INTERNATIONAL TECHNOLOGY EDUCATION SERIES

Technology Teachers as Researchers

Philosophical and Empirical Technology Education Studies in the Swedish TUFF Research School

Inga-Britt Skogh and Marc J. de Vries (Eds.)

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Scope
Technology Education has gone through a lot of changes in the past decades. It has developed from a craft oriented school subject to a learning area in which the meaning of technology as an important part of our contemporary culture is explored, both by the learning of theoretical concepts and through practical activities. This development has been accompanied by educational research. The output of research studies is published mostly as articles in scholarly Technology Education and Science Education journals. There is a need, however, for more than that. The field still lacks an international book series that is entirely dedicated to Technology Education. *The International Technology Education Studies* aim at providing the opportunity to publish more extensive texts than in journal articles, or to publish coherent collections of articles/chapters that focus on a certain theme. In this book series monographs and edited volumes will be published. The books will be peer reviewed in order to assure the quality of the texts.

Technology Teachers as Researchers

Philosophical and Empirical Technology Education Studies in the Swedish TUFF Research School

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CONTENTS

PREFACE

In this anthology researching teachers present their research on teaching and learning Technology. The idea for the book was raised jointly by supervisors and students in the early months of 2011, when the teacher graduate students were approaching the end of their Ph.D. training. The fact that the book is now complete, is something we have many people to thank for. A warm thank you to all authors, of which I, in particular, want to mention my colleague at KTH Sven Ove Hansson and Edvard Nordlander at the University of Gavle who both have joined me in leading the TUFF adventure. A warm thank you also to the Boost of Teachers Initiative and participating municipalities who funded the TUFF project and, last but not least to Marc de Vries, my most valued co-editor, and Peter de Liefde and Sense Publishers for making our idea become reality.

Stockholm in August, 2013
Inga-Britt Skogh

INGA-BRITT SKOGH & MARC J. DE VRIES

1. TUFF AND THE VALUE OF TEACHERS AS RESEARCHERS

INTRODUCTION

This book is the outcome of a Swedish project in which a group of technology school teachers carried out a research plan that eventually led to their Licentiate or Ph. D. theses. In the past it was rare when teachers did research. Now there seems to be a certain trend towards the teacher-researcher combination, at least for the time that is needed to produce a Ph. D. thesis. In e.g. Sweden the Swedish National Graduate School in Science, Mathematics and Technology Education Research (FontD) has been running since 2002. In the Netherlands 2013 was the final year of the DuDoc project in which also a group of teachers worked on Ph. D. theses. In this introductory chapter we will describe the TUFF project and discuss some of the pros and cons concerning teachers doing research as we find them in literature. Finally we will sketch an outline of the book and show how it is structured.

THE TUFF PROJECT

In Sweden, and probably in many other countries, the perceived distance between researchers/universities and teachers/schools is considerable. Hence the implementation of educational research in ‘everyday’ school practice is and has been problematic. To bridge the gap between academies and practice the idea of doctoral programs specially designed for teachers wanting to do research up to the level of licentiate (half a PhD) was launched in Sweden in the early years of the 2000s. The ‘first generation’ teacher doctoral programs in Sweden started in 2001 (Andrea-Thelin, 2009). This first venture was followed by a number of similar doctoral programs initiated by universities and municipalities wanting to collaborate. The ‘second generation’ programs were commonly funded by the Swedish research council and (to a lesser extent) by concerned municipalities. In 2008 a ‘third generation’ doctoral program designated towards practicing teachers was launched. Ten doctoral programs in selected subject areas received funding from the Government. In this venture in total 160 teachers participated. Twelve of these teachers were admitted to our graduate school called Technology Education for the Future (in Swedish TUFF) for research projects about teaching and learning technology.

I.-B. Skogh & M.J. de Vries (Eds.), Technology Teachers as Researchers, 1–13.

Between 2008 until 2012 the graduate school TUFF was run in partnership with Stockholm University (Host University), University of Gävle and Royal Institute of Technology (partner universities). In this introductory text graduate school TUFF is presented. Within the next pages you will find information regarding the project background, the aims and goals of graduate school TUFF, choices, activities and experiences and an update of the current situation for the TUFF PhD students.

PROJECT BACKGROUND

From Centralization to Decentralization

In the 1990s, the responsibility for schools in Sweden was transferred from central government to local municipalities. State influence changed from regular management to management by objectives and from centralization to decentralization. National goals and guidelines are specified by Government and Parliament through the Education Act, curricula etc. but the responsibility for the implementation and realization of these national goals were transferred from state to municipalities. The mission to, on behalf of the government, work actively for the achievement of these national goals is laid upon the National Agency for Education (NAE). The responsibility for educational research has also changed over the years. The municipal and local level has been given greater responsibility for both school improvement and educational research. How educational research is organized, how it is administered and the decisions on what content should be prioritized is today decided by local authorities. For example, since 2003 key education authorities have neither influence nor responsibility for the initiation or distribution of research funds (Andræ Thelin, 2009). The main source of funding in educational science in Sweden today is a research-driven committee within the national Research Council. In 2012 165 million Skr was allocated by way of grants for research within educational sciences from the council's total budget of 4.5 billion Skr (Research Council, 2013). Educational research oriented towards teaching and learning technology have only occasionally received financial support from the Council.

Educational Research, School Practice and Teacher Education

To what extent teachers (and teaching) are influenced by new educational research has been discussed by school authorities, researchers and politicians in Sweden for many years. Results seem neither to reach nor to involve practicing teachers as much as desired. Some even claim that there is a considerable gap between educational research and teachers' practice. Measures to address this perceived gap have however been taken. During the last ten years efforts have been made to promote and support practice oriented educational research in Sweden. The importance of a dialogue between research, training and the educational sector has been emphasized by stake holders and policy makers. This dialogue can (and should), according to decision makers, take the shape of collaborative research thus making research results available to interested groups (Thelin, 2009, Prop. 1999/2000:81).

Teacher education is, in this context, a particularly important arena. The teacher education reform launched in 2001 led to a rapprochement between theory and practice which meant a shift from 'know how' to 'know why'. A requirement for all teacher students to write a thesis based on theory and focusing relevant educational issues was also introduced in this reform. The link between teacher training and postgraduate education was however not thoroughly addressed. The European Union-harmonization of academic education through the so-called Bologna process has however opened for a clearer discussion of how teachers in Swedish can be connected to master's programs and doctoral studies. Teacher education in Sweden was recently revised and a new teacher education in line with the Bologna process (SOU 2008:109) was launched in 2011.

The First and Second Generation Teaching-graduate Programs

In 2001 the idea of so-called teaching-graduate students was introduced in a governmental proposal (Prop. 2000/2001:3). The proposal suggested that the National Agency for Education (NAE) should support the development of a scientific base for the teaching profession by investing in teaching graduate programs run in collaboration between the NAE, one or more universities, municipalities and school authorities. The NAE identified a number of strong research environments, selected subject areas to be highlighted in the research (e.g. pupils' learning, teachers' work and the leadership of this) and requirements for admittance to the program was set up (teachers diploma, two years of professional experience, employed as a teacher, listed in a regular research training program, financial support from municipality and the obligation to produce a practice-oriented thesis).

In the years following 2001 just over thirty PhD students were admitted to the program. It should however be noted that only a quarter of these PhD-students (two men and six women) were 'pure' teaching-graduate students who met all the above mentioned NAE-criteria. The average age among these eight 'first generation' teacher-graduate students was high (48, 6 years) and they were studying Didactics (e.g. music didactics) and Educational Work (Thelin, 2009). This teaching-graduate student program was a new instrument in the field of research. The example given by authorities was followed by a number of similar 'second generation' PhD-programs around Sweden. In e.g. 2002 a PhD program focusing educational research in science and technology (FontD) was launched. FontD was (and still is) hosted by Linköping University, funded by the National Research Council and run in partnership with a number of universities/university colleges from all over Sweden. This and other 'second generation' programs were however initiated by municipalities and/or universities wanting to collaborate. On a national level the effort to promote teachers to do practice-based research was followed up in 2008 within the frames of a new professional development program called the Boost for Teachers Initiative.

The Third Generation Teaching-graduate Programs – The Boost for Teachers Initiative

In 2008 the so called Boost for Teachers Initiative was launched. By means of continuing professional development for teachers this program should *"... strengthen teacher's competence, both in the theory of their subject and pedagogical approaches to teaching"* (NAE, 2009). Specially developed 'Boost for Teachers Initiative' courses in selected subject areas were ordered by the NAE to be developed by universities and colleges. Certain requirements must however be fulfilled before a teacher could enter such a course. The teacher must be eligible, have a teaching qualification in higher education and be a practicing teachers working at any level from preschool class up to adult education. The rules of the promotion stipulate still one further requirement. Teachers' participation in the program was to be governed by the needs and priorities of the local schools/ municipalities (Skogh, 2010).

Within the Boost for Teachers Initiative the government also decided to fund ten third-cycle study programs (graduate schools). The conditions of this initiative were very favorable to teachers as well as to organizers (universities). Two and a half years of study leading to licentiate level ('half a PhD'). Four days of studies and one day of teaching in school each week with full payment during the entire period of study. A state grant guaranteed 60% of the teachers' salary and participating communities/ schools contributing the remaining 40%. To be eligible teachers must fulfill the above mentioned requirements (including having a signed certificate of approval from the local school organizer) and, also be assessed by the university concerned to be qualified for doctoral studies. In the autumn of 2007 universities in Sweden were invited to develop special designed graduate school programs. In March 2008 ten programs were selected by the government (via the national Research Council). One of the selected programs was TUFF.

Aims and Goals

Three overarching goals of the TUFF program were formulated from the very beginning. The graduate school TUFF should:

– strengthen the status of technology and the efficiency in compulsory school
– technology education
– strengthen the recruitment to technical studies in high school and college and
– promote gender-neutral education and gender balance in recruitment.

From these aims three objectives were extracted. Research within TUFF should address the following areas:

1. explore factors affecting recruitment to technology training and develop methods to promote recruitment,

2. develop practical methods for teaching technology education in primary and secondary education and
3. explore how gender equality can be increased in recruitment and in the teaching of technology subjects.

TUFF started March 15, 2008 and was formally closed June 30, 2012. It was run in cooperation between Stockholm University (SU), the Royal Institute of Technology (KTH) and the University of Gävle (HiG). Two postgraduate education subject areas were included: Education in Arts and Professions (SU) and Philosophy (KTH).

The result of study for each student should continuously be fed back to their schools in order to certify a practice-related research situation as well as to inject the outcome of research in school practice.

Twelve teacher graduate students (six women, six men) worked in the research school.

Choices, Activities and Experiences

We have, during our work with TUFF, been faced with many choices. Each and every one of those choices has, in different ways, affected the outcome of the graduate school. Some choices were made early on in the process and others have been made 'along the way'. Some of the choices will be presented here.

Selection of Research Question and Development of Post Graduate Courses

To formulate research questions is painstaking and time consuming work for any researcher. To facilitate the students but also to guide research into issues of particular concern for the graduate school, we decided that we should present a list of research questions for the students to choose from (e.g. "Students' conceptions of technology", "Reasons for students' choice of technology studies at higher levels", "Assessment of pupils' achievements in technology" and "Technology education and gender"). The program also required the development of specially designed technology education oriented postgraduate courses (e.g. Technology Didactics, The Epistemology of Technology and Technology and Gender).

Selection of Students

During May of 2008 between thirty and forty applications were submitted. The applications were reviewed and valued by the management group (one representative from each university). In the call for applications we emphasized only teachers who had been given the 'green light' from her/his community and school principal were eligible for the program. However, early in the process we found that many of the candidates had not understood the need for approval from her/his employer. Of the twenty applications, which we deemed interesting, there were uncertainties about the municipal financing in more than half of the applications. In particular, smaller municipalities turned out not to be able (or willing) to commit to the financial conditions of the program. Consequently several of the high ranked candidates from smaller communities could not be admitted.

The question of what qualities we were looking for is reasonable to ask. In addition to the formal requirements stated by the government and the participating universities we were looking for persons having the ability to verbally and in writing present their research interest and their choice of research question/ research area with precision and in a credible manner. We also wanted our future students to demonstrate a number of subtle personal properties that are difficult to capture in words but still are well known to all researchers; purposefulness, a clear sense of reality, good reflectivity, openness to opinions and arguments and, not least, accuracy. Research work means both solo work and group work. We were therefore keen to find individuals with self-discipline and with good interpersonal skills.

Seven candidates were finally selected in the first run starting their studies in August of 2008. A second call for applicants was made in September of 2008 and five additional, equally qualified, teachers were selected to join the program in December of 2008. Table 1 gives some basic information about the whole group.

Supervising

With regard to the supervision of the TUFF graduate students, it was decided from the start that each student were to be assigned to one of the three participating universities where a work place and other resources were made available to the assigned students. The students' main supervisor was appointed from the institution where he/she was assigned. One assistant supervisor per student was appointed from one of the other universities. To students in need of further special expertise (e.g. specific methodological support) yet another assistant supervisor was appointed. The total amount of supervisors appointed within TUFF is 9 (professors, associate professors, assistant professors). Commonly tutorials have been individual but group instructions have occurred. All graduate students and main tutors have regularly met in research seminars. External experts/researchers have been invited for presentations and discussions. At least twice a year, representatives from

Table 1. Fact about TUFF students

Average age (at admission)	*Gender balance*	*Number of students assigned*			*School level focused*
46 years (from 35–56 years)	6 female, 6 male	kth 5	su 5	hig 2	*primary:* 5 projects *secondary:* 7 projects

participating universities and municipalities, representatives from various interest groups (e.g. teacher union representatives, engineering union representatives and policy makers) and representatives from the industry have been invited to meetings (so called reference group meetings) for information exchange, discussions and presentations. When necessary (on a regular basis) supervisors have met for follow-up discussions, information exchange and tutorial support.

