Delphi study. All data were coded reflexively and iteratively. Results indicate the following major categories of material-related subject content: materials' usage, groups of materials, properties, creation and refinement, environmental aspects, and modern materials. The themes identified in the study could be seen as limited and concretized set of content, and thereby a guiding tool for technology teachers.

Key words*:* technology education; materials; subject content; classroom; experts; text books

Corresponding author e-mail address: evabjork@kth.se

Introduction

Materials, practical purposes, design and construction are key aspects in technology (de Vries 2005). Within technology education knowledge of materials is considered as essential in design and product development, as well as in students' construction work. Within technology education in the compulsory school system in Sweden, the knowledge area of materials is regarded as core content (The Swedish National Agency for Education 2011). In the syllabus it is outlined that students should be given the opportunity to work with various materials in their own construction work, as well as identifying and analyzing both their own and existing technical solutions with respect to materials and their properties. Moreover, assessing consequences of different technological choices for the individual, society and the environment is highlighted. The specific materials mentioned in the syllabus, overarching nine years of technology education, are "common materials, such as wood, glass and concrete", as well as "a number of new materials" (ibid. pp. 255-258). However, the syllabus is still open for interpretation, and needs to be further discussed, concretized and specified in order to develop the field of materials as subject content within technology education. This further elaboration is important since the Swedish technology subject has a vague identity and lacks teachings traditions, which has resulted in that the body of knowledge for planning teaching and evaluating student knowledge related to technology is still emerging (Björkholm *et al.* 2016; Hallström *et al.* 2013).

A conceptual model regarding technical solutions; *The dual nature of artifacts*, developed by Kroes & Meijers (2000), was introduced into the technology education community by de Vries (2005). According to this model, artifacts can be described on the one hand with the physical properties such as materials, and on the other as objects with functional properties. A previous study (Björkholm 2014) showed that young students, when referring to the physical properties, primarily focused on the material and its functional properties. Knowledge of materials appears to be relevant to students as they analyze artifacts. Other studies show that young students, when describing different materials, have difficulty distinguishing between the properties of an object and the properties of the material the object is made of (Cajas 2001). The concept of materials can thus be seen as a relatively abstract phenomenon. Former classroom studies have shown that pupils working with own designs develop knowledge in terms of skills regarding, among other things, functional properties of various materials and methods for processing and joining (Björkholm *et al.* 2016). Additionally, conceptual knowledge linked to the materials is developed in relation to the objects being produced, such as the name of the material, shape, technical activities and tools (Chatoney 2008), or more general concepts such as malleability (Jones & Moreland 2003). Chatoney (2008), who analyzed the interaction between pupils and teachers in classes where toys were produced, claims that knowledge of materials becomes visible from the beginning of the activities as soon as the objects' functions have been defined, and remain visible throughout the entire process.

Chatoney (2006) also investigated text books and saw how institutional relations to knowledge objects of material at primary school are time fluctuant. However, four knowledge areas seem to persist with stability over time; "naming a few substrates, knowing their origin, knowing a few intrinsic properties, and knowing how to use codes and language" (Chatoney 2006, p.159). These categories are seen as minimal targets for primary technology education. According to Chatoney (ibid.), the concept of materials involves several sciences and technologies in overlapping epistemological fields, and teaching associated to this concept within primary school is seen as a true challenge for the technology teacher.

Even though earlier research indicates different knowledge areas related to materials, there are ambiguities and perhaps also areas missing in view of the general educational purpose of the subject of technology in compulsory school. Our starting point is that different aspects of materials are forms of technical knowledge embedded both culturally and historically in technical activities with the aim being produced, consumed and acknowledged as technological solutions (Fleer 2015). Technical knowledge is thus rooted in a specific practice where it fulfills a function. Characteristic of all knowledge is that it develops through both verbal and physical action. Knowledge is, so to speak inherent in the activity itself and is tied to specific situations. Through repeated acts and experiences of the aforementioned, knowledge is developed (Fleer 2015; Schön 1983).

