Technology and Design Education
From play to profession

Bjørn Magne Aakre

The purpose of this paper is to discuss the purpose and role of Technology and Design education, and to present the results from a case study on the topic. The motivations are the fact that modern Technology and Design constitute important part of our culture, and make strong influence on innovation and development in our society. Education also deals with formation of identity, attitude and behaviour, and about empathy and the enthusiasm we need to lead the development of our society in ways that serves humanity and our environment in the best possible way. For this purpose we chose study how Kongsberg municipality in Norway makes effort to educate the younger generation about Technology and Design through a centre outside the regular schools.

Introduction

Technology and Design was one of the core issues discussed when the Norwegian Government decided to prepare a new school reform few years ago. This reform[1] was implemented from August 2006, (KL06). Many special interest groups, and also educators, argued that now it was time for to introduce a new school subject for this purpose, and there was made a proposal to do so. However, the conclusion was a compromise: Firstly, information and communication technology (ICT) became one of five basic competences to be focused on through out all subjects in the school. Secondly, technology and design became an interdisciplinary topic within three existing subjects: arts and crafts, natural science and mathematics. Formulations about these are now included in the new national curriculum, and they are implemented in the schools.

Figure 1 Students in 6ᵗʰ grade making and programming a "smart house"

To obtain concrete knowledge of this important field of education, we decided to make a study in Kongsberg municipality. Kongsberg was chosen because they already made active steps to implement the idea, to defined technology and design as an integrated part of culture and as a strategy for the city, not only a subject in the schools. The city government decided to cooperate with main industries and businesses in the region in order to strengthen and to develop this cultural identity of the city and its inhabitants. A long term strategy was developed along with the same idea. We wanted to study the grounds and reasons for this strategy, and how a centre could work compare to regular lessons in each of the schools. Finally we wanted to study the use of materials, the learning strategies and the learning processes taking place at this local centre named *devotek lab*[2]. Since this study took place, the department of culture also established a special lab with focus on environmental energy and technology with focus on sustainable development. This program seems to be unique and interesting in relation to a growing demand for study on environmental technology and design, both in a national and international perspective.

Theory and Method

The formation of mind, and a personal identity of young people today, is to a considerable extent determined by the quality of the interaction between the individual and the culture. This is not only

---

[1] The Reform was named "Kunnskapsløftet".

[2] *devotek lab* is the trade mark of a learning centre located at the city library in Kongsberg, Norway. It is sponsored by the firm devotek, SpareBank1 and Buskerud county.

limited to formal education and the use of formal language, but also the artefacts they obtain and use in different ways. The way they stage and express their own person at school, in leisure time and other situations they take part in, plays an important role in this formation process. This process also includes toys used by kids as individuals, and modern tools used for exchange and communication between friends. For young kids, and especially teenagers, clothes of a special fashion, color or brand, and other more advanced artefacts like mobile phones, iPods and computer games plays an important role. This is not only about culture in a broad and general sense, but also includes segments of culture in special groups of ages and interests. Such groups could be teenagers in general as well as the negotiations taking place within small sub groups. This means that education today need to emphasize the different aspects of culture and their influence on the interest and behaviour of kids and teenagers, as well as their future vocational preferences and career.

Critical- constructive didactics seems well suited for further analysis and discussion of this case because the theory has many of the same characteristics as sociocultural theory, (Klafki:2001). This perspective has received much attention in educational research in resent years. The reason seems to be the growing problem of identity formation in a world that has become open and global, by means of for instance communication technology. Both theories emphasize the influence of culture in learning processes, and do not explain learning as pure intellectual training of the individual cognitive capacity. As an alternative, sociocultural theory focus on the cultural formation of mind from different aspects of culture the students take part in, both at school and on other arenas of life. Much emphasis is put on different kind of tools, and how cultural tools are used in different ways to mediate intellectual growth, understanding of meaning and formation of identity in a society that has become more and more blur and lacking fixed values and standards. This problem has been discussed from many perspectives, (Habermas:1981 and Vygotsky:1986). Meaning is another aspect related to hope and confidence about the future, and a basic belief that the individual as well as the society together will be able to cope with the challenges of the future and to make a sustainable society. That means technology and design is not longer a goal in it self, but means to fulfil hopes for a better society and a safe future for all. Based on this consideration we formulated the main question for this study:

What are technology and design education and its purpose, and how can it be organised to help foster harmonic identity as well as the competences needed to cope with the role of technology and design in a post-modern society?
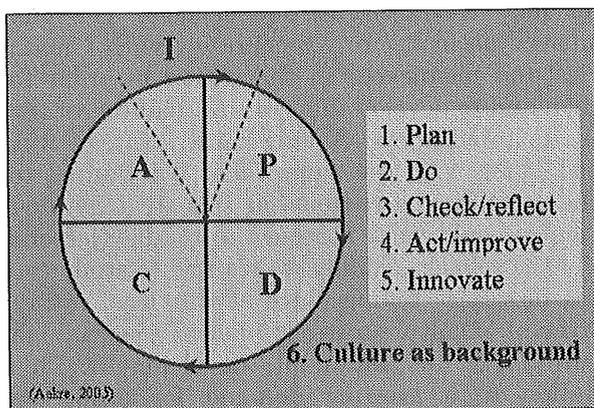

Figure 2 Research model

For this study we developed a theoretical model that try to balance between learning *practice* and *critical reflection* related to a cultural context. The model with its six categories is visualized in the figure. The prime source of this idea was Argerys and Scön, (1989), but also critical theory, (Habermas:1981). For instance: Habermas makes the assumption about identity that we learn who we are as autonomous agents from our basic relations with others. Therefore we included *culture (6)* as a category in the background. We also included *innovation (5)* as something important in education today. Competence in creativity and innovation seems necessary to cope with a society characterized by more or less continuous change. We also made the thesis that innovation could sometimes be a result of critical reflection, and sometimes part of a well planned strategy. The other four categories we got from the Deming "wheel", (Deming:1993 and Imai:1987). This model is widely used to explain quality systems, and common in for instance Japan. These categories are well known as: (1) *Plan*, (2) *Do*, (3) *Check/reflect* and (4) *Act/improve*. In a monoculture like an industrial production system they may still be useful, but for the purpose of modern education and cultural change we think to be *innovative*, to have knowledge of *cultural* resistance and willingness to take risks is also very important. In this case I

explain innovation as a more fundamental new way of thinking, or as a paradigm in science explained by Thomas Kuhn, (Kuhn:1996).