Students' Experiences

A minor follow-up study of TUFF was performed in 2012 (Skogh & Gumaelius, 2012). A survey was sent (by e-mail) to the twelve teachers in late May of 2012. The two part survey consisted of open ended questions. In Part 1 questions are posed about the application/ admittance procedures, working/studying conditions, the perception of goal fulfillment etc.). Part 2 consisted of questions about the students' attitudes towards graduate studies in general and to TUFF in particular (their own personal goal fulfillment, their contacts with their schools/municipalities and their future career plans). Ten of the twelve teachers answered the survey. Six teachers from each of the three participating universities were then selected for interviews. The semi-structured interviews were made in early July of 2012 via telephone. The aim of the interviews was to get a deeper understanding of statements regarding the teachers' views on their own personal goal fulfillment (having or not having completed the studies) and about their perception of interest from the municipal/ school regarding their research and future career. Collected data was systemized and thereafter analyzed through repeated readings of statements.

According to findings all TUFF-students have found their graduate studies valuable for their own personal devolvement. They all found their working tasks during their studies stimulating, mainly because of the significant change in their working conditions. As researchers they found time for reflection on teaching methods and subject development, which has not been the case when working in school. Six out of ten students express that they would like to continue their graduate studies to doctoral level. The opportunity to join this research school was a personal choice, which opened up the possibility for a new carrier. Several students point out that applying for admittance themselves and thereafter anchoring the application with their employer was the only way to do it as the time from when the positions were announced until time for application was very limited. Municipality and school management simply had no time to learn about this project in advance.

After completion of their study period most TUFF-students express that the quality of their own teaching has improved after the study period. Not more than four students believe that the quality of education in their respective schools/ municipalities has increased as a result of their education.

There are some negative statements mentioned by the TUFF-students. Most informants fear that their acquired competence will not be put to use in the school environment. Six students cannot see that their knowledge and competence will be used *at all* when/if they go back to their position as schoolteacher. This has caused a lot of frustration among the students as they themselves see great possibilities to make a difference in school. The four students who do feel that they are supported by school management or by their municipality have a much more positive attitude towards going back to school after finishing their thesis and they also think that their knowledge will be put to good use. Two out of ten students feel they have had a good relationship with their school management and/or with the responsible persons in 'their' municipality during their graduation studies. Only one student decided to participate in the TUFF research school as a result of a discussion and in collaboration with the municipality.

The students also found the available time for studies (2.5 years) too short. Since they all had to go back to a fulltime job after the time period had expired, it has, according to the teachers, been difficult to complete their theses even though they are work wise close to graduation.

None of the students think the requirements are set too high, but they admit that the high requirements has been one reason why they have not fulfilled the goals on time. (At the time all students had published articles in international journals, taken 45 units of courses, participated in national and international conferences and contributed to a Swedish anthology.) Several students feel that the requirements for this research school have been higher than for other similar research schools. On the other hand they appreciate this and are proud of this ambitious research school. They also feel that the step to reach the doctorate level is not so big.

A third factor that is often mentioned in the interviews is that it has been disrupting to work in school 20% of the time during the 2.5 years of study. Some felt that it was difficult to restrict the working time to 20%. It seems like the students who are most satisfied with this combination are the ones who has done their school duties in periods where they have spent more than 20% in school (in other words concentrated to fewer but longer periods of time). Finally most TUFF students express that it would have been even better to take a doctorate degree at once as this degree is more accepted in the academic world. However the students do acknowledge the difficulties in this arrangement for the school/municipality as 2.5 years are already seen as a long time period to be away from the position in school.

Lessons Learned

In retrospect there are obvious lessons to be learned. The requirement for each student to produce a compilation thesis with (preferably) internationally published articles in English is one such issue. This has without doubt delayed the students' examination. However the long term benefit of being published in international journals (by our judgment) does justify this requirement. There are other lessons to be learned. Let's look at the investment as a whole. What opportunities have been opened up – and for whom? Teachers have been able to do research. Municipalities and schools have gained additional didactic and research competence that they can use in the development of schools. Universities have gained extended research resources (academically and economically). The hypothetical possibilities are undoubtedly good. The problem is that the needs of the different parties (individual, municipality, university) are not compatible. It is rather the opposite. It seems like the needs for one of the actors risks becoming a restriction for one or both of the others. When a teacher is given the opportunity to do research, the demands from her/his municipality, school, university and from the teacher her/himself are tangible and obvious. However the benefit of successful studies (or the burden to having failed) primarily concern the teacher her/himself. From the municipalities' point of view successful research studies leads to a probable risk of losing a competent teacher to the university. The universities are in most cases the winners as they gain economic resources as well as access to qualified researchers. There are however limitations regarding the amount of available positions also at universities. The lesson learned for future investments in teacher graduate schools could be formulated in the following way: the opportunities of the individual teacher must be accommodated within the same constraints that surround municipalities and universities. This means that the planning, organization and implementation of teacher graduate schools must be coordinated more carefully by all concerned parties and span over a longer period than previous initiatives and projects.

CURRENT SITUATION FOR THE TUFF STUDENTS

Today (2013) five of the twelve teacher graduate students within TUFF have completed their studies receiving a licentiate degree. Four of these five students are admitted for further graduate studies towards a 'full' PhD exam. The remaining seven students have partly or fully returned to their respective schools/employers. Some have been appointed to positions where they are responsible for developing technology education in their municipality. Others have been involved in occasional or more long-term assignments as guest lecturers at universities. They are all expected/expecting to complete their studies – some in the coming semester, others in coming years.

TEACHERS DOING RESEARCH: PROS AND CONS IN LITERATURE

As stated before, TUFF is an example of a larger trend towards teachers doing academic research. As remarked before, the idea behind that is that it might help reduce the gap between educational research and classroom practice. Let us first see what causes this gap. In the first place the fact that teachers traditionally only serve as the people who provide pupils and classes to the researchers but otherwise are not involved in the research creates a lack of commitment to using the outcomes. In the second place, many studies have research questions that are not relevant for teaching practice but only have theoretical meaning. In the third place, the experimental research set-up requires a control over the variables that normally is not available in a classroom situation and therefore artificial situations have to be created that hamper transfer of the outcomes to normal situations. In the fourth place, the outcomes are usually published for researchers and are unreadable for teachers.

The effect is that a lot of educational research remains unused in practice (Broekkamp and Van Hout-Wolters 2007). This complaint is heard for many school subjects. In technology education, research is relatively young, but also in this domain it is not easy to identify a research study that really had a substantial impact on teaching. Having teachers themselves become researchers is seen as a possible solution. Success, however, is not guaranteed due to a number of barriers. In the first place, teachers often are insufficiently qualified to do research at the level that is required to publish in academic journals. They may have had a course in research methodology during their teacher education, but that may be long ago. A second barrier is that their school environment does not have the infrastructure that is needed for doing research: often access to scientific literature is not present, there is no community of researchers that they can discuss with, and they lack resources like time and money, as research is not the primary goal of the school and therefore only little resources are dedicated to that. Methodologically, there is a danger that when a teacher investigates interventions in his/her own practice/school, there is insufficient objectivity. As a result the outcomes of many studies done by teachers in their own school are of insufficient quality (Vrijnsen-de Corte 2012): validity and/or reliability are insufficiently warranted, and generalizability is questionable.

Even when the outcomes are such that they cannot really be called ‘academic research’, the experience of doing research can still be a useful activity for teachers. It is a form of professional development that can make a teachers more motivated to continue teaching. After all, many teachers leave school before the normal retirement age because the treadmill of daily teaching practice has made them loose interest in school life. Doing research as a side-activity can refresh them and give them opportunities for innovating their own teaching practice. It would be more appropriate, however, to call this ‘professional development’ rather than ‘academic research by teachers’ (West 2011).

The remedy for this seems to be to create communities in which teachers work closely together with qualified researchers at universities. This is the basis for creating research schools like TUFF and FontD in Sweden and DuDoc in the Netherlands. By creating such communities the advantages of school teachers doing research can be harvested without suffering the barriers mentioned. This requires, of course, active involvement of both parties. Teachers need to commit themselves to not wasting precious academic research and time and academic supervisors need to commit themselves not to cause irritation with teachers and sloppy supervision by seeing this supervision as less important than their own research activities.

Research by teachers fits well with a trend towards new types of research that have more potential of applicability in practice. Action research, design-based research, and in general, practice-oriented research are quickly emerging in the research arena and teachers are in a good starting position for that (apart from the barriers mentioned above), as they have their own teaching practice directly at hand to be used a ‘experimentation garden’ (Cochran-Smith and Lytle 2009). In fact, one would expect that teachers, when becoming involved in research school like TUFF, FontD and DuDoc, would have a strong preference for those types of research, as they offer immediate possibilities for improving their teaching practice. The strange thing is that both in TUFF and in FontD this is not the case. This book reflects that, too. Many of the research topics have no direct practical relevance for teaching practice. One may wonder why teachers still opt for such a topic. No research has been done into that, but one could guess that this has to do with teachers’ perception of what academic research is. It may well be they the traditional image of research as something that has to be either on a macro-level or has to be in a rather artificial ‘scientific’ setting, and that almost by definition has to be large-scale and quantitative, dominates teachers’ perception of what they ought to choose as a research topic in order to make it Ph. D.-worthy. This is something that needs to be worked on in the future and hopefully the traditional image of research will erode once sound action research and design-based research Ph. D. studies by teachers become published and used in practice. What is also needed is more attention for research capabilities in the teacher education programs in those cases where this attention is still small. Of course, this will always remain a minor element in the whole teacher education program. Teacher educators can be frustrated by the fact that it is almost impossible to bring future teachers up to a level of ‘qualified researcher’ in the little time that is available for research courses. Maybe a different content for those courses may improve this. Normally, the student teachers are required to do a (small but still) full research study in the course of the program. It is extremely unlikely that this will result in any serious research study given the fact that it is the teachers’ first experience. Maybe a more fruitful approach would be to have the student teacher do a sort of ‘apprenticeship’ with a professional researcher in the program. That may have as a consequence that the student teachers is not actively involved in all phases of a research, but the experience (s)he gets with the limited part of the whole research study probably is much more in-depth. To compensate for the parts of the research process the student teachers has not been actively involved in, (s)he may be required to at least read about that and perhaps in his/her apprenticeship report writes about it to show that (s)he does have gained an understanding of the whole research process.

STRUCTURE OF THE BOOK

TUFF has resulted in a variety of thesis topics, all related to technology education. One of the interesting aspects of the TUFF program is that it combined philosophy of technology and technology education research. The philosophy of technology generates perspectives on the nature of technology that are very useful for developing education about technology. Section 1 of the book is dedicated to the philosophy of technology. The three papers in this section deal with the nature of technological knowledge and contain contributions from the field of philosophy of technology. Sven Ove Hansson introduces some aspects in the nature of technological knowledge that make this type of knowledge different from knowledge in science. Per Norström shows that explanation and prediction, as knowledge-related activities in technology, also have some distinctive features in the technological domain. One of the aspects of technological knowledge that make it special is the importance of knowledge representation in pictures. Being able to understand those is therefore an important element in technological knowledge. In the chapter by Anna Stenkvist this type of knowledge is investigated theoretically. Implications for technology education are also presented.

Section II is about technology education research at national level. Inga-Britt Skogh first introduces the development of technology education in the Swedish curriculum and some previous study about its practice. Edvard Nordlander and Maria Cortas Nordlander present a study into the Swedish National Testand the way it deals with problem solving, a core activity in technology, but also in other domains. Joachim Svärd investigated an inquiry-based national support system for teachers. This and the previous chapter show that national interventions may not always work out what they intended. In particular for a relatively vulnerable school subject like technology education this can cause all sorts of problems. Another educational concern at national level is the extent to which girls have equal opportunities with boys. This gender issue is the topic dealt with in Gunilla Rooke's chapter. Although Sweden has been very active in this respect traditionally, the chapter shows that still further action is needed.

Section III is about engineering education. The first chapter builds a bridge between the macro-level of Section II and the micro-level in the remainder of section III. Håkan Ahlblom studied the way students make choices between regional engineering education programs. Several factors influencing this choice were identified in the study and those can be used to promote engineering education. Patricia Kingdon focused on one such factor, namely the image that young people have of engineers. It is evident that unattractive images of engineers will distract people from a study in engineering and therefore creating an attractive image in technology education is of great importance. Equally important is to know what engineers and designers themselves think they do and what they have to learn in engineering education. This is investigated in Helena Isaksson Persson's contribution.

Having seen the national level (curriculum) perspective and the students' perspective, it is logical that we also looked for the teachers' perspective. This is what section IV is about. There are two papers in this section. The first, by Eva Hartell, describes teachers' perspectives on assessment in technology education. The outcomes show that assessment is still by no means unproblematic in technology education and a lot of opportunities for improvement remain still unused. The final chapter, by Lennart Rolandsson, is about teachers' beliefs regarding programming education, which deals with a particular technological skill and for that reason is often seen as part of technology education. The study, together with Kingdon's earlier text, is a nice example of how relevant it is to know the ideas pupils are teachers hold, as this can be used to tune educational intervention better to where people are mentally seen.

