Technology & design as contexts for science and mathematics? An empirical study of the realisation of curriculum intentions in Norwegian schools

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Abstract

The research presented in this paper investigates how conceptual knowledge from mathematics and science is addressed in four extensive cross-curricular teaching projects in different Norwegian schools (year 3-10). Classroom sessions related to the project were videotaped with two cameras recording selected groups of students and one recording the classroom as a whole. Recordings cover a total of ca 250 hours. Selected parts of the material were analysed with regards to communication between teacher and students and within student groups. Results indicate that conceptual knowledge from science is rarely addressed by teachers and students. With some interesting exceptions, this also applies to mathematics. Knowledge discussed by teachers and students was for the most part technological in nature and did to a low degree draw on or motivate for conceptual knowledge from science and mathematics.

We interpret this finding as an effect of two matters: Firstly, technological tasks mainly require technological knowledge rather than science and mathematics in its pure form. Secondly, the conceptual knowledge that is of relevance is not brought to stage due to the strong focus students as well as teachers have on the practical aspects of the student project. From the study we conclude that technology in the Norwegian curriculum should be strengthened as a knowledge domain in itself, and not considered as merely contexts for the learning of conceptual knowledge from other subjects. Links between technology and science/mathematics need to be conceptualised in other ways.

Introduction: Design and Technology in the Norwegian curriculum

The research presented in this paper investigates the relationships of technological knowledge and conceptual knowledge from science and mathematics as it comes to expression in the classroom. This is done by means of six of four extensive cross-curricular teaching projects in different Norwegian schools (year 3-10). In our analysis of the teaching projects, we focus on conceptual knowledge, in the meaning of declarative, generic knowledge comprising concepts, relationships and principles that may have significance for action (see McCormick, 1997).

In the Norwegian curriculum for compulsory school, implemented in 2006, design and technology is positioned as a cross-curricular topic involving the three subjects Arts and crafts, Science and Mathematics (Utdanningsdirektoratet, 2006). This curriculum arrangement was partly based on the vision that practical, technological projects for pupils would serve as constructive and motivating contexts for learning science and mathematics (see Bungum, 2004, 2006). The curriculum document underlines the link to science in particular by stating: "The interaction between natural science and technology is a key part of this main subject area. Natural science principles constitute the basis for understanding technological activities" (Utdanningsdirektoratet, 2006).

The curriculum of the three subjects involved is, however, not very well coordinated. In Arts and crafts, design is represented as a main subject area. In lower secondary school it includes the design and making of products, tools and techniques for this process and also perspectives on consumerism and sustainability. In the mathematics curriculum, the subject area is represented mainly by aims about enabling students to apply skills from algebra and geometry in contexts such as design and technology. In Science, design and technology is described as a specific main subject area, combining aims that are technological in nature with aims that focus on applying science knowledge in practical contexts.

There is little systematic evidence of how the subject area technology and design is realised in schools, but a small survey indicates that many schools do not pay particular attention to the cross-curricular nature of the subject area (Dundas, 2011).

Epistemic perspectives on science, technology and their relationship in schools

The positioning of technology in the Norwegian curriculum actualizes various perspectives on the nature of technological knowledge. In the philosophy of technology it is commonly accepted that technology represents a domain of knowledge in its own right, and should not be regarded as straight-forward applications of generic knowledge from science and other academic disciplines (see e.g. Staudenmaier, 1985). The different purposes of science and technology are often used to make a demarcation between the two areas of activity. In addition, technology is highly situated in the practical context, and involves knowledge that cannot be understood simply by means of discerning the relevant scientific laws (Boon, 2006). To be useful, this knowledge needs to be reconstructed, combined with other forms of knowledge and adjusted to the situation at hand (Layton, 1991). Other forms of knowledge may be knowledge of operational principles (Vincenti, 1990) where pure theoretical knowledge may explain working principles of each component, but not how they operate together on a systemic level.

