Exploring Materials as Subject Content within Technology Education

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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 documents (syllabus, teachers' handbooks). 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 objects of teachers and students. Results suggest that the teachers highlight different aspects; one teacher focused on naming the materials and describing what products they are used for, while the other emphasized the materials' properties. Ten experts participated in the first round of the Delphi study. Their responses were coded reflexively and iteratively. Results indicate the following major categories of material-related subject content: groups of materials, properties, creation and refinement, use, development over time, environmental aspects, and modern materials. The syllabus states that young pupils should study materials that they can use (wood, cardboard). Later common materials (steel, concrete) are introduced and at the end of compulsory school modern materials. Materials' properties and use in solving technical problems is studied, and their environmental effects. Preliminary results indicate that some content emerges in all three contexts: material usage, the material's functional properties and origin of the material, production and processing.

Key words: technology education, materials, subject content, classroom, syllabus, text books, experts

Background
Materials, practical purposes, design and construction are key aspects in technology (de Vries 2005). Knowledge of materials is considered as basic in design and product development, as well as in model construction within primary technology education. 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 pupils should be given the opportunity to work with various materials in their own design work, as well as identifying and analyzing both their own and existing technical solutions with respect to, among other things, materials. However, what kinds of material that are relevant in the school context, and which aspects that should be highlighted, is not explicitly formulated in the syllabus.

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 they referred 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. Earlier 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 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, claim that knowledge of materials becomes visible at 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 a true challenge for the technology teacher.

Even though earlier research indicates different subject content related to materials, there are ambiguities and perhaps also a lack of subject content, among other things, 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 new 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 governing documents and 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?

Method

The overall study is based on three sub-studies:

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

In the first 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 the subject of focus in the activities but in different ways. One class consisted of a teacher-led classroom discussion focusing on different materials, which was intended as preparation for a student design task. The activities in the second class consisted of student design work where the material 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. The data analysis was inspired by the activity theory (Engeström 1987; 1990), focusing on the motives 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. In the second study, we have by mail put a question to various experts active in various areas of practice. The question being; what do they consider compulsory school technology teaching should include in terms of materials? They were asked to assume that the teaching would give both general knowledge and a little 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 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 (n=1). None of the participants was aware of the identity 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 through the use of an open-ended questionnaire which asked: What, if anything, do you think should be taught about the materials?

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. Six themes emerged from this analysis and a summary was composed for each emergent theme, capturing the essence of participants' statements.

In the third study we read the available textbooks in technology for compulsory school. 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 and comparison is to find out how materials science and engineering are represented on this intermediate level. 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.

Findings

The analyses of the teaching sessions show that different aspects of material were highlighted in the different contexts. Naming the materials and giving examples of products made by the material was greatly highlighted in the classroom discussion about materials. 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.

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 removal packing boxes from a user perspective, where corrugated cardboard materials were valued as more manageable. In contrast, 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. Pupils were encouraged to try different materials and evaluate their properties and suitability in terms of the design. Naming the materials was not explicitly highlighted in the teaching session. In table 2 (below) different areas of subject content are shown in the two classrooms.

Table 2. The content related to materials highlighted in the two classrooms.

		Lesson 1		*Lesson 2*	
Cat	*Technology content materials*	*Number of statements*	*Who initiated the content? Teacher (T) Pupil (P)*	*Number of statements*	*Who initiated the content? Teacher (T) Pupil (P)*
1	Material related to objects	66	58 (T)	2	2 (T)

	(the material's usage)		8 (P)		0 (P)
2	Process (shaping, joining etc.) the material in the making of specific objects	5	3 (T) 2 (P)	70	35 (T) 35 (P)
3	Identify and name material groups	45	37 (T) 8 (P)	2	2(T) 0 (P)
4	Evaluating the material in relation to the object's function	21	16 (T) 5 (P)	123	84 (T) 39 (P)
5	Material's constructional properties	12	5 (T) 7 (P)	-	
6	Several different materials in one object	7	1 (T) 6 (P)	-	
7	Material origins	1	0 (T) 1 (P)	-	
8	Name for material = name of object	10	1 (T) 9 (P)	-	
9	Process materials with no connection to the production of items	15	12 (T) 3 (P)	-	
10	Class objects in relation to the material	10	0 (T) 10 (P)	-	
11	Functional properties of materials	15	9 (T) 6 (P)	35	23 (T) 12 (P)
12	Materials from a historical perspective	3	0 (T) 3 (P)	-	
		210	142 (T) 68 (P)	232	146 (T) 86 (P)

In the experts' statements the following themes could be discerned on what the subject matter in relation to knowledge of materials can include.

Table 3. Descriptions of the themes interpreted in the answers from the experts.

Theme for materials knowledge content	*Description*	*Number experts that expressed and developed their ideas on this*
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.	9 of 9
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)	7 of 9

Theme 3: Material properties	That materials have 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.).	6 of 9
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.	6 of 9
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.)	5 of 9
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.	4 of 9

The analysis of the syllabus showed, that for the technology subject, the following aspects are mentioned as parts of the subject's core content. (The Swedish National Agency for Education , 2011, pp. 255–258):

Years 1–3 ‘Materials for their own constructions. Their properties and how they can be combined.