The whole set of chapters nicely illustrate the variety of technology education studies one can find nowadays. Some are more theoretical, others are more empirical; some are outspoken quantitative, others and very much qualitative and there are also mixed-method studies. Also the different perspectives of curriculum teachers and pupils are represented. The TUFF experience shows that a well-orchestrated effort to develop a collection of research studies in technology education with teachers as researchers can be successful. This is promising for the future of technology education. Research studies can be an important support for the development of a school subject that still is not reckoned with the traditional undisputed elements of the school curriculum. Such support is most welcome in that vulnerable situation. Educating future citizens in such a way that they have developed a sound technological literacy is well worth the effort of preserving technology education in the school curriculum in some form. Hopefully the TUFF project has made a contribution to that.

REFERENCES

Andræ Thelin, A. (2009). *På tröskeln till en okänd värld. Forskarutbildning och skolans vardag*. Rapport 31/2009. Oslo: Norsk institutt for studier av innovasjon, NIFU STEP.

Broekkamp, H., & Hout-Wolters, B. H. A. M. van (2007). The gap between educational research and practice: A literature review, *Educational Research and Evaluation*, *13*, 303–220.

Cochran-Smith, M., & Lytle, S. L. (2009). *Inquiry as stance. Practitioner research in the next generation*. New York: Teachers College Press.

National Agency of Education (2009). *The boost for teachers initiative*. Brochure. National Agency of Education. Stockholm: Fritzes

Proposition. 2000/2001:3: *Forskning och förnyelse.* Stockholm: Utbildningsdepartementet.

Proposition 1999/2000:135: *En förnyad lärarutbildning*. Stockholm: Utbildningsdepartementet.

Research Council home page Retrieved: 2013–04-10 www.vr.se

Skogh, I-B. (2010). Teachers becoming researchers – a way to bridge the gap between academy and practice. In H. Middleton, (Ed.), *Knowledge in technology education* (Vol. 2). Griffith Institute for Educational Research, Brisbane, Australia.

Skogh, I-B., & Gumaelius, L. (2012). Technology teachers as researchers; the TUFF experience. In H. Middleton, (red.), *Explorations of best practice in technology*, *design & engineering education* (Vol. 2). Griffith Institute for Educational Research, Brisbane, Australia.

SOU 2008:109: *En hållbar lärarutbildning. Betänkande av Utredningen om en ny lärarutbildning* (HUT 09). Stockholm: Utbildningsdepartementet.

Vrijnsen-de Corte, M. (2012). *Researching the teacher-researcher. Practice. Practice-based research in Dutch professional development schools*. Eindhoven: University of Technology.

West, C. (2011). Action research as a professional development activity. *Arts Education Policy Review*, *112*, 89–94.

SECTION I

PHILOSOPHY OF TECHNOLOGY

SVEN OVE HANSSON

2. WHAT IS TECHNOLOGICAL KNOWLEDGE?

INTRODUCTION

As usual, Joanne goes to work by bicycle. She is an engineer in a medium-sized company in the automatic control industry. The first thing she does after putting down her bag in her office is to make a pot of tea for herself and her closest colleagues. She pours four teaspoons of black tea into the pot, one for each person and one for the pot. After bringing a cup of tea to her own desk she begins the day's work. Her first task is to study a report from the company's laboratory. The technicians have tested the first prototype of a new thermostat that she has designed. Unfortunately the device did not respond rapidly enough to changes in temperature. In order to solve the problem she pulls out a couple of handbooks in thermodynamics from her bookshelf and starts to calculate the effects of several alternative designs.

In this short episode we find examples of four types of technological knowledge. The first is her ability to ride a bicycle. Most cyclists cannot tell how they keep balance on a bicycle (Jones, 1970). Such knowledge is called tacit. It has an important role in many types of craftsmanship and professional knowledge. Painters can seldom explain the hand movements by which they even out a surface much faster, and with much less spackling paste, than an amateur. The skilled lab nurse will find it equally difficult to explain to an inexperienced colleague how to take blood samples from patients with difficult veins.

When Joanne made tea she applied a traditional rule for measuring out tea leaves. Probably she does not know its background. She uses it because it works (gives suitably strong tea). This can be called practical rule knowledge. It differs from tacit knowledge in being expressible in words. She has in fact taught it to her five year old son (who is still not able to ride a bicycle). Joanne also makes abundant use of rule knowledge in her work as an engineer. When she designs a load-bearing part she always makes it strong enough to carry twice the intended load. This is a practical and reasonably simple way to ensure that her constructions do not break, but there is no theoretical ground for choosing 2 as a safety factor. (Doorn and Hansson, 2011).

When she studies the lab report she (and her colleagues in the laboratory) apply scientific methodology to investigate a technological object. This is technological science. Advanced engineering often proceeds in this way, i.e. technological constructions are investigated with scientific methodology. This means that the same methods are used as in the natural sciences to ensure a reliable result: control groups, randomization, blinding, control measurements, well-calibrated measurement

I.-B. Skogh & M.J. de Vries (Eds.), Technology Teachers as Researchers, 17–31.

instruments etc. But technological science differs from natural science in having man-made rather than natural objects of study.

Finally, when she applies thermodynamics to design a better thermostat she makes use of natural science to solve a technical problem. This is a type of problem solving that her education has made her well prepared for. Engineering education includes considerable amounts of natural science and training in its application to technological problems. But ten years ago, when working so hard with her course in thermodynamics, she had no idea that one day she would apply it almost on a daily basis.

FOUR TYPES OF TECHNOLOGICAL KNOWLEDGE

In summary we have four major types of technological knowledge: tacit knowledge, practical rule knowledge, technological science, and applied (natural or social) science. This is by no means the first attempt to classify technological knowledge; quite a few typologies and catalogues have already been published. (For an overview, see Houkes (2009, pp. 321–327) There are two major reasons why I have chosen to propose a new typology instead of applying one that is already available. One reason is that previous typologies have been based on mixtures of several criteria for the classification; some typologies contain both types defined in terms of what is known and types defined in terms of how something is known. The present proposal focuses on how we know, not on what we know. (I will return below to the possibility of combining these two crossing distinctions to obtain a more detailed typology.)

The other reason is that previous typologies did not seem to be well suited to educational needs. As we will soon see, the four types in this typology are acquired by different learning processes, which makes the typology relevant for studies of teaching and learning.

As shown in Figure 1, the four types can be linearly ordered in terms of how practical or theoretical they are. Tacit knowledge is decidedly non-theoretical. It is followed by practical rule knowledge that is somewhat more ”theoretical” since it is expressed in words. The two types of science represent more theoretical types of knowledge. Since technological science is focused on making things work, we can describe it as less theoretical than natural and social sciences that focus on explanations.

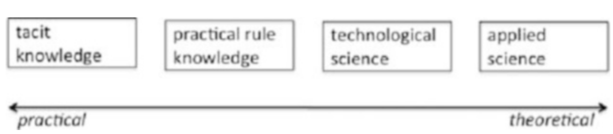

Figure 1. The four types of technological knowledge, ordered in the practical–theoretical dimension.

TACIT KNOWLEDGE

The expression ”tacit knowledge” is fairly new; it was introduced by the Hungarian-British chemist and philosopher of science Michael Polanyi (1891–1976). His book The Tacit Dimension from 1966 is still the starting-point of many discussions on tacit knowledge. However, his main interest was natural science rather than technology or technological science. He wanted to show that a strictly rule-bound road to scientific knowledge does not work; there is always an element of intuitive human judgement.

Today, technological knowledge is at the centre of the discipline of knowledge management that was established at the beginning of the 1990s. The Japanese researcher Ikujiro Nonaka (born in 1935) has had a leading role in applying Polanyi’s concept to practically oriented management and organization research. His main focus is on how tacit knowledge can be transferred from one person to another. There are two major methods for this. One is apprenticeship: the learner observes and tries to imitate someone who already possesses the tacit knowledge. In this way she can often herself develop the same type of tacit knowledge. The other method is based on prior articulation (externalization) of the tacit knowledge, i.e. it is described in words so that others can learn it more easily. (Nonaka and Takeuchi 1995. Nonaka and von Krogh 2009.)

Nonaka and his co-workers emphasized the latter method, the articulation of tacit knowledge in language. They provided a famous example of this: the development of the first bread-making machine for household use that was launched in 1987. (Nonaka och Takeuchi, 1995) The early prototypes did not produce bread of sufficient quality. In order to improve the machine, the designers had to find out how to knead a dough. Unfortunately this could not be learnt from books; it was tacit knowledge that one has to learn from a baker. To solve the problem a member of the design team apprenticed with a master baker at a luxury hotel. The baker was unable to tell her in words what to do, but she tried to imitate him and in this way she gradually learnt the right movements. Finally she managed to express what she had learnt in words: a “twisting stretch” was required. She and her colleagues in the design team managed to construct a machine that performed a twisting stretch and baked (sufficiently) good-tasting bread.

The articulation of tacit knowledge in the form of instructions and descriptions has been performed with at least three different purposes. The first of these is examplified by the bread-making machine: the mechanization and automatization of a work process. Since the industrial revolution, the articulation of tacit knowledge has been an important part of the mechanization of work tasks previously performed by craftspeople. Today, such articulation of tacit knowledge often takes the form of computer programming. The first step in programming is often to develop a detailed description of how a human expert performs a task. This description can then be codified into a computer programme.

The second purpose is to facilitate teaching and learning. Learning a craft or profession would be incredibly inefficient and time-consuming if every learner had to repeat the mistakes of her predecessors. Suppose that the tasks to be performed in the control room of a nuclear plant could only be learned in an intuitive, trial-and-error fashion. It would then be a much more precarious task to train a new generation of operators than if most of the knowledge they need is available in written form. The authors of textbooks for crafts and professions spend considerable efforts on articulating the tacit knowledge of experienced practitioners as far as possible.

The third purpose of articulating tacit knowledge is to control other people's work. Ever since the industrial revolution employers have systematically divided qualified tasks into simpler subtasks, most of which can be performed by cheaper labour. The extensive (tacit and explicit) knowledge of highly qualified workers has been codified and divided into small tasks that can more easily be taught and learnt. The assembly line is the most well-known example of this process. The American Frederick Taylor (1856–1915), the pioneer of the so-called scientific management movement, saw this dequalification of labour as a major purpose of new management practices. "All possible brain work should be removed from the shop and centered in the planning or laying-out department" (Taylor [1911], 2008, p. 50). But ever since the early days of the industrial revolution, critics, including Adam Smith (1776, V:i:ii) and Karl Marx (1867, I:12.5), have warned against the resulting deterioration of the quality of working life. (Cf.: Braverman, 1974; Campbell 1989, p. 226; Wood, 1982; Wood, 1987) However, it should be noted that this criticism has not been targeted at the articulation of tacit knowledge but at the use of this articulation to change the work process in ways contrary to the interests of workers.

On some occasions, tacit knowledge has been romanticized and described as a better type of knowledge that should be kept tacit rather than being articulated. In my view this is not a tenable position. We humans have developed language in order to convey insights, instructions, and other messages to each other. By articulating previously tacit knowledge we make it accessible to criticism, evaluation, and improvement. If physicians choose treatment methods intuitively (which previously was the ideal, cf. Wootton, 2006) it will be exceedingly difficult to evaluate and improve their treatments. In contrast, if they apply precisely described criteria for diagnosis and treatments, then such evaluation and improvement can be performed in a systematic fashion. Both tacit and explicit knowledge can be in error, but explicit knowledge is more easily corrigible since it is more accessible to critical discussion and evaluation.

In other words: Tacit knowledge that is valuable does not become less valuable when expressed in words. To the contrary, language is needed to transmit, evaluate, and improve knowledge. In some cases complete articulation may not be possible, but partial articulation may still be better than no articulation at all.

PRACTICAL RULE KNOWLEDGE

The second main form of technical knowledge is practical rule knowledge. Much technical knowledge is taught and learned in this form, not least in practical crafts. The practical knowledge of electricians is a good example of this. There are many rules for how to connect wire. Many of these rules have a theoretical justification, but in practical work the electrician does not refer to these justifications but to the rules that are based on them. There are for instance good reasons not use certain types of cable for tensions above 250 V, but the electrician applies the rules, not the underlying theory. Furthermore, many of these rules are based on a combination of theoretical justifications and convenient conventions. There are good reasons to use one and the same colour code for all earth wires, but the choice of green and yellow for that purpose is a convention that cannot be derived from physics.

Rules of this type are often called "rules of thumbs". A major characteristic of such rules is that they are easy to memorize and apply. The term "rule of thumb" has been in use at least since the latter part of the 17th century. Its origin is unclear, but one plausible hypothesis is that it derives from the use of the thumb as a unit for length measurement. (At least since the seventeenth century an inch has also been called a "thumb's breadth". In many languages, including French, Spanish, Swedish and Dutch, the word for "inch" is derived from that for "thumb".)

Although rules of thumb are used extensively in practical technical work, surprisingly little has been written about the ways in which they provide us with knowledge. Per Norström (2011) has recently compared rule of thumb knowledge with other forms of technological knowledge. He started out from his own experience as an engineer working with PID controllers (proportional–integral–derivative controllers) that are used to regulate the flow of liquids through pumps. On his former workplace there were two experts in the calibration of PID controllers, Paul and Nils. Both were highly skilled, but they worked in very different ways. Paul had remarkably accurate intuitions about the instruments, but he could never explain his intuitions or tell others how to calibrate an instrument. Nils performed the work with the help of mathematical calculations that he was happy to teach anyone who wanted to learn them, but that learning process would take some time. On one occasion when neither of them was available, Per had to step in and calibrate a PID regulator. Since he had neither Paul's intuitions nor Nils's skill in calculation methods he consulted a handbook. It contained a simple rule in the following style:

Set all parameters in zero position. Raise the Kp control until oscillation starts. Then lower the Kd control until the oscillations stop….