Critical- constructive didactics advise method integration in educational research, (Klafki:2001). The main argument is that research on education in most cases involves values of some kind that need to be analysed and discussed. Therefore also historical hermeneutic method is considered to be the main approach to educational research. However, in many cases there are no clear "historical text" available to study, it has to be produced. Therefore empirical studies also need to be made in most cases, unless pure historical documents are the sources of information. Finally, all sources, weather they are historical or empirical, need to be critically analyzed for inconsistency or arguments based on some concealed ideology.

Kongsberg municipality and *devotek lab* was chosen for a case study for several reasons. Firstly the city already made concrete steps to do something with this challenge, and there was already a lab available for the study. Secondly Kongsberg is one of the most technology oriented cities in Norway with many high tech industries who are concerned about how they will be able to maintain their position in the future. Finally, there was a good atmosphere of collaboration between government institutions and local industry that had already financed and established *devotek lab* as a learning centre for modern technology and design. First of all we studied written documents about the establishment of the centre, and the arguments that was the bases for this centre, and we compared with the national curriculum documents of Norway. We also visited the centre, observed the location, talked with the people who had been involved with the process and analysed the materials they used.

The empirical study consists of 13 groups: 11 groups of 84 students in technology and design, and 2 groups of 48 students in science and technology. The students were from 5th grade to upper secondary school, but we did not make any systematic stratification as we had to choose the groups available. We also studied 2 groups taking part in leisure activities. Analytical categories for the observations were organized according to the theoretical model we made. Within these categories learning processes were observed and recorded in tables. To support the observation we also some times used video recordings, but unfortunately not in a systematic way all the time.

Main concepts
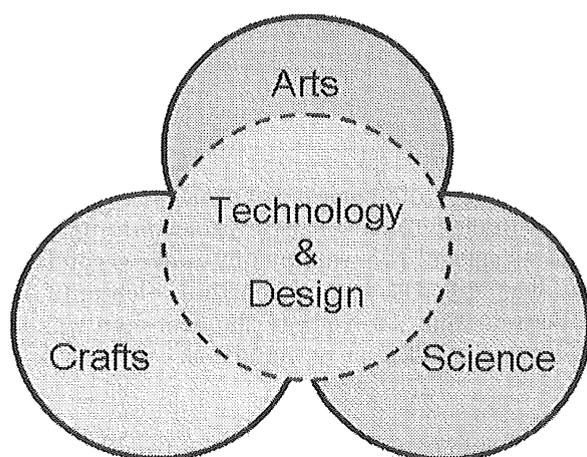
Aakre, 2006

Figure 3 Model of main concept

Technology and design education is about the discussion and implementation of technology and design in general education, not as special training for a specific vocation or profession. In most cases the context will be basic compulsory education like elementary and lower secondary school. In some cases it could be relevant also for preschool as well as upper secondary education. The main questions were why technology and design education should be part of general education, what should be the content of such education on different levels and how students can be able to learn relevant knowledge from such programmes in a best possible way.

Technology has its origin from the Greek word "techne", or "techné", which is often translated as *craft, craftsmanship* or *art*. It is explained as the rational way of making an object, or to accomplis a goal or objective by means of art. Techne resembles the implication of knowledge of principles, althougsh "techne" differs in that its intent is making or doing something, and not pure "disinterested understanding" as there is in art which is more aesthetic. The Greek probably did not differentiate

between arts and crafts. This differentiation was a result of the modernist way of thinking after the Medieval Era. Finally, "techne" is also related to science. In the same way crafts is the application of art, technology also involves the application of knowledge from science.

Historically, technology education has been related to practical and aesthetical aspects of education in different ways, but the basic understanding of the concept has changed over time. The Ancient Greek had practical and aesthetic activities in their educational program *paideia*, but work was not included, (Myhre:1991:22). However, later on great European educators like Comenius and Pestalozzi included work as a general concept of practical and aesthetical education in their programs. During the early industrial era technology education became very specialist and formal production systems, like the Swedish sloyd. However, Dewey and other progressive educators changed this trend back to a concept more like the one of Comenius and Pestalozzi. Art also gradually became an important part of practical aesthetical education in basic schools, and Dewey wrote important essays on the topic aesthetic experience, (Dewey:1938).

Design has an even more complex meaning as it could mean "drawing" or "planning". It was first introduced in Firenze about 1560 AC to distinguish between the drawing or planning of an artifact, and the pure making of it. Today design tend to involve the creative part of inventing and making something, to fulfill not only functional qualities but also aesthetic qualities like comfort vs. discomfort, beauty vs. ugliness, attractive colors vs. disgusting colors etc, (Aakre:2005). To summarize this discussion on concepts, I made the following definition:

> *Technology and design education is a general study on ways of thinking and the practical application of knowledge from arts, crafts and science, as well as critical reflection on its power and impact on our society and culture for the purpose of sustainable development.*

Today arts, crafts and science have a tradition as separate school subjects in most countries, at least in some way or another. However, the status of technology in general education still seems to be rather blur. In Norway for instance, handicrafts and drawing first became school subject, then gradually there were more emphasis on arts. Today the subject is called "Arts and Crafts". However, in recent years also technology has been discuss and implemented in the national curriculum, though not as a specific subject. So far, technology has become an interdisciplinary topic including arts, crafts and science. Design tends to involve the aesthetic aspects of something, while technology more often tend to be related to science, and finally the making process related to crafts. The concept of ICT has become even broader as it is now linked to all subjects in basic education.

National context, Norway

Since the 1980's there has been a discussion on the role of technology and design as a concept in general education. In the 1980's main focus was put on computer technology and software programming that was implemented as elective courses in basic education, and as special programmes in upper secondary school. During the 1990's also design and architecture was discussed as important elements in postmodern education, and finally included in the national curriculum. In Norway the first step was to change the content and the name of the former subject "forming" to "kunst og håndverk", or arts and crafts, in 1997, (KUF:1997).

In the last reform technology and design was proposed as a new subject in basic education from grade 1-10. However, the conclusion was a compromise: Firstly, information and communication technology (ICT) became one of five basic competences to be focused on through out all subjects in the school. Secondly, technology and design became an interdisciplinary topic within three existing subjects: arts and crafts, natural science and mathematics. Table 1 shows Technology and Design since 2006 and the way it is organized in relation to other contents of the three school subjects: Arts and crafts, Natural science and Mathematics, (KD:2006).

Table 1 Technology and design as an interdisciplinary theme, grade 1-10

Arts and Crafts	Natural Science	Mathematics
Visual communication Design Art Architecture	The budding researcher Technology and design Diversity in nature The universe Phenomena and substances/elements 11th grade: Bio-technology, Energy for the future, Sustainable development	Numbers Geometry Measuring Functions Probability Economics Culture and modelling etc.

The curriculum for mathematics has no explicit content area called technology and design, but contains explicit expressions like: *Mathematics shows its usefulness as a tool when we work with technology and design and when we work in practical applications.*

The content is described in the curriculum as competences after 2nd, 4th, 7th and 10th year. To make this paper short, we only include some main concepts of the content, (KD:2006).