In order to put further light on the field of materials as subject content, and to discuss and specify possible aspects that are relevant for technology education in compulsory school, we want to study how materials as subject content are handled and understood by different actors. Our purpose in this study is therefore to identify and discuss what materials as subject matter may be within the technology subject. This could result in implications for teachers' teaching practice, teacher training, with a more concrete and broader view on materials.

With our starting point that technical knowledge is rooted in a specific practice, we desire in this project to examine what aspects of materials as subject content in technology education emerge as relevant with the help of different concerned actors in different contexts: the classroom members, the group of experts and the text books.

Research question:

What knowledge content in relation to the area of materials within the subject of technology at compulsory school level in Sweden is highlighted among the various actors concerned?

Body

Method

The overall study is based on three sub-studies:

1. An analysis of statements in the technology classroom in primary school
2. A study of empirical data based on written statements by materials' experts
3. A review of text books

In the first sub-study, two teaching sessions in primary technology education (students 8-9 years old) in two different schools were video recorded. In both classrooms, materials were focused in the activities but in different ways. One session consisted of a teacher-led classroom discussion focusing on different materials, such as wood, textile and plastic, and objects made of these materials. This classroom activity was intended as preparation for a student design task. The activities in the second classroom consisted of student construction work where the material used was part of the content that was focused upon. The videos were transcribed, and the text was then read iteratively in order to identify categories of aspects of materials that were highlighted in the interaction and activities in the classroom. Inspired by the activity theory (Engeström 1987; 1990), we focused on the object of the activities of both teachers and students in relation to the content. Our theoretical starting point makes us see that any given view of materials science is developed within the practical context where one is situated.

The ethical guidelines stipulated for research in the social sciences (Vetenskapsrådet 2008) have been carefully followed. This means that the teachers, as well as the students and their guardians (since the students were minors) were informed about the purpose of the study, and the use of video recording as method of data collection. The guardians were asked to give written permission for the children to participate. All names of participants have been anonymized.

In the second sub-study, we have by e-mail put a question to various experts active in various areas of practice. The question being; what do you consider compulsory school technology teaching should include in terms of materials? The experts were asked to assume that the teaching would give both general knowledge and some basic knowledge for further studies. The method chosen for eliciting the expert community's view was inspired by the first round, of a three-stage Delphi study (Murray & Hammons 1995; Osborne *et al.* 2003). Although we only completed the first round, and our method therefore can be regarded as a survey, our starting point shared the Delphi method aims; to improve group decision making by seeking opinions without face-to-face interaction (Delbecq, Van de Ven & Gustafson 1975). The anonymity of participants and the use of questionnaires avoid the problems commonly associated with for example group interviews: reverence to authority, impact of oral facility etc. (Martorella 1991). The Delphi process forces group members to provide written responses and opinions can be received from a group of experts who may be geographically separated (Murray & Hammons 1995).

As technology educators, we (the researchers) have views about the practices of technology education. It was important that these views not impinge on participants' responses. Therefore, very little guidance was given as to the expected content of responses. The procedure seeks to establish the extent of consensus or stability in the community. Brooks (1979) identified consensus as ''a gathering of individual evaluations around a median response, with minimal divergence,'' (p. 378). Commonly, the minimum number for a Delphi panel is considered to be 10 (Cochran, 1983). In this context (*material within education)*, we chose to define experts as those with acknowledged expertise in research or exploring *the materials*. The common element shared by the group was an interest in the materials in their research, producing, or other work. Thus, we sought views from leading scientists (n = 4); producers /managing directors/ (n=4), innovators (n=1) and those engaged in the public understanding of materials, a museum educator (n=1). None of the participants was aware of the identity of the other participants. One respondent withdrew, and only 9 experts answered our question. Opinions were sought about what ideas about materials should be taught in the school technology. Participants were requested to give a description of each idea to indicate a particular context where they thought a person might find the idea useful and to state why such knowledge would be important for a pupil to know. All the responses were coded reflexively and iteratively. Discussions among three researchers resulted in agreed categorizations of the responses. It resulted in comments from what nine experts think about materials as subject content within the school technology context. Themes emerged from this analysis and a summary was composed for each emergent theme, capturing the essence of participants' statements.