Thus, Per employed a rule of thumb that had the considerable advantage that it could be learnt quickly. But he was aware that if something unusual happened, or if he were confronted by another type of regulator, then the rule of thumb could not be trusted. Chances would be much higher that Nils could have solved such a situation with his calculations. Rules of thumb tend to have a much smaller area of application than scientific knowledge.

Rules of thumb can have different origins. Some of them are the result of articulation of tacit knowledge. Others have been obtained through simplification of scientific knowledge. In yet other cases they are based on a combination of scientific knowledge and experience-based safety margins. This applies for instance to many of the rules that are used in engineering design.

TECHNOLOGICAL USES OF SCIENCE

Technological science, in the limited sense in which I use this term here, is science that systematically investigates different technological solutions in order to find out their properties. Just as natural science, technological science employs experiments as a primary source of knowledge. In fact, technological experiments have a much longer tradition than experiments in natural science. They can be traced back to the experimental traditions that have been found among indigenous peoples. The Mende people in Sierra Leone even has a special word, "hungoo", for experiment. A hungoo can for instance consist in planting two seeds in adjacent rows, and then measuring the harvests in order to determine which seed was best. Hungoos are probably a native tradition, not one brought to the Mende by visiting Europeans. They are definitely technological experiments, not natural science experiments, since their purpose is to find out how to achieve certain practical ends, not to understand nature. Similar experiments also occur in other parts of the world. (Richards, 1989). Through the centuries, technological development has largely been driven by craftspeople systematically trying out different constructions and methods.

The experimental tradition among craftsmen was one of the major sources of modern scientific methodology. Galileo Galilei (1564–1642) and other scientific pioneers learned much from skilled workers on the art of extracting information from nature by manipulating it, i.e. making experiments (Drake, 1978; Zilsel, 1942). But from the very beginnings experiments in the natural sciences had another goal than technological experiments. Craftspeople made experiments in order to solve technical problems, natural scientists in order to find out the workings of nature.

The experimental tradition in the crafts continued to develop in parallel with natural science. In the 18th and 19th century millwrights performed advanced experiments and measurements, but they had little or no contact with the academic science of their times (Layton, 1978). It was not until the latter part of the 19th century that natural science was employed on a large scale to develop new technology. The chemical and electrotechnical industries were the pioneers in this new development. Important inventions such as the telegraph were the outcomes of discoveries in university laboratories. (Böhme, 1978; Kaiser, 1995.) But in some technological areas, technology development continued well into the 20th century to have little or no contact with natural science. This applied for instance to metallurgy; new methods were tried out and tested in ironworks, based on experience rather than on principles and ideas from the natural sciences (Knoedler, 1993).

In the 19th and early 20th century, schools of engineering fought to obtain the same status as universities. To prove their case they had to base their teaching of technology on a scientific basis. Two different strategies were adopted to achieve this. One was to use results from the natural sciences to investigate the workings of machines and other technological constructions. Formulas from mechanical science were used to characterize the movements of machine parts, and the theory of electromagnetism was applied in the construction of electric machines and appliances. New disciplines, such as structural mechanics, were developed that broadened the basis of this type of calculations. This development has intensified over the years. Today, new physics and chemistry give rise to more and more sophisticated technology. The technological use of biological science is increasingly common, and so is that of the social and behavioural sciences (for instance in the construction of entertainment technologies and human-machine interfaces).

The other strategy was to apply scientific method directly to technological constructions. Machines and machine parts were built, and measurements were made on alternative constructions in order to optimize their performance. (Faulkner 1994. Kaiser 1995.) In many cases, this was the only way to solve practical technological problems. (Hendricks et al, 2000) The processes studied in wind tunnels were usually too complex to allow for a mathematical solution. Direct testing of technological constructions has continued to be an essential part of scientific engineering. Without crash tests, automobile safety would have been much worse. Even when a construction is based on relatively simple, well-known principles, it has to be tested in practice. Endurance tests of furniture and household appliances are among the best-known examples of this.

These two traditions, technological science (in a strict sense) and applied natural science, are still alive and well at technological universities. Today few would deny that they are both needed and that they complement each other.

Even if we run technologies on a daily basis with tacit knowledge and/or practical rule knowledge, when something goes wrong we tend to turn for science for a solution. A scientific approach or at least a science-based understanding of mechanisms is often necessary in troubleshooting. An operator in the control room of an advanced technological system cannot respond adequately to unforeseen deviations unless her knowledge of the system goes far beyond practical rule knowledge.

CHARACTERISTICS OF TECHNOLOGICAL SCIENCE

Technological science is much less discussed than natural science, and it is often seen as a variant of natural science. In fact it differs from natural science in several important respects. These can be summarized in the form of six distinguishing characteristics of technological science. (Hansson, 2007)

First and perhaps most obviously, the technological sciences differ from most of the natural sciences in that their study objects have been constructed by humans, rather than being objects from nature. This is a basic difference, but a clarification and an exception have to be made.

The clarification is that this difference refers to the ultimate study objects of the respective disciplines. Natural scientists often study objects that have been modified for the purpose of measurement or experiment, but this is done only as a means to understand objects or phenomena that occur naturally. As one example of this, in order to determine the structure of a protein it is often useful to produce a crystallized form of it. Spectroscopic studies are then performed on the crystallized protein in order to determine its structure. Obviously, the crystallized protein is not a naturally occurring object but one that has been modified by humans. However, for the biochemist the crystallized protein is not the ultimate study object. It is studied in order to understand the structure and the workings of the naturally occurring protein. In contrast, the human constructions studied by technological scientists, such as machine parts and computer programs, are their ultimate study objects.

The exception is chemistry that differs from the other natural sciences in this respect. Most of the substances studied by chemists are not known to occur in nature.

The second characteristic is closely connected with the first one: The design of new technological objects is an essential component of engineering. Design is also an important part of the work of many academics in the technological sciences. Technological scientists do not only study human-made objects, they also construct them.

Again, a caveat concerning chemistry is needed: Synthetic chemistry is similar to the technological sciences in that it aims at the construction of new objects (in this case, new chemical substances). (Schummer, 1997) There is, however, an important difference between chemical synthesis and engineering design. Chemical synthesis is aimed at obtaining a substance with a specific, predetermined molecular structure. In contrast, engineers designing a new product work with a complex and often not fully explicit list of design specifications or goals. The ideal outcome of the design process would be a product that fully satisfies all the design goals. In practice, however, such an outcome is seldom achieved. Compromises and trade-offs between conflicting design criteria have to be made in the course of the design process. (Asimov 1974. Vincenti 1990. Vincenti 1992.)

Engineering design has an important role in the development of new experiments in the natural sciences. It is common for new experiments to depend crucially on the design and production of new experimental equipment. From this point of view, the natural sciences are in part based on the technological sciences, just as technology is in part based on the natural sciences. (Janich 1978. Kroes 1989. Lelas 1993.)

The third characteristic is that the study objects of technological science are largely defined in functional terms. In order to determine if an object is a screwdriver we have to determine whether it has the function of driving screws. Therefore, screwdrivers are a functional category. The same applies to object categories such as saws and diodes, ladders and lamps, refrigerators and particle accelerators. These are all functional categories. The functions that define these and other classes of technical objects serve as conceptual bridges between human intentions and the physical world. (Kroes and Meijers 2002. Hansson 2002. Hansson 2006. Vermaas and Houkes 2006. Kroes 2006,)

Again, an exception has to be made. There is one of the natural sciences, namely biology, in which functions have a central terminological role. Concepts such as fin, eye, gland, stem, flower, and food are all defined according to their functions for the organism. The major difference is of course that whereas technological functions have been intentionally assigned to objects, biological functions are our way to describe the outcomes of evolutionary processes.

The fourth characteristic is that the conceptual apparatus of the technological sciences contains a large number of value-laden notions. (Layton, 1988) Concepts abound that have a clear value component, such as "user friendly", "environmental friendly", "risk", "safety", and "disaster". We have explicit technological norms in the form of written codes and standards that provide us with detailed specifications for a wide variety of technological products, practices, and procedures. Most importantly, evaluations of technological objects have a central role in technological science and research. We perform research in order to construct better bridges, cars, computers, computer programs, medical implants, etc. Contrary to natural scientists, technological scientists freely evaluate their study objects in value terms. In this respect they are close to medical scientists, who feel no need to make their science value-free by eliminating references to "better" treatments or "bad" developments of a disease. In this respect, technological science is also closer to the social than the natural sciences. Value-laden concepts such as "justice", "welfare" etc. have a central role in several of the social science disciplines.

The fifth characteristic is that technological science has less room than the natural sciences for idealizations. In the natural sciences, far-reaching idealizations are made in order to isolate natural phenomena from each other. (McMullin, 1985) A physicist who studies electromagnetism uses models of electromagnetic phenomena in which gravitation is absent. Similarly, in studies of gravitation she will use models in which there are no electromagnetic forces. Often, scientific experiments are performed under specially constructed conditions that are tailored to suit such simplified models. Physical experiments are often performed in vacuum in order to correspond to theoretical models in which the impact of atmospheric pressure has been excluded. Chemical experiments are performed in gas phase in order to ensure that each pair of reacting molecules has no interaction with other molecules. This brings these experiments into closer correspondence to theoretical models of reaction mechanisms.

All this works well in the natural sciences, but it does not work for engineering. The physicist can use a theory of electromagnetism that does not take gravitation into account, but the engineer who constructs an electric motor for an elevator cannot disregard the effects of gravitation – unless the machine is intended for use in a space station. Similarly, theoretical mechanics does not take weather conditions into account. In the construction of a suspension bridge the same idealization can lead to disaster. (Layman, 1989)

The sixth and last characteristic concerns the attitude to mathematical problem-solving. Both in the natural and technological sciences, many problems refer to measurable quantities and require a mathematical solution. There is, however, an important difference in the very nature of the precision requirement. The precision that the engineer needs is always obtainable by means of a sufficiently good approximation. Thus, if the choice of wire dimensions for a suspension bridge depends on the solution of a complex system of equations, the engineer does not need an analytical solution of the system; if a solution has been obtained with a sufficient number of decimals the problem has been solved. In this she differs for instance from an astrophysicist or a population geneticist who needs to solve an equally complex system of equations. For the purposes of the natural sciences, an analytical solution is always preferred (although there are areas, such as quantum chemistry, in which it is seldom obtainable). This may partly be a matter of the aesthetic qualities of the solutions, but it is also a matter of their explanatory qualities. There is a good chance that the insights obtainable from an exact solution can contribute to the solution of other similar problems in the future.

TRANSFORMATIONS BETWEEN THE FOUR KNOWLEDGE TYPES

As already indicated, the four types of technological knowledge can be ordered linearly according to how practical or theoretical they are. This also makes it possible to systematize the different ways in which one type of knowledge can be transformed into another. This is illustrated in Figure 2.

We can divide knowledge transformations into two major groups depending on whether they transfer knowledge to a more theoretical type (a movement to the right in the diagram) or a more practical type (a movement to the left).

One type of transformation to more theoretical knowledge has already been mentioned, namely the articulation of tacit knowledge that then becomes practical rule knowledge (arrow 1 in the diagram). When a transformation in the theoretical direction results in (technological or applied) science, we can call it a scientification of knowledge. An explanation of bicycle riding in terms of physics is a case of scientification (arrow 2 in the diagram). Another example is the development of theories about heat engines into more general of thermodynamic theory (arrow 3 in the diagram).

Next, let us consider transformations in the other direction, i.e. to more practical knowledge. An important group of such transformations are those that result in tacit knowledge. It is usually practical rule knowledge that is starting-point for such a transformations. It can be called a routinization (arrow 4). One typical example is when a young car-driver learns to gear up or down without thinking of it. Another

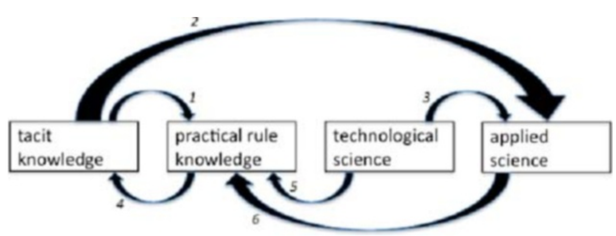

Figure 2. Transformations of technological knowledge: articulation (1), scientification (2 and 3), routinization (4) and application (5 and 6).

example of routinization is learning to play a musical instruments. In these and many other cases the routinization of practical rule knowledge is necessary to make us able to perform various tasks without too much delay or effort.

Other transformations in the theoretical-to-practical direction are those that result in practical rule knowledge or in technological science. These transformations can be described as the application of science. The rules of thumb that Per Norström used to calibrate a PID regulator must have originated in application of either technological or natural science (arrow 5 or 6).

LEARNING

The four knowledge types differ substantially in how easy or difficult they are to learn. This is schematically illustrated in Figure 3, where the thickness of arrows illustrates the ease with which the different knowledge types are learnt. It must be emphasized that actual learning processes are much more complex than the transfer of a piece of knowledge from teacher to student that is depicted in the diagram. The communication between student and teacher is almost always bidirectional, and communications with others than the teacher (such as fellow students) are often essential for the learning process. However, the diagram illustrates one central feature of learning, and one in which the four types of technological knowledge differ in important respects.

As indicated in the diagram, practical rule knowledge is by far the knowledge form that is easiest to learn. It is followed by technological and applied science. Learning science takes much more effort than learning rules of thumb. All these three can be taught by conventional methods in which verbal instructions and explanations have a central role. By far the most difficult type of knowledge to learn is tacit knowledge that cannot be taught by verbal instruction. As discussed above, tacit knowledge can be acquired through imitation attempts in apprenticeship, but in many cases that is a difficult and uncertain procedure.