After 2nd the students shall be able to make simple objects and designs in paper and textiles by tearing, cutting, gluing and braiding, and to tell others about what they have made. They shall also be able to make artefacts that propeller by water or air, and artefacts using reflection of lights.

After 4th year the students shall be able to both plan and make simple artefacts by knitting, weaving, felting, sewing, nailing and fixing by screws in various materials. They shall also be able to plan, build and test simple models of building constructions and to document the process from idea to complete product.

After 7th year the students shall be able to prepare simple artefacts using various materials and explain the relation between idea, choice of materials, craft techniques, form, colour and function. They shall also be able to use different tools and various techniques for joining hard- and soft materials. They shall be able to elaborate how transfer of movement has been used throughout history to exploit energy potential in wind and water. They shall be familiar with how materials, problem solving and production can constitute the basis for innovation and entrepreneurship.

After 10th year the students shall be able to design products based on a specification of form and function, and to describe different solution for design of products using sketches and digital software. They shall also be able to create clothing and discuss fashion, price and quality in a consumer perspective, and talk about how indigenous peoples and other cultures have influenced and inspired various cultural expressions. The students shall be able to explore, experiment with and formulate logic reasoning by means of geometric ideas, and elaborate on geometric relations that are particular important in technology, art and architecture.

After 11th year the students shall be able to explain genetic coding and the main characteristics of protein synthesis and discuss the importance of heritage and the environment. They shall also be able to assess information about and elaborate on ethical issues related to technology and design.

Local context, Kongsberg

Technology, design and innovation are concepts often used to express rapid change, and sometimes even easy ways to success. However, this idea seems not very true. Innovation is also about long term commitment to a well planned strategy, ability to see trends and possibilities, and finally the ability to act on the possibilities available at the right time. The context of this study was the city of Kongsberg, and we found that this was the best explanation for the success of the industry in this city during the last 20 years. Twenty years ago the local industry turned into deep crises when the main company[3] with its about 5000 employees world wide, were close to bankruptcy. The effort that was done since 1987 explains much of the success today. However, behind this success is a strong culture for high quality work and innovation that over time became part of the identity of the city and its inhabitants[4]. It was

---

[3] Kongsberg ASA, first established in 1811: http://www.kongsberg.com/
[4] Based on written reports of 2006 by the Head of Culture, Heidi Hesselberg Løken

this identity the local government wanted to maintain and to improve for the future when *devotek lab* was established in close collaboration with the local industry. It started as a leisure activity in the evenings to reach out to young people in the ages between 10-13. However, today both students from preschool, elementary school, lower secondary school and even upper secondary schools are target groups. The project has also been extended to include more municipalities in the region, and also more programs like "innovation and research programs for kids". In 2006 about 305 groups came to the centre. At the same time the local high tech industry experience rapid growth and there became a problem to recruit highly skilled people like scientists and engineers. Therefore the role of the centre also became part of a long term strategy to motivate young people for such careers in the future. Now the trend seems to fulfil some of these ambitions. The results of our study specifically related to the establishment of the centre, could be sorted into three main categories:

Firstly, both documents and statements made by some of the respondents we talked with, argued from the perspective of the kids. They argued it is good for them to learn about technology, design and science. Some did not give any further explanation of their arguments, except that this kind of knowledge is something good in itself. However, some also argued that it would be even better if they could get such knowledge through play and activities they find interesting and enjoying. These respondents tend to think that kids already spend a long time in school, and if there are some variations from the ordinary programs in school, they would not be bored, they would probably put more effort into their activities and also learn better. Some also argue that childhood is not only about schools and study and to prepare for a future life. Childhood has a value in itself and they should be allowed to play in variety of ways. In this way play and learning could be combined, and it would be easier and more motivating for them to learn.

Secondly, both some documents as well as statements made by the respondents argued from an external point of view. These arguments focus on the fact that we live in a society that is very much based on technology, design and science. Therefore knowledge about this will be even more important in the years to come in order to maintain a competitive industry and to afford a welfare society at the same level we have today. Therefore they argue, kids need to obtain this knowledge from early age on so they can easily adapt to the requirements of higher education in these fields, and to be well prepared to manage a job as an engineer, designer or scientist in the future.

Finally there were some arguments related to the type of learning materials used in this learning centre. They argue that schools are not capable to teach students technology and design because they lack proper tools and equipment. Teachers may also lack proper education, so therefore a centre with the right equipment and the trained people would be better. Most of the materials used are basically advanced Lego system with programmable robots that can be designed and built in variety of ways. The students can start very easy, they argued, and then go on to more advanced projects as soon as they master the basics. They do not need to wait for the teacher or the other students to finish their part. The respondents tend to think that this is more motivating and gives better learning.

Is this project and these arguments unique for Kongsberg, or could they be understood in a wider national context? And even more, as part of an international trend? Let us look at some historical trend from the last 15-20 years. In 1989 the Norwegian national organisation of trade and industry (NHO), made a strategic plan that said the organisation would play a more active role in education, (Aakre:2005). Since then the organisation took several initiatives to involve in areas like vocational education, technology education and business. Especially in the 1990's there was a close collaboration between the organisation, the national organisation of labour (LO) and the Norwegian Government about a new and better structure of vocational education based on 2 years of education in the schools and 2 years of apprentice training in a workshop or business. This system was implemented from 1994. Today about 50 % of the students choose a vocational program in Norway. However, the criteria for passing the apprentice examination was set very high, and still many students with low motivation seems to choose a vocational program too difficult for them, and therefore drop out before they graduate. There was also a decline in the interests among young people to take programs suited for industrial skilled work, and especially science and technology. Therefore, the same organisations began

to address kids and students at lower ages than high school to motivate them for a future career as an engineer, scientist or similar professions.　The result has been different kinds of science and technology centres aiming at these younger groups of students. The way of learning in these centres has changed from the traditional way of learning in the schools, toward combining play and leisure activities. The main motif is not to learn specific subject like mechanics or physics, but to have positive experiences with such activities, and to be motivated to study such subjects in the future.

It seems the initiative in Kongsberg municipality, and the learning centre *devotek lab*, can be understood as part of this national, and may be also international, trend of stronger influence from business organisations on education in general. The initiative in Kongsberg came from the industry, and the engineering firm *devotek*[5] sponsored some of the equipment for the lab, as well as the salary for the staff to operate the centre on a daily bases.　Later, a local bank also came in as major sponsor as well as the educational ministry of the county that are responsible for upper secondary education.