In the third sub-study we read the available textbooks in technology education for compulsory school. In the content analysis (Bergström & Boréus 2009) we searched for explicit mentioning of materials or descriptions of technical phenomena and problems where the choice of materials affects the outcome. The purpose of the textbook study is to find out how materials science and engineering are represented. There are very few textbooks in technology available in Sweden. The curriculum was revised in 2011, and some publishers have not yet updated their products. The books studied are the following:

Table 1. Books studied

Author(s)	Year	Title [English translation]	Grade (age)
Sjöberg, S.	2013/2003	*Teknik med fysik och kemi* [Technology with physics and chemistry]	1–3 (7–10 yrs)
Sjöberg, S.	2013	*Teknik grundbok* [Technology, fundamental book]	4–6 (10–13 yrs)
Sjöberg, S.	2012	*Teknik* [Technology]	7–9 (13–16 yrs)
Börjesson, G. *et al.*	2008	*Teknik direct* [Technology immediately]	7–9 (13–16 yrs)

The three books by Sjöberg (2012, 2013a, 2013b) all belong to the same series of textbooks, *Puls*, and are intended to be used one after the other.

The three different methods for gathering data generated different categories and themes. Those data sets were read over and over again within an iterative process. The aim was to interpret different themes covering all the three data sets. This iterative analyzing process was made by at least two researchers individually and all text content was used within the final themes. This iterative method of thematizing is described by McCartan & Robson (2015).

Conclusion

As an overall result, six themes emerged in the analysis of the whole amount of data. The six themes is presented and described in table 2 below. The descriptions of the themes in are greatly inspired by the experts' statements.

Table 2. Descriptions of the themes interpreted in the answers from the experts, the interaction in the two classrooms and in the text books.

Theme for materials knowledge content	*Description*
Theme 1: the materials' usage	That all products and buildings consist of materials. The material is the prerequisite of technologies and artifacts. The application (the goals of the problem, the need, purpose, function, context) determines the choice of materials. The material's limitations are significant.
Theme 2: That there are different materials - which kinds?	That there are different material groups and that these groups should be made visible: stone, wood, ceramics, polymers, metals, composites, textile.(Ceramics: clay, brick, glass, concrete)
Theme 3: Material properties	That material has different properties. The properties depend on how the material is built up. Chemical composition determines the properties: strength, toughness, softness, hard / brittle, temperature resistance, electrical, magnetic, etc. tendencies towards deformations Importance of the 'right' properties. Highlighting the special features. Advantages and disadvantages with different characteristics. The concept of strength. The concept of structures (electrons, atoms, cracks, pores, etc.).

Theme 4: Environmental impact of the material	The material's lifecycle The material's environmental impact. How the material can be recycled. The raw material: how does the raw material affect the world? Human experience of the material, the environments that are created.
Theme 5: How material is formed, refined and changed during use. Also a retrospective view of material production.	The materials have been created by man. How materials are produced, manufactured, processed. Possible methods of production for the material, price, availability. Material is seldom homogeneous, various additives and a structure which has significance (grain size, crystal forms, etc.) The material's historical importance: the Stone Age - Iron Age - Bronze Age etc. How production fits in together with other developments. Development of Swedish material industries (mining, steel, paper, textile, etc.)
Theme 6: New materials	That new materials are developed. Biomimicry - the way we humans mimic nature. That development is rapid thanks to new databases and modeling tools • Nano materials. • Plastic from algae.

All themes were identified in statements within texts (figure texts included) in the text books, but not to a very high extent. Among the experts, all themes emerged in various extents (see Table 3). In Table 3, the contexts of experts, classroom one, and classroom two are compared in terms of themes identified. Moreover, the statements in the classrooms have been analyzed based on who initiates the content of materials, the teachers or the pupils. Table 3 illustrates the distribution of the emerging themes among the different actors.

Table 3. The content related to materials highlighted by the different actors.