Years 4–6 ‘Common materials, such as wood, glass and concrete, their properties and use in solid and stable constructions.’

Years 7 – 9 ‘The importance of properties, such as tensile and compression strength, hardness and elasticity when choosing materials for technical solutions. Properties and applications of a number of new materials.’
‘Recycling and reuse of materials in different manufacturing processes. How technological solutions can contribute to sustainable development.’

The syllabus is based on a set of subject abilities and a list of core contents. For the technology subject, the abilities that pupils are to develop are as follows (The Swedish National Agency for Education, 2011, pp. 254–255):

- identify and analyse technological solutions based on their appropriateness and function,
- identify problems and needs that can be solved by means of technology, and work out proposals for solutions,
- use the concepts and expressions of technology,
- assess the consequences of different technological choices for the individual, society and the environment, and
- analyse the driving forces of technological development and how technology has changed over time.

In the four studied books, descriptions about materials appear in the following forms:

Functional characteristics	Copper is a good conductor of electricity.
Actual use	Roof-tiles or sheet metal is used to cover roofs. Bicycle tyres are made of rubber.
Creation or extraction	Glass is made by heating sand (Börjesson)

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, syllabus 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: the material's historical development (by the students), and that there are different material groups (the teachers).

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. Experts, however, emphasize themes that do not emerge among the other parties: 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 chemistry and technology are separated. 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 book.

References

Björkholm, E. (2014). Exploring the capability of evaluating technical solutions: a collaborative study into the primary technology classroom. *International Journal of Technology and Design Education*, *24*(1), 1-18.

Björkholm, E., Andrée, M. & Carlgren, I. (2016) Exploring technical knowledge in the primary technology classroom. *Australasian Journal of Technology Education*. http://www.ajte.org/index.php/AJTE

Brooks, K.W. (1979). Delphi techniques: Expanding applications. *North Central Association Quarterly*, 53, 377-385.

Cajas, F. (2001). The science/technology interaction: Implications for science literacy. *Journal of Research in Science Teaching, 38*(7), 715-729.

Chatoney, M. (2006). The evolution of knowledge objects in the primary school: A study of the material concept as it is taught in France. *International Journal of Technology and Design Education, 16*(2), 143-161.

Chatoney, M. (2008). Contemplation and use of technical aids in primary school. In J. Ginestié (Ed.). *The Cultural Transmission of Artefacts, Skills and Knowledge: Eleven Studies in Technology Education in France*, 125-147. Rotterdam: Sense Publishers.

Cochran, S.W. (1983). The Delphi method: Formulating and refining group judgements. *Journal of the Human Sciences,* 2, 111-117.

Delbecq, A.L., Van de Ven, A.H., & Gustafson, D.H. (1975). *Group techniques for program planning*. Glenview, IL: Scott Foreman.

De Vries, M. J. (2005). *Teaching about technology. An Introduction to the Philosophy of Technology for Non-philosophers*. Dordrecht: Springer.

Engeström, Y. (1987). *Learning by expanding: An activity-theoretical approach to developmental research.* Helsinki: Orienta-Konsultit Oy. Retrieved March 28, 2015, http://lchc.ucsd.edu/MCA/Paper/Engestrom/expanding/toc.htm

Engeström, Y. (1990). *Learning, Working and Imaging. Twelve Studies in Activity Theory.* Helsinki: Orienta-Konsultit.

Fleer, M. (2015). Theorising technology education from a Cultural-Historical perspective: foundations and future imaginings. In P.J. Williams *et al.* (eds.), *The Future of Technology* Education, Contemporary Issues in Technology Education, 35-55.

Jones, A. & Moreland, J. (2003). Developing classroom-focused research in technology education, Canadian Journal of Science, Mathematics and Technology Education, 3(1), 51-66.

Kroes, P. A & Meijers, A. W. M.(2000) Introduction: a discipline in search of its identity. In P. A. Kroes & A. W. M. Meijers (eds), *The Empirical Turn in the Philosophy of Technology*, pp. xvii–xxxv. Oxford: Elsevier Science.

Martorella, P. (1991). Consensus building among social educators: A Delphi study. Theory and Research in Social Education, 19, 83-94.

Murray, J.W. Jr. & Hammons, J.O. (1995). Delphi: A versatile methodology for conducting qualitative research. *Review of Higher Education*, 18, 423-436.

National Curriculum (2011), “Curriculum for the compulsory school, preschool class and the recreation centre”, available at: http://www.skolverket.se/publikationer?id=2687 (accessed 15 May 2016).

Osborne, J., Collins, S., Ratcliffe, M., Millar, R., & Duschl, R. (2003). What “Ideas-about-Science” Should Be Taught in School Science? A Delphi Study of the Expert Community. *Journal of Research in Science Teaching, 40*(7), 692-720.

Schön, D. A. (1983). *The reflective practitioner: How professionals think in action.* New York: Basic Books.