However, the initiative was also coordinated with government interests that already made strategic plans about Kongsberg as city devoted to modern technology and design as their main position in the future.　For the centre a board was also elected, with representatives from both government and commerce interests, one of the members a rector from a local school. A youth board was elected and the youth were allowed to control some money for projects and further develop of the centre. The idea was to train the kids not only for technology, but for management and to take responsibility. It was not so easy though to see how well this board worked in practice. We had the impression it was not so easy to manage.

Learning materials

Most of the learning material used at *devotek lab* is based on *play* as a main concept, and using the Danish system LEGO[6] bricks that can be put together in many forms and combinations. Some bricks are simple blocks most of you may have seen and even tried. Others modules are more advanced functions like mechanical gears, electrical generators, solar cells and wind mills. Some modules are even more complex with programmable units with a microcontroller inside. The programming can be made from a regular computer and special software with visual objects. The final program can be transferred to the robot or unit via wireless communication based on the same standard as Bluetooth[7], and commonly used in regular controllers for TV, camera and similar equipment. Similar systems, but more professional, were introduced in upper secondary schools in Norway around 1990, (Aakre:1992).

The educational idea of play and using bricks or blocks the kids can use and construct in many creative ways, are not entirely new. The first one to use this idea was probably the well known educator Fröble, (Myhre:1991:85). There also seems to be some similarities to find in the Montessori and Reggio Emilia system of education.
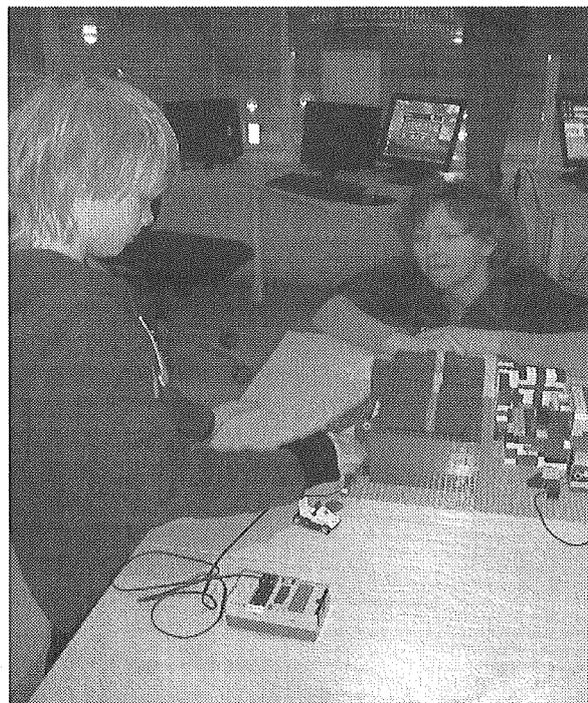

Figure 4 LEGO with programmable controller

---

[5] *devotek* is an engineering company that originate from Kongsberg ASA about 1980, http://www.devotek.com/sw353.asp

[6] LEGO is a trade mark of toys made in Denmark. It means "LEg GOdt", in English: Play Well.

[7] Bluetooth is an industrial standard for wireless communication between electronic equipment like mobile phones, computers, cameras, computer games and iPoD. Young people today are often equipped with such devices and well familiar with them as part of their identity.

From this point of view the system also seems well suited for training professions like engineer. Modern technology is often made of intelligent modules that can be designed and combined in many different kinds of functions and systems. The challenge in modern technology and design is therefore to analyse user requirements and to make systems that comply with a certain specification. Interfacing between different intelligent modules is also an important aspect of modern design. This is challenged in the Lego system. The results from our study also indicate that the learning materials comply with good pedagogical principles. The tasks can easily be varied in complexity, and the students are challenged in in many different ways. We also observed that the tasks motivated most of the students, they were active in the process of solving the tasks, and they had to cooperate to get the best solution in time. We think these are competences we often need to have, both in a job and our daily life. .

The objects used in the software are visual and easy to understand, and it was easy for the students to understand weather he or she was programming a motor, a controller, a temperature sensor or a lamp. However, from a professional point of view we like to question the design and use of symbols in the software. The idea was probably to make them popular for the students, but we are not sure they are better to understand than for instance symbols based on an international standard like the IEC standard. The popularisation may even be confusing. Especially for older students, like students in upper secondary school, it would have been better to follow an international standard.

For the learning materials there was good instructions with illustrations that proved to be easy to read and follow by the students. The instructions were designed for different ages and seemed to work well for the students to work by their own and just some help from the teacher. There were also special guidance pamphlets for the teachers. The pamphlets referred to educational theory and gave advice on how each lesson could be organised to cover the different topics. The majority of the areas covered technology and physics. There were no clear advices related to design or aesthetic aspects of design. The concept design were used, but basically limited to a kind of planning.

The instructions for the students consisted of a description of the construction procedures and visual drawings of the models the students could follow. Both the drawings and the physical modules had different colours that made it easy for the students to sort out the different building blocks, both during the construction and also after the job when the materials were put back into the storage boxes, specially designed to keep good order.

Figure 5 Teacher students testing robot

A positive aspect of the materials for the teachers were instructions on how to help the students reflect on their work after the lesson, and to test their scientific knowledge related to formal concepts and theories. However, only one of the eleven groups we observed used this material and completed these tests. That was rather disappointing as we think, from a pedagogical point of view, this is a very important part of a learning lesson. We observed that this one group was followed up by the teacher who motivate the students to do the tests. However, still very few students took the time to do it well. On this matter we think there is a great potential for improvement in order to have better effect of the lab. Better collaboration between the lab and the schools could improve this. Especially if the students could do some preparations in the school before they go, and also do some work in the school after they come back.

The teaching materials was explain by educational science theory that looked a like cognitive psychology influenced by Jean Piaget, though it did not refer to

him or any other educator. One main concept is the "floating zone". They claim the material help keep the students in the "floating zone", which means that the students can always balance between too difficult tasks and to easy tasks. This is explained as an optimum criteria for learning we know from for instance sports psychology, (Rand:1991). In this case there seems to be something about it, though we were not able to test if it is true or not. The same argument was used for the process of collaboration in the group. If the task for the group is too complicated, the members of the group will soon be too frustrated and give up the job. If the task is too easy anyone can do it by himself, and there is no need for collaboration. To stay in the floating zone the students need to be able to regulate the difficulties and challenges as they work, if not the process may stop. On the other hand: what we could observe in the lab is not a normal situation they experience every day. They come to the centre for very short time, it is a brake from the daily routine and they might be curious about this new situation. Therefore they may behave different in this test situation than in a normal school day. The way the training is carried out today is more like leisure activity without the same requirements of documentation and testing as there is in a normal school lesson.