	Theme 1	Theme 2	Theme 3	Theme 4	Theme 5	Theme 6
Experts (n=9) *Number of experts expressing these ideas*	9	7	6	6	5	4
Teachers Classroom 1 % of initiated statements (n=141)	43%	26%	21%	0%	10%	0%
Teachers Classroom 2 % of initiated statements (n=146)	1%	1%	74%	0%	24%	0%
Pupils Classroom 1 % of initiated statements (n=59)	49%	12%	26%	0%	13%	0%
Pupils Classroom 2 % of initiated statements (n=86)	0%	0%	59%	0%	41%	0%

The analyses of the teaching sessions show that different aspects of material were highlighted in the different classroom contexts. Naming and identifying the materials (theme 2) and giving examples of products made by the material (theme 1) was greatly highlighted by the teacher in the general discussion in classroom one. These themes are exemplified in the following excerpts.

Teacher: All these things here in the box, do they have anything in common? Is it anything that is the same with them?

Pupil: Everything is kind of … is called something with metal also
(Classroom 1)

Teacher: What do you make of glass?
Pupil: It can be used for windows
(Classroom 1)

While the teacher focused on linking a specific material such as plastic, wood etc. one at a time to certain products, the pupils initiated groups of materials in different products, as shown in the following excerpt.

Pupil: You usually use metal, fabric and plastic in vehicles.
(Clasroom1)

Moreover, the origin of materials was highlighted by pupils:

Pupil A: Paper
Pupil B: Yes, but it's tree
(Clasroom1)

The aspect of materials' historical development was also initiated by the pupils:

Pupil C: One more thing, nowadays one usually don't use leather, but instead something artificial
Pupil D: Looks like leather
Pupil C: Leather, I think that's kind of 19th century-ish
Pupil D: A Stone Age thing

The functional properties of different materials and how these properties relate to suitability for use in different products were not brought up specifically by the teacher in this classroom. However, the pupils introduced these aspects in the classroom discussion and they contributed e.g. with knowledge of various types of plastic materials and the materials chosen for moving boxes from a user perspective, where corrugated cardboard materials were valued as more manageable.

However, the issue of the material's functional properties in relation to the object to be manufactured was greatly emphasized in the technology classroom focusing on design and construction work (theme 3). Pupils were encouraged to test different materials and evaluate their properties and suitability in terms of the design.

Teacher: If this stick was made of metal, could it be bent like this wooden stick?
(Classroom 2)

To summarize, the aspects of materials presented in Table 2 can be seen as delimitation and concretizing of the knowledge field of materials in technology education in compulsory school. Moreover, we have seen that the pupils contribute strongly to the common content knowledge that is made possible to develop in the technology classrooms. Two of the themes are not, or to small degree, present in the text books and in the classroom; environmental impact of the material (theme 4), and new materials (theme 6).

Discussion

This study aims to examine what subject content in relation to the field of materials in the compulsory school technology subject is highlighted by different actors concerned; classroom teaching, experts, and text books. Some content emerges in all three contexts: material usage, the material's functional properties and origin of the material, production and processing. Such content is also indicated by Chatoney (2006). Some content appears only among the experts and in the classroom discussion, such as the material's historical development, which is initiated by the students.

In one of the classrooms, great emphasis is placed to name different materials which is not explicitly highlighted by the experts but is a form of content found in studies by Chatoney (2006). In the technology classroom where students do their own design work, the task comprises a context where knowledge of materials is crucial to the construction being as good as possible, i.e. to realize the desired functions. Naming the material also becomes important and necessary in the interaction between pupils and between teachers and pupils. The focus on the different aspects of materials is clearly related to the different classroom activities.

The experts emphasize themes that seem to not emerge in the classrooms and to a small extent in the text books: the material's environmental impact and new materials. In addition, the experts emphasize the importance of explaining the material properties in terms of chemical composition despite the fact that technical features are in focus. In school subjects, chemical and functional properties of are separated in chemistry and technology, respectively. Consequently, students may not receive explanations of functional properties. If material properties are explained by chemical composition etc. it will be possibly easier to understand the material's environmental impact and its life cycle. We see the absence of such interdisciplinary aspects in the classroom and in text books.

The method we have used in this study could be used to identify and concretize the subject content in technology. Giving different actors a voice could be a way of broadening the definition of a content area. The themes identified in the study are consistent with the core content described in the Swedish technology syllabus. It could be seen as limited and concretized set of content, and thereby a guiding tool for technology teachers.

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