The focus on technology as independent of science may, however, become too one-sided (Tala, 2009), as science and technology are in their modern form highly interrelated, described as a "seamless web" (Hughes, 1986), post-academic science (Ziman, 1984) or technoscience (Bencze, 2001; Tala, 2009). Many have pointed to that this close relationship should also be represented in the schools' curricula, in teaching and in how students engage with science and technology in their general education (Barlex & Pitt, 2000; Bencze, 2001; Hadjilouca, Constantinou, & Papadouris, 2011; Petrina, 1998; Sidawi, 2007).

The way technology is framed in the Norwegian curriculum provides opportunities to explore the potential for the teaching of science and other subjects in a context of design and technology, and to investigate how students may make use of knowledge from these subjects in creating technological artefacts and systems.

Research methods

The empirical study presented in this paper investigates how conceptual knowledge from mathematics and science is addressed in four extensive cross-curricular teaching projects in different Norwegian schools (year 3-10). Four teaching projects were developed by the research group in cooperation with the local teachers, but fully taught by the teachers in six different schools. In the development, we attempted to create cross-curricular projects with a good potential for incorporating science and mathematics, but also that the projects should be realistic to run in schools with regards to materials as well as teacher knowledge and skills. With one exception, which was a one day event, each project lasted ca 30 hours, and the schools involved ran only one project.

Classroom sessions related to the project were videotaped with two cameras recording selected groups of students and one recording the classroom as a whole. Recordings cover a total of ca 250 hours.

From the video material, we have analysed approximately 100 situations of communication, where either students or teacher made contact in order to discuss aspects related to the project. The analysis focuses on dialogues between teacher and groups of students, since the use of language constitute an essential aspect of learning (Mortimer & Scott, 2003). This means that we have not considered the value of mere practical experiences for future learning and motivation in science and mathematics.

Selected parts of the material were analysed with regards to science and mathematics content in the communication between teacher and students and within student groups. The first step in the analysis was to choose situations where either the students or the teachers made contact in order to discuss aspects related to the project. Thereafter the communication in each situation was classified based on whether concepts related to science or mathematics was discussed or not. The need for science and mathematical knowledge in order to solve the technological challenge given was also evaluated.

In order to secure data validity, observer triangulation (see Robson, 2002) was conducted between members of the research group in interpreting and coding the video data.

The student projects

The four student projects were:

1. Models of buildings

In this project students used the software Google Scetchup to design a building on the computer, and to make templates of the individual parts with correct measures. The conceptual knowledge involved is the scales students work with in order for the measures to be accurate. With help from the templates students then built the model in cardboard and other materials. This project was put into practice at three schools. At one school students in grades 3-7 designed a simple open shelter to be used for outdoor activities in the local community. The fact that such a shelter was to be built, and that the students' models would be used to generate ideas for its design, added an aspect of authenticity to the project. In another school, students in grade 9 designed the house they wanted to have in the future. And at the last school students at grade 8 designed constructions for a playing ground, also a project that was to be realised in full size by the local authorities.

2. Model of town with lights

The project involved building a model of the students' home town Hammerfest, with streets and buildings, and surrounding landscapes including mountains and the fjord with an island. The project was undertaken in a class of grade 10, where students worked in groups performing various parts of a joint model. Students themselves were to decide on what scales to use and what parts of the city and the landscapes that were to be represented in the model. The model was to be enlightened by electric light, making a link to the fact that Hammerfest was the first town in Norway with electric street lights. The project has potential for working with conceptual knowledge in terms of scales in mathematics and principles of electrical circuits in science.

3. Model of oil platform and drilling system
The activity was undertaken in grade 8 and formed part of a larger project about oil exploration. Students used Lego Robotics to construct the drill, and were allowed to use various materials for making the platform. The main challenge for the students was to design a motor system that allowed the drill to rotate and simultaneously make a vertical movement. The project potentially involve concepts and principles from mechanics, such as force and transformation of movement.

4. Model of the solar system
In this project students in grade 5 created a model of the solar system with correct scaled-down dimensions. They made models of the sun and the planets in various materials with appropriate colours and relative sizes calculated by using scales and information about real planet sizes. The model of the sun was placed at the school, and students used a GPS system to find the correct position of the planets in the landscape surrounding the school. This way the project aimed at facilitating students' skills in working with scales in general, and dimensions in space in particular.