Finally, the centre was located in the city library, which gave the library a new function: not only a place to borrow books, but also a place for the public to meet for information and knowledge on a broad scale. The new purpose of the new library idea was not only a place to collect information and knowledge, but also a place for kids and teenagers to display their work. School classes were invited to make their exhibition of arts and design so it could have a broader public audience. Figure 6 is an example of design related to architecture made by students from arts and design in upper secondary school. The idea seems unique and very interesting. However, so far the combination of technology and design seems rather blur in this project, and seems not very easy to combine. Arts and technology seems to be divided in two different worlds with few or any interconnections, leaving functional qualities and aesthetic qualities of a good design separated fields.

In some cases, like a project for preschool kids, they were able to make a combination. First, the kids and their teacher got a picture book from the city, and then followed a special rout in the city to see different kinds of buildings and constructions like a church, a bank, a living house, a school and a shop. After the tour they went back to the lab to make their own constructions based on the experience they had from their walk.
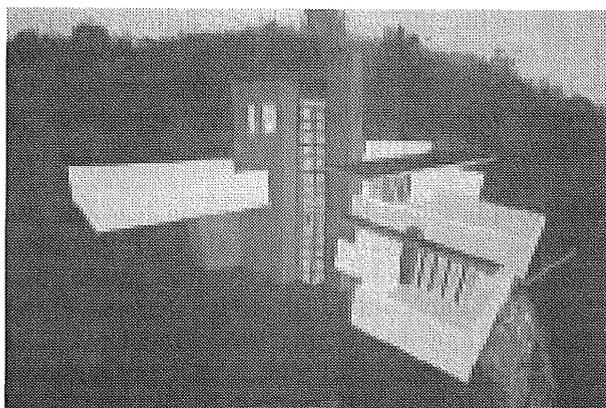

Figure 6 From exhibition of architecture made by students

Generally speaking: A better integration between art and technology would be a good improvement in this project. We also see many possibilities to do so. For instance, one of the popular projects in the *devotek lab* is the "smart house". The "smart house" has many nice programmable functions for objects like the lights, the heating system, the doors, the alarms and several more. However, the model of the house is a very simple structure of Lego blocks of plastic. The design of this structure could be improved in many ways by using different types of materials like wood, metal and even concrete that is used in regular houses. Isolation and design for environmental energy could also be included in the project. Finally, art and design history could be integrated to challenge the students on different styles of construction, shape and ornament. Combination of art and technology could also successfully be made in other projects like programmable robots, cars, space ships and many other types of installations. May be better collaboration between the centre and the schools could improve this. Unfortunately, collaboration with the schools seems not as good as it could be. It seems the schools and the teachers are somewhat sceptical, and may think that it would be better for this type of activity to take place in the schools.

Empirical study 1, Technology and Design (N=84)

In this empirical we had 84 students from 11 different groups. In the groups there were students from primary, secondary school and adults. We also studied 2 groups who came to the lab in the evening as a leisure activity. The table below shows the population.

Table 2 Population and stratification

Category of students	Groups	Girls	Boys	Sum
Primary	5	22	19	41
Upper scondary	1	0	4	4
Evening class	2	1	10	11
Adult/students	3	23	5	28
Sum	11	46	38	84

Primarily we studied groups and not individuals because we realized it would be too difficult to follow both groups and individual students in the same study. In most cases they worked in pairs with 2 students in each group. As far as possible we also tried to observe differences between the groups, how they worked, how they solved problems, their pace of work and their communication, both inside the group and between the groups. We also looked for differences between groups with boys and girls.

We considered using video recorders for the observations, but did not do so. The reason is that is it's a very complicated procedure to be allowed to do it in Norway, and some may not have wanted to take part any way. This made both the observations and the analysis more complicated, and not as reliable as we wish it could be. In future studies we recommend doing the observation more systematic and to use video if possible.

We observed the students and write log about their performance every 10 minutes. In this way we could construct a picture of the characteristics about their learning process, in which order they made their designs, constructions, made their testing and improved their design. We also studied carefully each step in the process according to our model: planning, doing, testing, improvement and possible innovations that were made. We studied not only one sequence, but 2-5 sequences in order to see if there were any changes from one sequence to the next. In each sequence we observed how problems related to mistakes or malfunctions were solved. Especially we looked for changes in the way the group solved the task, if the group followed the rules from the instruction or if they started to go outside the instruction to make something very different and innovated something completely different from the original task. The results from the 3 sequences are visualized in the graph.
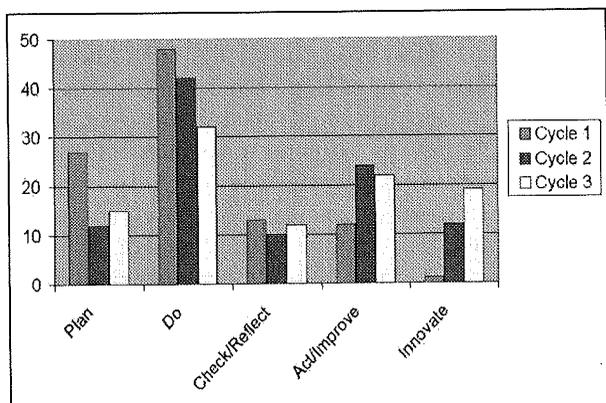

Figure 7 Graph 1 – distribution

The first graph shows the graph for each of the five steps in one sequence, and how they are repeated three times (phases/rounds). In the first phase (blue colour) the students put most of the effort and time on steps planning and doing, and almost 50 % on doing. Included in the planning is also preparations and information from the teacher. In the first round a little over 10 % was spent on testing, corrective actions and improvements of the first model. In the first round there were very little innovation as the students had focus on making the first model according to the instruction.

In the second round (red colour) less effort was put on the planning step, and a little less on doing and testing. However, in the second round more efforts

were put into improvements, about 25 %, and innovation about 12 %. This trend indicates that the students are getting more creative and start to experiment on their own modifications or design.

In the third round (yellow colour) the students used about 30 % on doing step. That seems to indicate that they are getting used to the material and they need less time for problem solving in the making process. They also spent about the same effort on improvements as they did in the second round. However, the innovation part was higher than in the first two rounds. This indicates that most of the students had moved further away from the original model, and now doing more experiments on their own. From the mainly "model making" process in the first round, most of the students seems to change "modus" and more and more use their creativity in making their own innovative designs.

We also tried to compare groups with girls and boys, and found some interesting differences: Groups with girls had a tendency to plan their work better than the boys, often by neatly picking the right parts and preparing the components before they started to do the assembly work. Girls also seemed to put more attentions and interests to colours, both by picking the same colour according to the assembly list, and later by experimenting with different colours in their own design. Boys did not seem to have the same interest in colours.