Fortunately, there is an alternative way to learn tacit knowledge: In many cases it can be articulated to practical rule knowledge, which is then taught in the usual way in which verbal instruction has an essential role. This results in practical rule knowledge

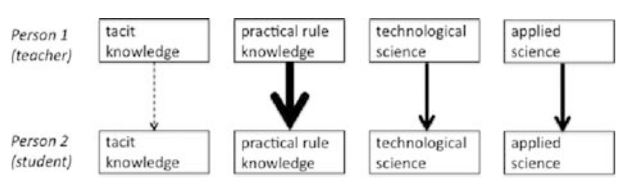

Figure 3. Schematic representation of direct learning processes for technological knowledge. The dashed arrow represents imitation whereas the solid arrows represent methods in which verbal instruction has an essential role. A thicker line denotes more efficient learning.

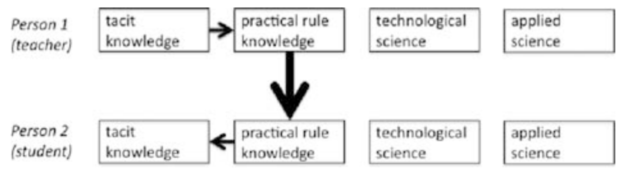

Figure 4. Schematic representation of an indirect learning process for tacit knowledge.

that can then finally be routinized through training. This three-step procedure for acquiring tacit knowledge is illustrated in another schematic diagram, Figure 4.

In summary we have five learning processes for technological knowledge:

- Tacit knowledge through imitation. (Leftmost arrow in figure 3.)
- Tacit knowledge through articulation, verbal instruction, and routinization. (Figure 4.)
- Practical rule knowledge through methods in which verbal instruction has an essential role. (Second arrow in figure 3.)
- Technological science through methods in which verbal instruction has an essential role. (Third arrow in figure 3.)
- Applied science through methods in which verbal instruction has an essential role. (Rightmost arrow in figure 3.)

A COMBINED CLASSIFICATION SCHEME

The fourfold classification of technological knowledge refers to how one knows, not to what one knows. Alternatively, we can classify technological knowledge according to its contents, i.e. to what one knows. Such a classification would have to contain categories such as: knowledge about how to construct an artefact, knowledge about how to use an artefact, knowledge about (and ability to explain) how an artefact works, etc. Table 1 gives an indication of how these two ways to classify technological knowledge can be combined. As the table illustrates, some knowledge contents can be known in different ways. It is proposed that this two-dimensional classification can be useful for practical teaching. You need to know what type of knowledge you want the student to acquire in order to determine how to teach. The reader is invited to add more rows to the column, illustrating different types of technological knowledge that students are required or encouraged to acquire.

DISCUSSION

In summary we have identified four major types of technological knowledge: tacit knowledge, practical rule knowledge, technological science and applied (natural and social) science. Technology educations differ in the relative emphasis that they

Table 1. Combined classification of technological knowledge, referring both to how the person knows and what she knows. "+" denotes appropriate, "(+)" partly appropriate and "–" inappropriate form of knowledge for the knowledge contents in question.

	Tacit knowledge	*Practical rule knowledge*	*Technological science*	*Applied science*
ability to ride a bicycle	+	–	–	–
ability to shift gears in a car	+	(+)	–	–
ability to construct a suspension bridge	–	+	+	(+)
ability to determine the aerodynamic properties of a new car model	–	–	+	(+)
ability to explain how one rides a bicycle	–	–	–	+

put on each of these knowledge forms. Education for practical crafts will usually put more emphasis on tacit knowledge and practical rule knowledge, whereas engineering education puts more emphasis on the two scientific knowledge forms. Basic technology education in compulsory schools should presumably aim at some sort of balance between the four in order to provide a basic understanding of how practical and theoretical knowledge is combined in technology. Within the limited time allotted to technology in most educational systems, this is no easy task.

One of the factors that complicate this task is the lack of technology teachers who are sufficiently acquainted with all four types of technological knowledge. In Sweden, the introduction of technology education in primary school led to a conflict between crafts (sloyd) teachers and physics teacher, who both wanted to teach the new subject. This was a clash between teaching professions that represent different types of technological knowledge. Crafts teachers represent both tacit knowledge and practical rule knowledge. Learning how to hit the nail and not your own fingers with the hammer is for the most part an acquisition of tacit knowledge. Learning which types of saw or knitting needles to use for different purposes is much facilitated by rules of thumb. Physics teachers, of course, represent natural science. A physics teacher is well equipped to teach students how the laws of physics can be used to understand and predict the behaviour of technological objects such as electric motors, binoculars, and pulleys. Neither crafts teachers nor physics teachers tend to be knowledgeable in technological science. And most importantly, neither of them has the education needed to teach how the four types of knowledge meet in technology.

But this is a difficulty that can be turned into a strength. Technology education can become a meeting place for different types of knowledge. It can be a place where students begin to understand the relationships between theoretical and practical knowledge. It can thereby also become a source of understanding and respect for the different types of knowledge that are needed to build a society. For this to succeed we need technology teachers with broad knowledge and understanding of both the theoretical and the practical forms of technological knowledge.

REFERENCES

Asimov, M. (1974). A philosophy of engineering design. In F. Rapp (Ed.), *Contributions to a philosophy of technology* (pp. 150–157). Dordrecht: Reidel.

Böhme, G., Daele, W. van der & Krohn, W. (1978). The 'scientification' of technology. In K. Wolfgang, E. T. Layton Jr., & P. Weingart (Eds.), *The dynamics of science and technology: Social values, technical norms and scientific criteria in the development of knowledge*, (pp. 219–250, Vol II). Dordrecht: Reidel.

Braverman, H. (1974). *Labor and monopoly capital: The degradation of work in the twentieth century*. New York: Monthly Review

Campbell, R. A. (1989). Work, workers and working-class hyistory. *Le Travail, 23*, 221–234.

Doorn, N., & Hansson, S. O. (2011). Should safety factors replace probabilistic design? *Philosophy and Technology,* 24,151–168.

Drake, S. (1978). *Galileo at work: His scientific biography*. Chicago: University of Chicago Press.

Faulkner, W. (1994). Conceptualizing knowledge used in innovation: A second look at the science-technology distinction and industrial innovation. *Science, Technology and Human Values, 19*, 425–458.

Hansson, S. O. (2002). Understanding technological function. Introduction to the special issue on the Dual Nature programme. *Techne*, *6*(2), 87–88.

Hansson, S. O. (2006). Defining technical function. *Studies in History and Philosophy of Science, 37*, 19–22.

Hansson, S. O. (2007). What is Technological Science? *Studies in History and Philosophy of Science, 38*, 523–527.

Hendricks, V. F., Jakobsen, A., & Pedersen S. A. (2000). Technical matrices in science and engineering. *Journal for General Philosophy of Science, 31*, 277–305.

Houkes, W. (2009). The nature of technological knowledge. In A. Meijers (Ed.), *Handbook of the philosophy of science* (pp. 310–350, Vol. 9). Philosophy of Technology and Engineering Sciences, Elsevier.

Janich, P. (1978). Physics – natural science or technology? In W. Krohn, E. T. Layton & P. Weingart (Eds.), *The dynamics of science and technology, sociology of the sciences* (pp. 3–27, Vol. II). Berlin: Springer.

Jones, D. E. H. (1970). The stability of the bicycle. *Physics Today*, *23*(4), 34–40.

Kaiser, W. (1995). Die Entwicklung der Elektrotechnik in ihrer Wechselwirkung mit der Physik. In L./ Schäfer & E. Ströker (Eds.), *Naturauffassungen in Philosophie, Wissenschaft, Technik, Band III: Aufklärung und späte Neuzeit* (pp. 71–120). Freiburg and Munich: Verlag Karl Alber.

Knoedler, J. T. (1993). Market structure, industrial research, and consumers of innovation: Forging backward linkages to research in the turn-of-the-century US steel industry. *Business History Review, 67*, 98–139.

Kroes, P. (1989). Philosophy of science and the technological dimension of science. In K. Gavroglu, V. Goudaroulis & P. Nicolapoulos (Eds.), *Inre lakatos and theories of scientific change* (pp. 375–382). Dordrecht: Kluwer.

Kroes, P. (2006). Coherence of structural and functional descriptions of technical artefacts. *Studies in History and Philosophy of Science, 37*, 137–151.

Kroes, P., & Anthonie M. (2002). The dual nature of technical artifacts – presentation of a new research programme. *Techne*, *6*(2), 89–92.

Layman, R. (1989). Applying idealizing scientific theories to engineering. *Synthese, 81*, 353–371.

Layton, E. T. (1978). Millwrights and engineers, science, social roles, and the evolution of the turbine in America. In W. Krohn, E. T. Layton & P. Weingart (Eds.), *The dynamics of science and technology. Sociology of the sciences* (pp. 61–87, Vol. II). Dordrecht: Reidel.

Layton, E. T. (1988). Science as a form of action: The role of the engineering sciences. *Technology & Culture, 29*, 82–97.
Lelas, S. (1993). Science as technology. *British Journal for the Philosophy of Science, 44*, 423–442.
McMullin, E. (1985). Galilean idealization. *Studies in History and Philosophy of Science, 16*, 247–273.
Marx, K. (1867). *Das Kapital*. Hamburg: Otto Meisner Verlag.
Nonaka, I., & Georg von Krogh (2009). Tacit knowledge and knowledge conversion: Controversy and advancement in organizational knowledge creation theory. *Organization Science, 20*, 635–652.
Nonaka, I., & Hirotaka T. (1995). *The knowledge-creating company: How Japanese companies create the dynamics of innovation*. New York: Oxford University Press.
Norström, P. (2010, in press). Technical know-how from rules of thumb. *Techne.*
Polanyi, M. (1966). *The tacit dimension*. London: Routledge.
Richards, P. (1989). Farmers also experiment: A neglected intellectual resource in African science, *Discovery and Innovation*, *1*, 19–25.
Schummer, J. (1997). Challenging standard distinctions between science and technology: The case of preparative chemistry. *Hyle, 3*, 81–94.
Smith, A. (1776). *Wealth of nations*. London: Strahan & Cadell.
Taylor, F. W. ([1911] 2008). *Shop management*. Sioux Falls: NuVision Publications.
Vermaas, P. E., & Houkes, W. (2006). Technical functions: A drawbridge between the intentional and structural natures of technical artefacts. *Studies in History and Philosophy of Science, 37*, 5–18.
Vincenti, W. G. (1990). *What engineers know and how they know it*. Baltimore: Johns Hopkins University Press.
Vincenti, W. G. (1992). Engineering knowledge, type of design and level of hierarchy: Further thoughts about What engineers know…. In P. Kroes & M. Bakker (Eds.), *Technological development and science the industrial age* (pp. 17–34). Dordrecht: Kluwer.
Wood, S. (ed.). (1982). *The degradation of work?* London: Hutchinson.
Wood, S. (1987). The deskilling debate, New technology and work organization. *Acta Sociologica, 30*, 3–24.
Wootton, D. (2006). Bad medicine. *Doctors doing harm since Hippocrates*. Oxford University Press.
Zilsel, E. (1942). The sociological roots of science. *American Journal of Sociology, 47*, 544–562.

PER NORSTRÖM

3. EXPLANATION AND PREDICTION IN TECHNOLOGY EDUCATION

INTRODUCTION

– Why does the toaster get hot?
– Because I switched it on by pushing that lever. (1)

– Why does the toaster get hot?
– Otherwise it wouldn't toast the bread. (2)

– Why does the toaster get hot?
– Because an electrical current passes through the resistive wires in the heater. That makes them hot. (3)

All three answers above are examples of explanations. Which is preferable depends on the context where the question is posed.

In everyday language, an explanation is a relevant answer to a real or imagined question of *why* or *how* type. It can often be formulated as a phrase beginning with *because*. A good explanation helps increasing the understanding of a situation or phenomenon. In educational situations, explanations are made by the teacher or found in the textbook, often without anyone explicitly asking for them.

In philosophy, the concept of explanation has received considerable attention, especially scientific explanations, but there is no universally accepted definition. Explanations and predictions can be used for different purposes, use different types of models and modes of explanation, and have different styles. What kind of explanation is preferable in a particular situation depends on the *explanandum* (that which is to be explained), the purpose, and the intended recipients. A good explanation has to provide the information sought for in a style that is comprehensible and efficient.

In the technology education in Swedish compulsory school, explanation is mentioned in the curriculum, in the assessment criteria (Skolverket, 2011a), and in the commentary material for teachers (Skolverket, 2011b). Being able to explain a phenomenon, a mechanism, or a design principle is a sign of deeper understanding than just being able to describe it. A few examples are provided. How parts interact to satisfy a purpose is for example mentioned in connection with explanations (Skolverket, 2011, p. 258), but there are no proper definitions or comments to how knowledge, explanation, and understanding in a technological context might differ from their counterparts in other school subjects

I.-B. Skogh & M.J. de Vries (Eds.), Technology Teachers as Researchers, 33–51.

The purpose of this article is to propose a reasonable interpretation of explanation and prediction in a technology education context. It is based on findings from general epistemology, studies of explanations in science education, and various accounts of technological explanation that have been put forward in the philosophy of technology. A sketch of a classification system for explanations in technology education is provided. It is intended to be used in the analysis and evaluation of existing explanations, and could also be used to guide the process of designing new ones.

EXPLANATION, UNDERSTANDING, AND PREDICTION

Understanding implies knowledge about a relation between two or more phenomena. You might know that the toaster is hot, without understanding why. If you know that the toaster is hot, and also know that it is used to heat bread, and manage to put these pieces of information together, you have some kind of understanding. If you know that it is hot, that it is electrical, and that $P = U^2/R$, you have the prerequisites for understanding something else about it. An explanation is something that helps understanding. You are prepared to understand something about the *explanandum* (that which is to be explained) if you know the *explanans* (that which explains).