Results

Results indicate that conceptual knowledge from science and mathematics is rarely addressed by teachers and students. Knowledge discussed in the dialogues was for the most part technological in nature. Clear evidence of increased motivation among students can be found, but this motivation seemed to be directed towards the project as such and not towards specific school subjects.

In none of the situations analysed students or the teacher discussed any concepts or principles from science. With some interesting exceptions, this also applies to mathematics in project 1-3. When mathematics was brought into the discussions, the initiative came from the teacher and was not really necessary for solving the task. In project 4, however, mathematical calculations of measures were crucial for finding the distances in the model of the solar system. Mathematics thus formed part of the initial work in the project.

The lack of science and mathematics content in project 1-3 can be illustrated through three situations that appeared to have a good potential for incorporating concepts and principles from science and mathematics. In the first situation, grade 10 students in project 2 (model of town) are working with scales between a map and the decided size of their model. Buildings were supposed to also have a correct scale relating to the landscape. The task of calculating with scales soon became very complex, due to the irregularity of the shapes. Some of the students then figured out they could make use of an overhead projector in transferring the map to the size of their model. In this tool, the transfer of measures to a different scale is "inbuilt". Students made use of their creativity and understanding of how a projector can assist in fulfilling their task. This illustrates how technological work is dynamic and draws on combinations of knowledge and ideas. Understanding of scales formed part of the students' solution, even if they didn't succeed with calculations. They did, however, succeed in finding an effective solution for an optimal result, and thus did not need to conduct the complex calculations that would be needed if a polygon should be scaled up.

The second situation is drawn from the same student project, and relates to electricity. Since electric light chains (for Christmas decorations etc) are cheap and easily available, neither students nor teachers found it worthwhile wiring their own circuits with bulbs. This could have given opportunities to learn about differences between ways of connecting (series / parallel), and relations between voltage, current and energy use. However, from a technological point of view, the class chose the optimal solution with regards to stability in the circuit and their use of time and effort, which solved the problem without time consuming activity that were doomed to give suboptimal results.

In the third situation, students in project 3 were working with construction of a model of a drilling rig. The task of making a system that allows for rotation and vertical movement simultaneously can be interpreted as involving mechanics in terms of forces, transformation of movement and energy transfer. Yet they have some relevance, concepts and principles from physics were not of any use in solving the task itself. The task rather required experience with and understanding of technological principles in a less abstract form and adjusted to the actual context as described by Layton (1991).

Conclusion and implications

The results of the study shows that conceptual knowledge from science and mathematics to a little degree formed part of the cross-curricular projects on design and technology, neither as tools to solve the tasks nor as a learning outcome. This deviates somewhat from the curriculum intentions and some of the arguments put forward to introduce design and technology as a cross-curricular topic in Norwegian schools.

We interpret this finding as an effect of two matters: Firstly, technological tasks often require mainly technological knowledge rather than science and mathematics in its pure form. Secondly, the conceptual knowledge from science and mathematics that is of relevance is not brought to stage due to the strong focus students as well as teachers have on the practical aspects of the student project. Project 4 about the solar system works as an exception here, showing that mathematics may form a constructive part of a technology project, given that the mathematics knowledge is an absolute prerequisite for solving the task. In the other projects it was not.

From the study we suggest that technology projects *may* provide useful practical contexts for conceptual knowledge from mathematics and science, but if it does not form a necessary tool this knowledge should be addressed in separate sessions in the subjects. Rather than viewing technology and design as contexts for the learning of science and mathematics, effort should be put into identifying and conceptualising the genuine technological knowledge to be represented in the curriculum.

This does not mean that links to science and mathematics are absent from the technology projects we have studied. The links do, however, go beyond the learning and application of pure conceptual knowledge. Firstly, the projects provide opportunities for experiences that facilitate a deeper understanding of specific topics in science and mathematics. For example, in project 4, gave students a bodily experience of the relative dimensions in the solar system, an experience that is hard to get from textbooks and classroom teaching. Secondly, the projects involve aspects of systematic experimentation that resembles how professionals educated in a range of disciplines, including science and mathematics, work with problem solving in authentic projects in technological contexts. In order to have any effect on students' motivation and understanding, these links must be made explicit to students.

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