On the other hand, we observed that boys seemed to be more action oriented when they started to solve their task. They did not plan as well as the girls, and more often run into problems that had to be corrected after the first testing. The boys also seemed to be more competitive in their behaviour, to be first finishing their construction, and to be the first to start the testing, and making their model running fastest. Boys also tended to be noisy, especially when they started the testing and competed with their models.

We could also observe some interesting individual differences, but not related to gender. Some students could sit very passive in the beginning and just observe their mates doing the work. Then, after a while, and especially if there was some problem, they gradually came into the "game" to support. In some cases this "slow bloomer" became the leader of the group and proved to be very skilled and creative.

Finally, we could see some interaction between the groups. In some cases it could like "looking over the shoulder" about what and how the other group does, and also helping each other by making comments and solving problems. Some students also developed a kind of "problem solver role, called upon when someone needed help. He or she could move over to the other group for a short time until the problem was solved, and then go back to continue own work.
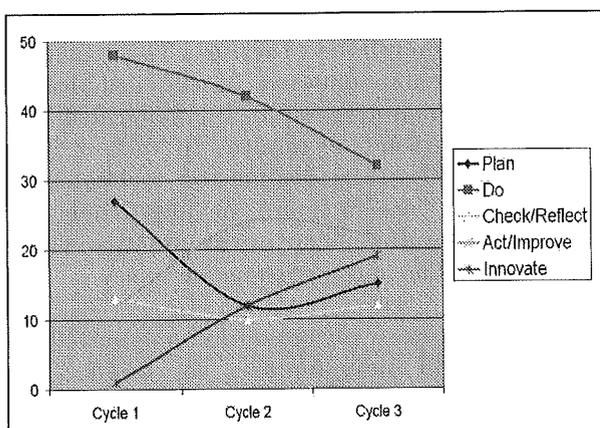

Figure 8 Graph 2 - trends

In the second graph we organized the result in a graph to show the trends from what has been explained above. Firstly, we see that the "doing" step decrease when there are included more rounds in the learning process. When the pure process of making decreases, the other processes increase, especially on "improving" the design and gradually also more on "innovation" and creating something completely different for the original model. Programs like the one at *devotek lab* has been criticised by some educators because they think it is too instrumental and do not really foster creativity at all. However, there are no empirical proofs behind these arguments: therefore it was one of the questions we wanted to study and discuss in this project.

The results indicate that there is a risk that program like the one at *devotek lab* could be quite instrumental and not really lead to any deep learning, but just to follow some simple instructions. Quite

a lot of the program at this lab seems to be "doing" something, but not so much deep learning. However, it depends on how activity is organized and carried out. If the projects are organized as pure making what the students are told from the instructions, that is what they learn: to follow an instruction. That is not all bad though, because in many situations of life we phase the situation of reading an instruction and get something to work, weather it is a new TV, refrigerator or installing a program into our computer. However, this activity may not foster creativity or result in very much knowledge of technology.

To foster creativity and innovation through this system, it seems important that the students have the chance to do something more than making the models according to the instructions. They need to continue the learning process into more complex models, do some improvements and even make something new that is not mentioned in the instruction. The students also need time to reflect on what they learn and how they learn. If they also want to learn formal knowledge from science or technology, they also need to go deeper into the knowledge of the program, the computer, the electric motor and so on.

Our analysis indicates that though the learning strategy in this project seems quite instrumental in the beginning of each task, the system have a potential beyond that. The students show quite some interests and enthusiasm from the beginning, and the tasks seems to motivate the students to continue their experiments after the first tasks are successfully carried out and to make new designs in a creative way. It also seems the students easily can adapt the proper level of skills, and still feel comfortable with what they do.

A closer analysis proved that the students are well motivated by the system, and they tended to continue their work after they accomplished the first round, and then into more complex models more and more designed by themselves. Most of the students tended to be more creative in their way of working, and few students gave up their task, though we could se some do. Our observations also indicate that the students could adjust their work according to their competence, thou we could se some who had too high ambitions in the beginning and therefore gave up their project. However, in most cases they went on some easier task. The data also shows that the process of testing and improvement was relative constant, while the process of innovation and creating something new improved when they continued their work. On the other hand, this was a test situation and not a normal school lesson. Therefore their motivation and effort could be higher than in a normal day at school.

Empirical study 2, Technology and Science (N=48)

Figure 9 Experimental school in a real science context and properly dressed

In the definition of technology and design education I included a dimension related to science. This aspect of technology is also implemented in the practice at *devotek lab*, and should therefore be elaborated and explained through some examples. In fact, I have already made the conclusion that the technology – science dimension seems more obvious than the technology – design dimension in the practice at the centre. There could be many reasons for this.

Firstly the centre was initiated and supported by interest groups and individuals in the science and engineering field as an attempt to motivate young kids for similar careers in the future. On the other hand, the centre is not run by engineers, but educators with interests in the well being of children and teenagers, not because they want to invent some fancy machine. Thirdly, the profile could have something to do with the learning materials. Even

though it is very advance with programmable units and so on, the bricks and blocks do not have any plasticity. Therefore they can not be shaped in any form like a piece of clay, wood or metal. The colours are more or les determined. Therefore the learning materials do not challenge the kids in areas like form and colour composition. The design activity is more or less limited to the shape, the form, the colour and function of the bricks, the modules and what can be achieved through software programming.

Environmental energy and science education for kids has been two of the most focused issues so far. The energy lab is still in its experimental phase, and still searching for its main profile. Therefore I am using examples from the science course for kids age 10-13 in this paper. There are also programs for older kids, but not explained here.

The programme was originally developed by a lady, Hanne Finstad, a doctor in biology, who started to make some experiment for her own kids. These experiments, very　much based on the idea of play, were developed into formal courses under the name "Forskerfabrikken". Forskerfabrikken now offers quite many courses in evening schools, in student vacations and sometimes as extra courses in schools. As teacher they use professionals in the field, like doctor, masters or graduate students, but not necessarily regular teachers. Emphasis is made on professional qualifications in science. They also put emphasis on making a *scientific context* in their courses, so the kids should have the feeling of being a scientist. For this purpose they use real equipment, doing real equipment. They also use proper cloths, protective gloves and goggles if necessary, and to be aware of security. In this way they use *role playing*. Another aspect of role playing is using some attractive materials, for instance to explain and make a model of DNA they use a type of candy that is popular among kids. Of course this use can be discusses from many aspects like the bad effect of sugar and so on, but I think we should see this is as a joyful means that makes a lot of comments and communication. This aspect of initiating communication is in fact interesting.

In the courses we observed, we could see experiments related to biology, chemistry and physics. The majority of the activity, and may be also the most successful ones, where related to biology and chemistry. A possible explanation for this is probably the background of the people who took the initiative of the programme and their main background in biology and chemistry.