Several attempts to classify explanations have been made. One system commonly described in textbooks about the fundamentals of epistemology or theory of science (for example Føllesdal, Walløe & Elster, 1993) divides explanations into *causal*, *functional*, and *teleological* explanations. In a causal explanation, a phenomenon is explained by what caused it. Functional explanations explain a phenomenon through what it causes. Teleological explanations are based on the intentions of the agent who made the phenomenon occur.

In the natural sciences, causal explanations have the highest status. In idealised physics and chemistry, they are the only valid type – gravity causes the acceleration of a falling body, the acceleration can therefore be explained by referring to gravity; the different chemical polarities of oil and water cause them to be insolvable in each other, chemical polarity can therefore be used to explain why they do not mix. In biology, functional explanations are commonly used – the existence of animals' hearts is explained by their function to pump blood. Another functional explanation can be found in answer (2) to the question about the toaster's heat in the introduction to this article. Explanations in terms of what an instigator of a phenomenon intends it to are called teleological explanations; explanations in terms of purpose or intention. A variety of other types exist in the philosophical literature, such as different types of social explanations. There is no consensus concerning which classification system to use or the exact limits between different types.

The product of science is knowledge. Therefore explanations have a prominent position in science. They are used to show how conclusions are drawn from data and how different pieces of scientific knowledge support each other. The best known model for scientific explanation is the classical deductive-nomological model (also known as DN or the covering law model), first presented by Hempel and Oppenheim

(1948). In this model, the explanans is a set of propositions that describe a situation or phenomenon. At least one of the propositions has to be a natural law. From these propositions, the explanandum can be concluded using classical logic. Later on, Hempel (1965) created a supplementary model, the inductive-probabilistic model which has a similar form, but in which the result is only reached with a certain probability. In Hempel's and Oppenheim's terms, the latter is not a true explanation, but a device for the justification of expectations. The deductive-nomological model and related variants can in many situations be seen as ideals of scientific explanation, but they are not very common outside of the laboratory context. A deductive-nomological explanation of why the toaster gets hot could be summarized thus:

Explanans: The toaster contains nichrome wires.
Nichrome wires are electrical conductors.
Nichrome wires have electrical resistance.
When electrical current passes through a medium that has electrical resistance, the medium will heat up (physical law).
Electrical current passes through the wires.

Explanandum: The toaster gets hot.

This is similar to answer (3) to the question about the hot toaster in the introduction. The other two variants cannot be captured by the DN model, which in Hempel's and Oppenheim's opinion disqualifies them as explanations (or at least as scientific explanations). There are nonetheless contexts where they would be valuable.

In certain contexts, there is a close relationship between the ability to explain and the ability to predict. According to von Wright's (1971) comments on Hempel, the main difference between explanation and prediction is the time perspective. The deductive-nomological model explains what has already happened. If the data in the explanans is known before, it could also be used to predict what will happen. This is true in many contexts, but misses one important difference between explanation and prediction, namely that explanation (in Hempel's and Oppenheim's sense) depends on understood causality, while prediction needs only correlation. Scriven (1988) shows this by referring to the fact that he can predict rain by watching cows in a field. If the cows lie down in the middle of the day, it will soon start to rain. According to Scriven, the method is reliable. Yet, it contains nothing that could in any reasonable way be said to explain precipitation. There are also more scientific examples of divergence between explanation and prediction. There are well established ways to explain earthquakes through the movement of tectonic plates. In spite of this, the prediction of earthquakes has proven difficult. The theory of evolution explains why the elephant has a trunk, but it is not likely that it could have been used to predict the development of this versatile appendage. The ability to explain does not necessarily lead to an ability to predict or vice versa. This is a strong indicator of there being something intrinsically different between them.

In Engineering and Technological Science

Hansson (2007) describes technological science roughly as technological knowledge gained by using scientific methods. The technological knowledge domain is delimited as being about man-made objects, created with a purpose in mind. The objects studied in technological science are real ones, not the idealisations commonly found in the natural sciences. In technological science, gases are not ideal, all construction materials have impurities, and even the thickest wires have electrical resistance. Engineers and technological scientists have to take this into consideration, for example by using safety factors or by stating probabilities instead of facts. “Given that the load will not exceed 10 kN, there is a 95 % probability that a ball bearing from this batch will last for at least 10^7 revolutions” could be a statement belonging in the domain of technological science. “If the load is 10 kN, this ball bearing will last for 13050204 revolutions” belongs to the world of idealisations.

It is obvious that in the engineering context, prediction is more important than explanation. Explanation of why the ball bearing broke is needed when an accident has occurred. To predict whether it will break before the product’s estimated lifespan is useful to produce artefacts that can be trusted, whether an accident actually occurs or not. Models for prediction are important products of research in technological science, and important tools in engineering. Some of those models are based on knowledge from the natural sciences; others are developed through inductive reasoning from practical experience, experiments, or the trial-and-error method.

Explaining Technological Artefacts

As stated above, the common modes of explanation used in the natural sciences are not sufficient for the technological domain. The main reason for this is the important part played by intentions, goals, and wishes in technological activity. The natural sciences can help us to explain why a certain object broke when hit with a certain force, or to predict whether it will break when exposed to such a force. It cannot, however, be used to determine whether the breaking was intended (as when buildings are demolished or nuts are cracked) or accidental. As the purpose of an activity or an object is an essential component for it to be technological, we clearly need something more than the scientific models for explanation to fully understand technology.

One important difference between a natural object and a technological artefact is that technological artefacts are created by humans (or other intelligent creatures) with a purpose in mind. This leads to them having dual natures. The technological artefacts are physicochemical as well as functional objects (Kroes, 1998). My toaster’s exterior is made from sheet metal. There are two slots on the top. The bottom parts of those slots are metal grates, held in place by a spring. Connected to the main unit is a soft plastic cord (1.8 metres) with three embedded copper wires (each with an intersection of 1 square millimetre). The whole unit weighs 900 grams and reaches 152 millimetres above table level. Those are some of its physicochemical characteristics. They can be determined scientifically in an objective, non-normative way. It would be ridiculous to claim that the mains cord contained good or bad copper atoms or that the toaster weighed 900 good or bad grams.

The toaster's functional nature is defined by its function to toast bread. It was designed and manufactured to be an object that toasts bread, and that is what I use it for. The functional characteristics are highly normative; it can perform its task badly or well. Whether a specific toaster is good or bad frequently depends on who evaluates it. I want my toast with a dark, almost black crust along the edges. My toaster delivers that kind of delicious toast. Therefore, I regard it as a good one. Somebody who prefers healthier toast (without the carcinogenic, poisonous and generally harmful crust) would think otherwise.

The dual nature is typical of technological artefacts. Natural objects such as stones and trees are only physicochemical objects. From a physicochemical point of view, the heater in a toaster is just a resistive wire that becomes hot when a current passes through it. From a functional point of view, it is something that enables a piece of bread to be toasted. If the very same hardware were placed in a hairdryer, it would still be same physicochemical object. As a functional object it would be different due to its changed purpose.

During the last decade, the dual nature model has grown into a quite complex set of theories and models concerning accidental function, malfunctioning, the role of users in functional ascriptions, and more (de Ridder, 2007; Vaesen, 2008). For the present purpose of explaining technological artefacts and mechanisms in fundamental technology education, only choice morsels of this theory will be used.

For the functional nature of a technical artefact to come into play, a user (real or imagined) is necessary. Houkes and Vermaas (2002) introduced the concept of *use plans*, in which the function of an artefact is realised. The main point of this theory is that an artefact fulfils its function when handled according to its use plan. The use plan justifies the belief that the object has a particular function. As Vermaas (2010, p. 68) has since pointed out, the original model is of limited use in engineering contexts. The reason for this is that the engineer ascribes functions to the artefacts that he creates, while the original theory also considers so called accidental functions, where an artefact is successfully used for something that it was not intended for.

De Vries (2005, p. 16f) describes artefact function and use by referring to *user plans*. These seem to be related to Vermaas' and Houkes' use plans, but are not as elaborate. De Vries (2005) makes no effort to define or explain the concept in detail, instead he provides a few examples where the same artefact is used according to different user plans – a screwdriver used to tighten screws (proper function, intended use), and to open cans (accidental function, non-intended use). For the purposes of discussing technological explanation in technology education, de Vries' user plans are sufficient. Answer (1) to the question about the hot toaster in the introduction is an attempt to explain the heat by referring to the user plan.

Technological Knowledge and Knowledge About Technology

By technological knowledge, I mean knowledge that enables an agent to partake in technological activities. This knowledge guides and/or enables action. It can be based on experience or science, it can be tacit or written down. Hansson (this volume) refers to it as *technological knowledge* and Vincenti (1990) calls it *engineering design knowledge*. The action-enabling and action-guiding knowledge is justified primarily by being able to repeatedly produce the results aimed for. Explanations are useful to gain deeper understanding of the activities and their results, but not to be able to perform the tasks. It is perfectly possible to be skilled in soldering without knowing anything about cooling curves of alloys or the eutecticum at 63 % tin and 37 % lead. It is enough to know that the filling material for soft soldering that is marked 60–40 goes from liquid to solid almost instantly. Being able to predict the outcome is sufficient to justify the action-guiding knowledge (Norström, 2011).

There are plenty of examples from engineering where scientific knowledge is necessary to be able to partake in technological activities, especially when dealing with modern technologies. There are also examples of the opposite, where scientific understanding of a phenomenon or process provides little or no help at all. When making toffee, amateur confectioners use the 'small ball test' to determine when it is ready: You drop some of the hot sugary mixture into cold water. If it solidifies, and it is possible to form a small ball from it without it sticking to your fingers, it is finished. Professionals use a thermometer; as the mixture thickens, its boiling point increases, and at between 110 and 130 degrees Celsius (depending on the type of toffee), it is finished. None of these procedures demand any understanding of what really goes on. They are examples of action-guiding knowledge. It is not trivial to explain in a scientific way why the characteristics of sugar, fat, and water combined in a pot change during heating. The concentration of sugar increases as the water evaporates, which leads to increased viscosity. The characteristics change also because of the heat causing the sucrose to split into fructose and glucose. In this case, being able to explain what happens does not necessarily lead to an ability to act. A confectioner with a thermometer, experienced in toffee-making, or even an amateur knowing about the 'small ball test', are better suited for the task than a chemist equipped with all imaginable knowledge of the peculiarities of polysaccharide solutions.

A multitude of examples are available from the engineering and technology domains. Kempton (1986) investigated how a group of people believed that their thermostats worked, and how this affected their use. The interviewees could be divided into two distinct groups, those who believed in the *valve theory* and those who believed in the *feedback theory* of thermostat function (p. 4). The valve theory proposes that the thermostat works like a valve; if it is set to a higher value, the heat increases, much like the water flow increases when a tap is opened. The believers in the *feedback theory* claimed that the thermostat is set to the preferred temperature once and for all, measures the temperature continuously, and switches on the radiators when the room is too cold. The feedback theory is the correct one; it can be used to explain the function of the thermostat, and to predict how the heat in the room will vary. The valve theory is also useful for prediction, but it is incorrect and therefore cannot increase understanding beyond the trivial (that the setting of the thermostat affects the heat). Its explanatory power is therefore significantly lower. A comparison between the two groups showed that both managed to keep their homes at a comfortable temperature and that they used roughly the same amount of energy for heating. The valve believers tended to set the thermostat lower when they left home or during the night, which made up for the greater amount of energy that they used when repeatedly adjusting the thermostat during their waking hours. Both groups possessed effective action-guiding knowledge, know-how, for home thermostat operation. The feedback theory group also had an understanding of how the thermostat worked. If the aim is to teach a group of pupils how to use a thermostat to get a comfortable indoor temperature, both theories would work equally well, and the theory that the pupils find easiest to understand could be used. If they should learn about control systems with feedback in general, using the thermostat just as an example, the feedback theory is the only suitable one.

Wash (2010) studied folk theories about computer security and explicitly based his study on Kempton's results. He found that the respondents' understanding of computer viruses, hacker attacks, and other threats to home computers was largely based on misconceptions and models lacking important characteristics. Just as Kempton, he concludes that, from the end users' point of view, it is largely irrelevant to evaluate models according to their correctness. Instead they should be evaluated according to whether they encourage rational behaviour or not. At the same time he also recommends security advice to include information about how the threats can affect the computer, as this will serve to motivate users to take correct action and also evaluate what advice is useful (Wash, 2010, p. 12). In educational situations, the same phenomenon may occur. Even though action-guiding knowledge is enough to partake in an activity, scientific or science-like knowledge may be needed to encourage the behaviour.

The examples above concerned action-guiding knowledge, knowledge that enables or guides technological activities such as design, construction, adjustment, use, and maintenance of technological artefacts. Apart from this, there is also knowledge *about* technology; the history, philosophy, and sociology of technology, and knowledge about the scientific principles behind inventions and processes that you most likely will never experience, for example. This knowledge is justified by its coherence and relationship to other well-established pieces of knowledge, rather than by its use to reach a particular result. It can be explained by referring to science, social phenomena, intentions, and historical events, as well as the physicochemical and functional natures of the artefacts themselves.

Technological explanations are useful in different types of situations: when analysing failures and accidents, when analysing competitors' products, for persons with a profound interest in the inner workings of technological artefacts, and in educational situations, to name a few. What demands to put on a technological explanation depends on the situation where it is used and by whom it is requested. One important division is between the internal and the external audience; the creators and advanced users of a technology on the one hand, and the regular users, on the other (Pitt, 2009, p. 866). While the ability to predict often suffices for the regular user, being more concerned with the outcome than how it is reached; the advanced users such as creators, maintenance personnel, and instructors might need the in-depth knowledge provided by explanations.