However, one of the tasks was related to technology, design and making. It was to make a periscope from a prepared prescription and to test its function. The students were asked to bring an emty carton of milk from home to be used for the making. The instructors provided the drawing, two mirrors, a small knife to cut slice for the mirrors, and got two mirrors. The student could well understand the principle and function of the periscope and they were very eager in the activity of making it. Most of the students could do very well, though some of the youngest students did not have the motor skills to make the cuts in the right place and proper size. However, by some help from older students or the instructor, and by using tape they could manage to get the mirrors in a correct position. The most active part of the task, and the part that also created most communication, was the testing of the periscope. The students were very creative in the way of testing from different positions and angles. They could

Figure 10 Testing periscope

experience that they could use the periscope from a dark position into an area with light, or from under a table or behind a corer. Some even got the idea of putting two periscopes together.
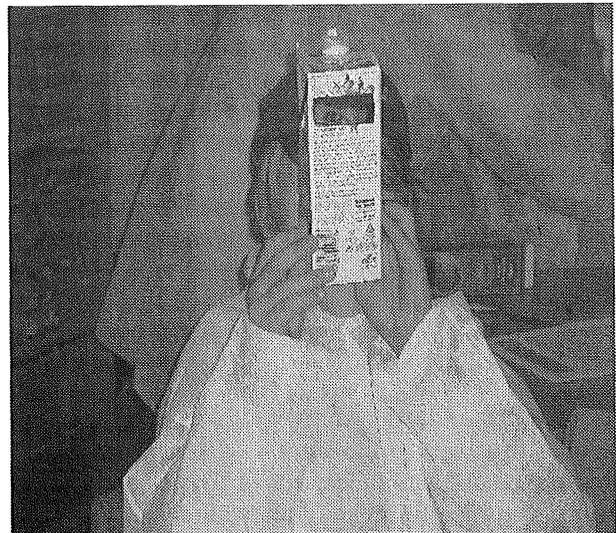
We could see some differences between the technology projects and the science projects. The science projects followed more strict plans, and there was less variations in the final results than in the technology projects with LEGO bricks. The science projects also had a more clear start and end, while the technology and design projects tended to continue into more complex and variety forms and shapes. On the other hand, the instructors in the science courses had a more active role both as instructors and counsellors. The science instructors also used a more formal language related to the specific type of science, and they used more time after the tasks to discuss with the students what they had done and to explain both the process and results. This indicates there are two different teacher roles: one more scientific related to the profession of science, and the other leaving more to the students to find out by themselves and may be assist with some counseling by asking questions more that giving the answer. However, we could not decide which one of these are the best. May be they are both good teacher practice, but under different conditions.

Finally we wanted to find out the effect of the science course and weather the kids really becomes more interested in technology and science through this type of programmes or not. For this purposes we added some extra questions to the evaluation form that was a questionnaire. Firstly, the results from the questionnaire concluded that kids were very well satisfied with this type of course and wanted to take more such courses. However, few could make the conclusion that they wanted to be a scientist. Some of the results are included in the figure.
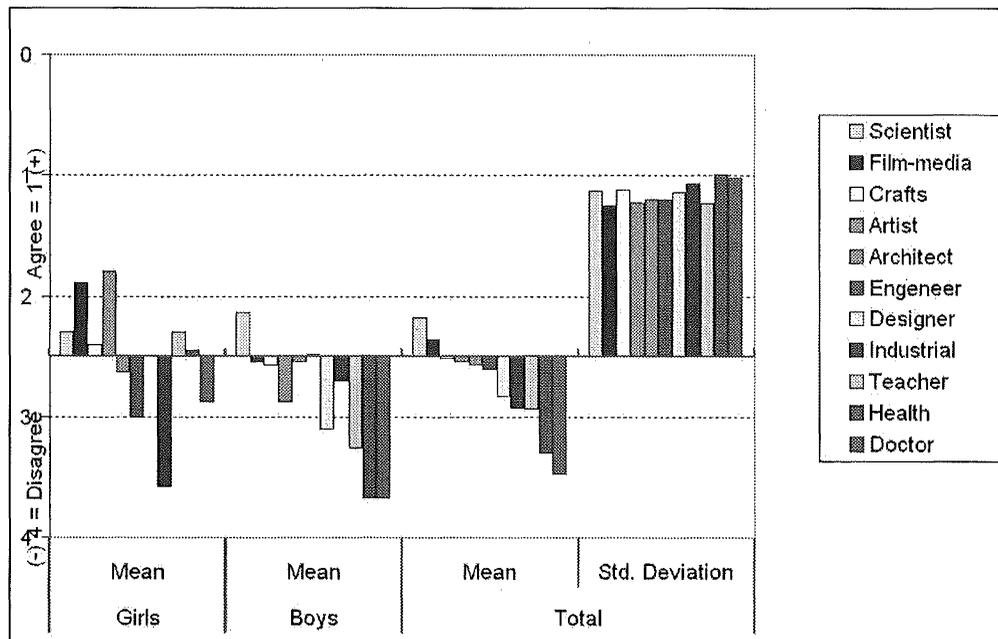

Figure 11 Career preferences (N=48)

On the other hand, the results gave a good feedback on the interest profile of the students when it comes to career preferences. "Science" (yellow) came out positive among both girls and boys, and the highest score among the boys. Girls also scored positive, but two other careers came out with higher score among the girls: That was artist (blue) and "film and media" (dark blue). And most important: compared with an other questionnaire from a reference group, there was a significant change in favour of science and technology as a possible career for further studies in these classes , and may be also a future professional career. The standard deviation is close to one, which indicates the answers were quite consistent. From this we can conclude that playful activities related to science, technology and design from early ages, may improve the chance for further studies of this topics and a future career in jobs like engineering or science.

Conclusion

In this study we investigated the idea of technology and design education from a sociocultural perspective. We tried to see technology and design as a cultural phenomenon typical for our modern society, its relation to the formation of identity and how it could be implemented as proper general education. Table 1 list in few points the main conclusion, both what we found positive as well as areas we think should be improved:

Table 3 Main points of conclusion

Positive results	Areas of improvement
• *Definition, theory and method proved to be suitable for the purpose* • *Learning materials was relevant and very well suited for problem solving* • *Students active in problem solving* • *Good communication and collaboration in and between student groups* • *"Floating zone" theory proved working* • *Technology, design and identity* • *Student reported significantly higher motivation for studies and careers related to science and technology*	• *Weak on integration between arts, crafts and design* • *Weak on crafts skills related to materials and techniques* • *Weak on aesthetic and artistic expressions related to colour, form and visual design* • *Too much emphasis on activity* • *Too little emphasis on formal knowledge* • *Weak collaboration between the centre and the schools* • *Observations should be supported by voice recording or video*

For this purpose we came up with a definition of technology and design that balances constructive learning processes with critical reflection. In the first case technology and design is about the practical implementation of knowledge from arts, crafts and design for a specific goal or purpose. That means to invent and to make something for use, like a house, a car or a computer. On the other hand, critical reflection is about evaluating the power and the impact technology an design may have on our society and culture, and weather it supports the idea of sustainable development or not. Technology and design is a "double-edged sword" that raises many ethical questions that need to be answered if we want to improve our society and culture, and to make a better and safe future. Global as well as local environmental issues are one aspect of this. However, environmental issues also focus on aesthetic aspects of life. City planning for instance, could be very functional, but still not provide the aesthetic qualities and the beauty in design and construction we need in order to improve an urban lifestyle.