TECHNOLOGY EDUCATION

Technology education in compulsory school varies between countries. Nevertheless, there are some themes that occur almost universally: the design process, the relation between science and technology, and the interplay between technology and society all belong to the common educational core (Rasinen, 2003). Pupils are supposed to acquire skills and knowledge that they can actually use to solve technological problems, create artefacts, and be active agents in a technologically advanced society. They should also learn about inventions, technological mechanisms and technological principles, some of which they will most likely never see or experience directly. This knowledge is used to understand technological artefacts and socio-technical systems, not primarily to intervene with them.

What Needs to be Explained in Technology Education?

Pitt (2009) divides those who benefit from technological explanation into an internal and an external audience. These two groups have different foci in their interests, and generally demand different levels of detail. This division is not always applicable in the educational situation. Pupils have to learn brief descriptions of nuclear power plants. This is not knowledge needed by the average end user of the electricity created by the power plant; we just plug our devices in and switch them on. It is not the knowledge of the advanced user either, as its lack of depth and precision makes it useless in the operation or creation of power plants. The pupil is supposed to learn a simplified version of the power plant's interior, where a vast majority of the crucial functions are hidden in 'black boxes'. It is a knowledge that is not in any way practically useful for the vast majority of the pupils. It is an orienting knowledge that is typical of neither the internal nor the external users. It is useful when trying to gain a further understanding of our technologically advanced society, and partake in the political debate about the environment and energy supply. Pupils are supposed to develop an *orienting knowledge*, a school understanding, of the concept, demanded by the curriculum. Content-wise, it is similar to popular (technological) science. As pupils are forced to learn it, and often will have to pass a test afterwards, the context is quite different from the average casual reading of popular science, though.

Gilbert, Boulter, and Rutherford (2000) present a typology and evaluation system for model-based explanations in science education that forms a useful starting point for a discussion about explanations in technology education. Their typology divides explanations in the educational context into *intentional*, *descriptive*, *interpretative*, *causal*, and *predictive* explanations. I use a different terminology, where neither the descriptive nor the predictive are called explanations. The other three, or variants of them, are relevant explanation types in technology just as in the sciences.

Intentional explanations explain why a certain theme is taught in school; why it is important, or why it is included in the curriculum. They are used to answer questions of the "Why do we have to learn this?" variety. The *causal explanations* are simplified version of the deductive-nomological model or something similar. They are not technological in themselves, but make up important parts of technological explanations of for example mechanisms. *Interpretative explanations* are described as answers to the question "of what is the phenomenon composed?" (Gilbert, Boulter & Rutherford, 2000, p. 196). The examples provided by Gilbert, Boulter, and Rutherford come from school chemistry, where pupils have to accept the existence of atoms and molecules without having the means to examine or observe them. Interpretative explanations of this kind are also important in school technology, where pupils have to accept that an integrated circuit contains millions of non-visible transistors.

Educational texts, films, computer programs, et cetera in the area commonly combine descriptions with explanations. The types of explanations listed below are all common in technology education.

– Curricular explanation

  You are supposed to learn about the toaster because its thermostat controlled heater is an example of a simple feedback system. Feedback systems are common in technological applications of many different kinds, and an understanding of them is necessary to understand control theory and various kinds of automatic systems, such as robots.

  This is what Gilbert, Boulter, and Rutherford (2000) calls intentional explanations, explaining why a concept should be learnt. The name has been changed to avoid confusion with intentions concerning technological artefacts and their use.

  In an oft-cited article, Roberts (1982) describes curriculum emphases in science education. He lists seven major ways to motivate why an educational content is important: Everyday coping; Structure of science; Science, technology, and decisions; Scientific skill development; Correct explanation; Self as explainer; and Solid foundation. With slight modifications, replacing science with technology and scientific phenomena and knowledge with their technological counterparts, these are used in technology education as well.

– Intentional-functional explanation

  The electrical toaster was created to enable housewives and servants to toast bread in a way more convenient than doing it on the stove or in gas-powered toasters.

The existence of an artefact with a particular function is explained by referring to the needs, wishes, or intentions of its creator. This can be a teleological type of explanation.

– Physical–functional explanation

The toaster gets hot to toast the bread.

This explanation shows how the function (toasting the bread) is realised by the toaster's physical change (the increase in temperature). More elaborate versions may be based on top-down or bottom-up thinking, explaining how the heat comes about through the interaction of the toaster's parts.

– Side effect explanation

With the advent of the electrical toaster and other electrical household appliances in the 1910's and 1920's there was a huge increase in the demand for domestic electrical installations, which lead to a marked increase in the amount of electric energy used in homes. (Freely adapted from Parker Smith, 1926.)

Artefacts commonly cause effects even to others than the primary users or those in the direct vicinity, such as the increased demand for electricity in homes in the example above. It could also be for example environmental or large scale economical effects. Side effect explanations function as answers to questions about what indirect consequences the use or invention of an artefact lead to for society or individuals peripheral to the artefact.

– Usage–function explanation

To toast the bread, put it in the slot and push the lever.

Explanations of this kind explain how to behave, which actions to partake in, to make the artefact perform its function. If more detailed, this kind of explanation may be based on top-down or bottom-up thinking. They can take the form of usage instructions and thereby be useful for action-guiding and prediction.

– Usage–physical behaviour explanation

The toaster gets hot because I switched it on by pushing that lever.

These explanations concern the connection between the artefact's physicochemical behaviour and the user's actions (the user plan). It can have many different levels of detail, from the overview in the example, to a very elaborate description of every little sub-action when the lever hits the switch that turns the current on, et cetera. This kind of explanation can often be designed to be useful for prediction and action-guiding. From the example above it is easy (and probably correct) to conclude that the toaster will get hot also on other occasions when the particular lever is pressed.

EXPLANATION IS NOT ALWAYS NECESSARY

What is to be explained depends on what is to be learnt, why it is to be learnt, and by whom. The learning objectives in school technology consist of both *action-guiding* *knowledge* (enabling the pupils to perform a certain task) and *orienting knowledge.* The orienting knowledge does not necessarily lead to an ability to act, but provides understanding of social effects of technology, standard mechanisms, the relation between science and technology, and more.

Action-guiding technological knowledge consists of the knowledge, skills and abilities that enable the pupils to actually create, adjust, maintain, and use technological artefacts. These are often practiced through "learning by doing". After a brief introduction, pupils practice soldering by performing increasingly difficult soldering operations; they practice searching the Internet and library data bases by attempting to find information of increasing obscurity, et cetera. The action-guiding knowledge can often be learnt without explanations. In the examples presented above, about home thermostats, computer security, and toffee-making, explanations would be essentially unnecessary if it is the abilities that constitute the learning objective. Curricular explanations, telling the pupils why the action-guiding knowledge should be learnt, could be useful though. Explanations and understanding of underlying mechanisms could be necessary to motivate learning and give knowledge of a higher quality – knowledge about the underlying mechanisms could be highly useful when trying to modify the knowledge to adapt to new contexts, for example. But, as is shown above, to be able to perform the tasks successfully, there is often no need of proper understanding; the ability to predict success is enough.

The orienting knowledge that pupils are supposed to acquire during technology lessons is not primarily aimed at making them able to act. Very few pupils will ever tinker with a nuclear power plant or assemble water pipes with standardised dimensions from the days of the Roman Empire. Nevertheless, the areas of energy supply and history of technology are common in technology curricula (Rasinen, 2003), and power plants as well as obsolete plumbing standards are included in technology textbooks (Alfredsson et al., 2003, pp. 27f; Sjöberg, 2004, pp. 159f). In spite of the information being useless for practical purposes, there are good reasons for including these items. The example of the Roman water pipes shows both the advantages of standardisation and the disadvantages of using lead piping in water systems. With proper understanding this could stimulate pupils to reflect upon unknown dangers of seemingly practical technical objects and substances, and comprehend how standardisation may increase the efficiency of manufacture and the ease of replacing broken parts. The orienting knowledge is intended to make pupils understand the world around them, act as illustration of scientific principles, or function as an introduction to more advanced technological studies.

WHAT TYPES OF EXPLANATION CAN BE USED?

Explanations in school technology use models. In this article, a wide concept of model is used. A model is a representation of an object or phenomenon that is to be examined, explained, communicated, and/or understood, where superfluous features are left out. The model can be based on empirical data, or on descriptions in the form of natural laws. What is excluded or simplified depends on which of the object's characteristics that are interesting in the particular context. If a jack stand is to be tested, a car may be modelled as a block of concrete; all that matters is that its mass and its distribution of it are similar enough to those of the car. In a wind tunnel test, the car model has to have the right shape and surface characteristics, but its colour and weight matter very little. What constitutes a good model depends on what one wants to achieve and what resources are available.

Educational technological explanations may be presented in a wide variety of ways and use a multitude of model types: verbal descriptions, drawings, flow charts, exploded views, and more. Combinations are common. Many of the styles available differ very little from the ones used in school science. Gilbert (2004, pp, 118f) divides teaching models used in science education into five different modes of representation: *concrete* (three dimensional and made of resistant material), *verbal* (spoken or written descriptions of entities and relations), *symbolic* (symbols, formulas, mathematical expressions, et cetera), *visual* (graphs, diagrams, animations, two-dimensional representations of three-dimensional objects, and more), and *gestural* (using body parts). All these are also used in technology education. Concrete models are created by pupils and shown by teachers. Verbal models are typical of classical Western teaching traditions; the teachers tell the pupils how something works. Visual models are at least as important in technology as they are in science. The ability to sketch, draw, and interpret drawings is demanded by curricula in for example Sweden (Skolverket, 2011a), England (Department for Education and Skills, 2004), and the United States (International Technology Education Association, 2007). The ability to communicate visually has even been put forward as one of the defining characteristics of the engineers' special knowledge (for example by Ferguson, 2002). Gestural models are also used in technology education as well as in science. Gilbert's example from school science is making pupils move in counter-flow to represent the movement of ions during electrolysis. Similar exercises can be performed in school technology. A former colleague of mine used a model of the Internet constructed from pupils during a technology lesson. One group of pupils represented data packages, and moved around a football field according to information they received from their classmates who acted as routers, domain name system servers, and other Internet components. The model showed the distributed character of the domain name system, as well as the multitude of ways that data packages can take to reach their destinations.

Apart from how they are presented, models can also be classified according to their contents and purposes. If the purpose is to explain a scientific concept through a technological model, very different demands are placed upon it than if it is intended solely to guide action. Every model has a limited scope, and the purpose of the model must be possible to fit into that scope for the model to be useful. Many models used by practicing technicians are not scientific, but based on experience or obsolete science. Whether to include these or not in technology educations depends on its purpose. If the purpose is to illustrate science, there is no room for them. If on the other hand, the purpose is to train the pupils in technological work, they are absolutely necessary (Norström, 2011).

Common modes in the technological pedagogical explanation genre include the following:

– Animistic

In the animistic style, a certain intelligence or will is attributed to the artefact. Levy and Mioduser (2008, p. 343) studied children working with a simple robotic system controlled by a light sensor. That the robot moves towards the light is described by referring to its intentions and preferences concerning light and darkness (described as a *psychological explanation*). The descriptions are useful for prediction in that context, but do not explain anything in the proper sense.

– Anthropomorphic

The functioning of an artefact is explained by likening it to a human body or parts thereof. When two parts of an industrial robot are described as being an 'arm' and a 'hand' respectively, it should be obvious to the listener what they are intended for. Therefore the names in themselves have, in that context, a (limited) explanatory power. The anthropomorphic style is a special case of the metaphor variant (see below). It has been given a name of its own because it is very common; gas sensors are referred to as 'electronic noses' (Aiken, 2004), the processor of a computer is compared to its brain (Liu, 2004; Garratt, 1996), et cetera.

After telling the reader that robots have advanced control systems, are able to work in hazardous environment, and are often quicker and more reliable than human beings, Garratt (1996) concludes his textbook description of robots in the following way:

A true robot has an 'electronic brain'. This is used to store and process the information which controls the actions of the robot. If the robot is required to do a new job, it can have its 'memory' rubbed clean and a new set of instructions given – this is called programming. (p. 109)

The part quoted provides a description of the robot's function using the anthropomorphic style – the central processing unit is described as an electronic brain, which also has a memory where its instructions are stored. There is also an explanation of the usage–functional type, the user can rub the robot's memory clean and input new instructions to make it behave in the ways described.

– Metaphor

The purpose of metaphor is to explain the unknown through the well-known. Metaphors are commonly used in science education. Ogborn et al. (1996) present various ones used in chemistry and biology. They quote one teacher who describes the endocrine system as being like an orchestra with the glands as individual musicians in need of a conductor (p. 73). Another teacher (p. 74) explains the human eye by comparing it to a camera. Metaphors are used in technology education as well. Sjöberg (2004, p. 147) compares electrical current to water flowing through a closed system of pipes, with turbines as coils and rubber membranes as capacitors. Alfredsson et al. (2003, p. 175) describe analogue versus digital processes by referring to time measurement by sandglass (analogue, the sand level varies continuously) and a prisoner making a mark on his cell wall every day (digital, no fractions of days are measured, time seems to pass in discrete steps).

– Scientific

  Components' interaction or their inner mechanisms are explained using the language and/or models of science (or their simplified counterparts used in school science).

– Structural

  The main parts of an artefact (components of a system) are described as 'black boxes', defined by their functions, inputs and outputs. The interactions of these components explain the composite function of the artefact. Structural explanations lead to what Ropohl (1997) calls *structural rule knowledge*. It is invaluable for activities like designing and assembling systems from standardised components (like personal computers), and for troubleshooting.