We also studied more specifically the situation in Kongsberg municipality, and how the department of culture was involved in the establishment of the learning centre *devotek lab*. The concept seems unique and interesting from many perspectives. Firstly, it is not so common that the culture sector involve with education, and certainly not in areas like technology. However, this came about because the culture sector defined technology as an integrated part of culture and the identity of the city and its inhabitants. Finally, it is not so often to see successful partnership with local industry and finance institutions in cultural and educational areas. Some may even criticise and argue this is not so good, as it could be the beginning to the end of national responsibility for these important areas of education. Some may also argue it is the beginning of more private schools, which never was very common in Norway, and also lead to growing class distinctions instead of the idea of equality that so far had a strong support in Norway. However, so far the project seems to have strong support from many groups, both political and non political. Gradually also other municipalities in the region support the idea, and now motivates their schools to use the centre. One reason might be they see this activity proved the students with valuable experiences, and also help the students to see connections between their own life experiences and the ways of working in trade and industry.

Play as a basic and natural way of learning was often used by respondents when they made positive comments about the program at *devotek lab*. This also seems to be a new trend. Not many years ago, play was considered by many people as something childish and not very serious. Many tended to make

associations with kindergarten and other Fröbelian ideas as something not not very relevant in relation to topics like science, technology, business or professional work. However, in this study we observed a new trend: Both engineers and business people now make positive comments about play as a way of learning. Some even claimed that play may be necessary when dealing with innovation and creative searching for new and unique ideas. On the other hand, most of the respondents tended to see play only from a perspective of usefulness, not as a value in it self or as a fundamental way of human learning.

The learning material was found to be well suited for the purpose, as well as different ages and different abilities. Especially this was true when it comes to functional qualities, constructions, creative problem solving and science areas like cybernetics and technical physics. These areas haves a strong position in the industry in Kongsberg, and could be one reason we had some many positive comments. On the other hand, the design aspects of making, and aesthetic qualities was not so easy to see in the works we studied. The students were seldom challenged to think in terms like form, shape, colour or composition when they made their constructions. However we saw many possibilities on improving this area by combining with art and design history, and especially design and making houses, bridges and bodies for cars and robots. Improvements on design can also be made by involving teachers in arts and crafts.

Our empirical study, and our analysis of the learning materials, concluded that the programme is based on well documented pedagogical theory, especially cognitive psychology. The majority of the students solved the tasks with enthusiasm. They were also to adjust the complexity of their design according to their own skill and imagination. In the beginning their work seemed to be quite instrumental, and it had its focus on following the instruction and to make a copy of the model described in the book. However, gradually they could move away from the model and create their own design in a variety of ways, shapes and colours. Our empirical study had this phenomenon as one of the main objectives, and the data proved the ability of the system to keep the students active, inspire their creativity to make more and more complex designs. From the data we concluded that both improvement and especially innovation of new designs became more complex when they continued to work.

A weakness we observed was lack of support to help the students construct formal scientific knowledge. For instance, there is a lot of physics in the involved with the tasks, but they did not seem to be able to construct physical laws or apply such laws after the session. The idea and value of activity seems overemphasized in the programme, but activity in itself may not be any guarantee the student will be able to construct a theoretical model or knowledge related to a specific science. Even though the idea of counselling from the teacher is emphasized, this is probably not enough help for the students to construct such scientific knowledge. One way to improve this is better collaboration between the schools, the subject teachers and the centre. It could be organized in the way that there are made preparations in the school before they go to the lab, and also do some work after they finished the projects at the lab. The system even has materials for this, but we could not see it was used very often, may only in one of the eleven groups.

The final and most positive and interesting observation we made was related to communication, both inside the group and between the groups. In most cases the students worked in groups of 2 or 3. In the beginning there was little communication, mostly just some few comments, helps on finding the right parts or reading the instruction. However, gradually when the design became more concrete and more complex there was more communication. Some times they shared help across the groups or made comments about what they made. It was like they created their own personality into this external forms and functions. In this way they were not only able to communicate the object as an object, but also communicate their own personality and receive feedback from their mates. In other words, they did not only learn technology and design, but also communication, problem solving, and may be most of all: personal knowledge as something important for the formation of their own identity. This was one of the results we hoped to see, but not really believed would be possible before we started the project.

Literature

Argyris, Chris and Schön, Donald (1989): Theory in Practice
　　　　Jossey-Bass Publishers, San Fransisco
Aakre, Bjørn Magne (2005): Formgiving og design i et didaktisk perspektiv
　　　　Norwegian University of Science and Technology, Trondheim
Aakre, Bjørn Magne (1992): Datateknikk
　　　　NELFO, Oslo
Deming, W. Edwards (1993): The New Economics for Government and Education.
　　　　MIT, Boston
Dewey, John (1938): Experience and Education
　　　　Collier Book, London
Imai, Masaaki (1987): Kaizen
　　　　Random House, NY
Habermas, Jürgen (1981): The Theory of Communicative Action.
　　　　Translated by Thomas McCarthy. Cambridge, Polity
Klafki, Wolfgang (2001): Dannelseteori og didaktikk
　　　　Forlaget Klim, København
KD (2006): Knowledge promotion – Kunnskapsløftet
　　　　Kunnskapsdepartementet, Oslo
Kuhn, Thomas (1996): The structure of scientific revolution
　　　　University of Chicago Press
KL06: Kunnskapsløftet, Læreplan. Kunnskapsdepartementet, Oslo
Myhre, Reidar (1991): Grunnlinjer i pedagogikkens historie
　　　　Gyldendal Norsk Forlag, Oslo
Rand, Per (1991): Mestringsmotivasjon
　　　　Universitetsforlaget, oslo
Vygotsky, Lev (1934/1986): Thought and Language
　　　　The MIT Press, Cambridge Massechusettes
KUF (1997): Læreplanverket for den 10-årge grunnskolen
　　　　Kirke, utdannings og forskningsdepartementet, Oslo