Combinations are of course possible. A common strategy in technology textbooks is to give a structural explanation, followed by a scientific explanation of the inner secrets of one or a few key components.

In Alfredsson et al.'s (2003) textbook about the fundamentals of technology, intended for students in upper secondary school (16–19 years old) who attend a science or technology programme, there is a short section on automatic control. In the introductory paragraph of this chapter, an explanatory description of James Watt's centrifugal governor is provided. The purpose of this invention was to enable steam engines to work at a steady pace in spite of a varying work load (Hills 1989, pp. 85f). Alfredsson et al.'s (2003, p. 193) description consists of two images and a short text. One of the images is a technical drawing of the governor, clearly showing its different parts. The other is a perspective sketch of the governor and the steam valve that it controls. The text describes how high rotational speed causes the centrifugal force [sic!] to lift the governor's rotating weights. The weights are attached to a system of mechanical linkage, which closes a steam valve when the weights rise at high speed, leading to the engine slowing down. If the speed is too low, the weights sink, which causes the valve to open and thereby the speed to increase. Alfredsson et al.'s purpose is to give orienting knowledge; the pupils should learn about the centrifugal governor to gain knowledge about the history of technology and control equipment in general. It is a physical-functional explanation presented in mixed modes: visual and verbal. The explanation is structural and scientific (even though the concept of centrifugal force is dubious from a scientific point of view, centripetal force tends to be more popular among physicists). Structural explanations, where individual components are mainly presented as 'black boxes', are prominent in the text, with statements such as (my translation from Swedish) "[a] certain mechanism closes the valve in the steam tube" (p. 193). The mechanism is presented by referring to its particular function, but how it performs its duties is not described. For the purpose of providing an example of an early automatic control device, this is perhaps sufficient. Peculiarly enough, Alfredsson et al. describe neither why it is necessary to control the speed nor why the process should work automatically. After reading this description, pupils will still not know why this invention was so important and vastly increased the possible uses of steam engines; the text lacks curricular as well as intentional-functional explanations.

EVALUATING EXPLANATIONS

Haglund and Strömdahl (2010) studied how students experience two different models explaining how Otto engines (the regular four-stroke engines found in cars, motorcycles, et cetera) work. The models were in the form of computer animations that showed valves opening and closing, the piston moving up and down, air mixed with petrol entering, and exhaust gases leaving the cylinder. In the terms above, the animations were intended as physical-functional explanations, showing how the function – to turn the axle – is implemented by making a piston move by the pressure generated through combustion. The model has a structural style and is presented in visual mode. One of the models (TIMLOTO, 2007) is based on a technical drawing of an actual engine and has easily identifiable parts (including cam shafts, piston seals, and a branded spark plug). The other (Cox et al., 2003) is highly stylized, and supplemented with a graph and numerical indicators, dynamically changing to show how the pressure, temperature and active volume of the cylinder vary throughout the cycle (visual–symbolic model). The respondents belonged to two different groups: some of them were training to become vehicle mechanics, while the rest were science and technology students in upper secondary school and at university level. The two groups experienced the models in quite different ways. Both groups understood the models, but the mechanics found the less stylised model, based on a technical drawing, to suit their purposes, while the students trained in science preferred the other. The two groups approach engines in different ways, the mechanics wanted the model with recognizable parts, while the science students attached great importance to the numerical data. The value of an explanation in an educational situation is ultimately determined by its usefulness for pupils who attempt to learn. That is obviously ultimately an empirical question.

Gilbert, Boulter, and Rutherford (2000, pp. 200ff) have described a framework for evaluation of explanations in science education that can be adapted for use in technology education. Their ultimate, aggregated assessment result is the *appropriateness* of an explanation. In short, this could be described as how well the explanation fulfils its role as an adequate answer to the implicit or explicit question that it is intended to answer. The appropriateness is highly context dependent and varies with the questioner, his needs, wishes, previous knowledge, et cetera. The appropriateness of an explanation is described as a function of its *suitability*, *relevance*, and *quality.*

The suitability of an explanation refers to whether it is of an appropriate type; it is a matter of validity, whether it has the potential to answer the right question. The relevance of an explanation depends on whether it fulfils the questioner's needs; does s/he have the ability to understand and make use of it? This makes it a matter of the explanation's mode and style. Using a metaphor based on something that the questioner does not recognize is an example of a mistake that can make an otherwise flawless explanation irrelevant in a particular situation.

In Haglund's and Strömdahl's (2010) article, the appropriateness of the two explanatory models varied significantly between the mechanics and the science students, even though both groups were able to understand them. The mechanics did not see the relevance of the graphs or numerical figures, which those trained in science found enlightening and possessing a great explanatory value. The relevance varied as the two groups had different learning objectives and different previous knowledge; they asked different implicit questions, and interpreted what they saw using different frameworks.

Quality is the most complex of the three characteristics. In the model of Gilbert, Boulter, and Rutherford (2000), the quality is related to how well the explanation agrees with science per se. In school science, historical models are commonly used (Bohr's model of the atom, Newton's mechanics, et cetera). A quality measurement that is suggested is how modern a model is. This is not appropriate in a technological context, where different models may co-exist without any of them being obsolete or even inferior to another. A consequence of this is that Gilbert, Boulter, and Rutherford's concept of *quality* cannot be used to evaluate explanatory models in technology education.

In the philosophy of engineering design, the concepts of *effectiveness* and *efficiency* are important when evaluating models and work-processes. The effectiveness is a measure of the result reached when using the process. The efficiency depends on the amount of resources used to reach the result. A less accurate mathematical model can be better in engineering than a more accurate one. If both models lead to useful results (are effective enough), the one that is easiest to use (is most efficient) is the best one. In another context, where a higher degree of accuracy is needed, the more complicated one would be the best one. While the quality of an explanation in Gilbert, Boulter, and Rutherford's (2000) sense is determined from the explanation itself and its comparison with current and historical scientific models, the quality of a technological explanation must be determined using technological evaluation criteria. These depend on the user and his/her needs rather than accurateness or generality. This leads to a notion of *quality* that is indiscernible from that of *relevance*. It is the pupil and his/her needs that determine the quality, not the explanation's relation to scientific or technological theories per se.

This means that the *appropriateness* of a technological explanation in an educational situation is a function solely of its *suitability* and its *relevance*; whether it provides the necessary information, and whether the questioner is able to use and understand it.

CONCLUSIONS

Scientific explanations may be parts of technological explanations, but they are not technological in themselves. An explanation needs references to the users, creators, society or their intentions to be technological. Technology is created with a purpose, and that purpose should be present in the explanation.

The appropriateness of an explanation cannot be determined without a context including a recipient. The demands on the explanation depend on what should be explained and who is to use it. Textbooks in physics and chemistry often contain explanations of how different artefacts work, which mechanisms they use, and which scientific laws that can be used to analyse them. In a technological context, this does not suffice. In science, a lever is a mechanical principle that can be analysed using the golden rule of mechanics. In technology it could also be something that enables people to move heavy objects. Without a purpose – a functional nature – it is not technology.

Knowing how to practice technology and knowing about technology are different types of knowledge, even though the border between them is blurred. It is perfectly possible to be able to partake in a technological activity without being able to explain the actions or their results scientifically. The knowledge, skills and abilities of this type are justified primarily by producing the expected result over and over again. Knowing *about* technology is different. This knowledge does not necessarily enable the knowing person to actually do anything, and it is justified by being compatible with other pieces of knowledge. To learn this orienting knowledge, explanations are essential to give what is learnt a solid foundation and a context where it can be used. In technology education, pupils gain action-enabling as well as orienting knowledge; they should learn how to use a gun-shaped dispenser for hot-melt adhesive, as well as be able to describe how a hydroelectric power station works and how the expansion of the railroad network affected society. These different types of knowledge must be treated separately when discussing teaching methods and evaluation procedures. In the Swedish curriculum, this is not explicitly stated. Terms such as ‘know’, ‘understand’, and ‘explain’ are used throughout the curriculum text without any comments suggesting that they should be interpreted differently in different contexts. Knowing how to use the glue gun is something completely different from knowing about how it works. The former implies an ability to do something, the latter of being able to recall and see connections between information about heat, electricity, polymers, and more. To learn the former, you need practice and experience of repeated success. To learn the latter, you need explanations of how heat affects the glue and what it is used for.

An explanation is appropriate only if it answers the questions (whether implicit or explicit) posed by the receiver, or in school situations: the curriculum. Without a purpose, an explanation cannot be evaluated. An explanation must also be adapted to its receivers; teenage pupils might be better off with a crude analogy than with a complicated mathematical formula. If the formula is not understood, it does not matter how much information that is hidden in it.

It is not an easy task to create models of technological artefacts and phenomena that fulfil the demands of the curriculum and are easy to understand for the pupils. It involves complex processes of selection, simplification, and presentation. It is difficult, but cannot be avoided as it is one of the core competences of technology teachers.

REFERENCES

Aiken, T. (2004). MOS air quality sensors make vehicle cabins safer. *Sensors*, *21*(2), 2–4.

AlfrEds.on, A., Bjärbo, A., Hjort, G., Lindén, B.-E., Norberg, R., & Nyberg, Y. (2003). *Teknisk basbok* [Technological base book]. Stockholm: Liber.

Cox, A. J., Belloni, M., Dancy, M., & Christian, W. (2003). Otto engine. URL http://webphysics.davidson.edu/physlet_resources/thermo_paper/thermo/examples/otto_engine.html. Accessed January 21, 2012.

Department for Education and Skills (2004/1999). *The national curriculum for England – Design and technology; Key stages 1–4*. London: Department for Education and Skills. URL http://www.education.gov.uk/schools/teachingandlearning/curriculum/secondary/b00199489/dt. Accessed January 21, 2012.

de Ridder, J. (2006). The (Alleged) Inherent normativity of technological explanations. *Techné*, *10*(1). URL http://scholar.lib.vt.edu/ejournals/SPT/v10n1/deridder.html. Accessed January 21, 2012.

de Ridder, J. (2007). *Reconstructing design*, *explaining artifacts*. Doctoral dissertation from the Delft University of Technology.

de Vries, M. J. (2005). *Teaching about technology.* Dordrecht, The Netherlands: Springer.

Ferguson, E. S. (1992). *Engineering and the mind's eye.* Cambridge, MA: The MIT Press.

Føllesdal, D., Walløe, L., & Elster, J. (1993). *Argumentationsteori*, *språk och vetenskapsfilosofi* [Argumentation theory, language, and philosophy of science]. Stockholm: Thales.

France, B., Compton, V. J., & Gilbert, J. K. (2010). Understanding modelling in technology and science: The potential of stories from the field. *International Journal of Technology and Design Education.* DOI 10.1007/s10798.010.9126–4.

Garratt, J. (1996/1991). *Design and technology*. Cambridge, United Kingdom: Cambridge University Press.

Gilbert, J. K. (2004). Models and modelling: Routes to More Authentic Science Education. *International Journal of Science and Mathematics Education*, *2*, 115–130.

Gilbert, J. K., Boulter, C. J., & Rutherford, M. (2000). Explanations with models in science education. In J. K. Gilbert & C. J. Boulter (Eds.), *Developing models in science education* (pp. 192–208). Dordrecht, The Netherlands: Kluwer Academic Publishers.

Haglund, J., & Strömdahl, H. (2010). Perspective on models in theoretical and practical traditions of knowledge: The example of Otto engine animations. *International Journal of Technology and Design Education.* DOI: 10.1007/s10798.010.9146–0.

Hansson, S. O. (2007). What is technological science? *Studies in History and Philosophy of Science*, *38*(3), 523–527.

Hempel, C. G. (1965). *Aspects of scientific explanation and other essays in the philosophy of science.* New York: The Free Press.

Hempel, C. G., & Oppenheim, P. (1948). Studies in the logic of explanation. *Philosophy of Science*, *15*, 567–579.

Hills, R. L. (1989). *Power from steam.* Cambridge, United Kingdom: Cambridge University Press.

Houkes, W., & Vermaas, P. E. (2002). Design and use as plans: An action-theoretical account. *Design Studies*, *23*, 303–320.

International Technology Education Association (2007). *Standards for technological literacy* (3rd ed.). Reston, VA: International Technology Education Association. URL http://www.iteaconnect.org/TAA/PDFs/xstnd.pdf. Accessed November 30, 2011

Kempton, W. (1986). Two theories of home heat control. *Cognitive Science, 10*, 75–90.

Kroes, P. (1998). Technological Explanations: The relation between structure and function of technological objects. *Techné, 3*(3). URL http://scholar.lib.vt.edu/ejournals/SPT/v3n3/KROES.html. Accessed November 30, 2011.

Levy, S. T., & Mioduser, D. (2008). Does it “want” or “was it programmed to...”? Kindergarten children’s explanations of an autonomous robot’s adaptive functioning. *International Journal of Technology and Design Education*, *18*, 337–359. DOI 10.1007/s10798.007.9032–6

Liu, A-S. (2004). *Heat sink fastener.* US Patent 6,731,504.

Norström, P. (2011). Engineers’ non-scientific models in technology education. *International Journal of Technology and Design Education.* DOI: 10.1007/s10798.011.9184–2.

Ogborn, J., Kress, G., Martins, I., & McGillicuddy, K. (1996). *Explaining science in the classroom.* Buckingham, United Kingdom: Open University Press.

Parker Smith, S. (1926). An all-electric house. *Journal of the Institution of Electrical Engineers*, *64*(351), 289–301.

Pitt, J. C. (2009). Technological explanation. In A. Meijers (Ed.), *Philosophy of technology and engineering sciences* (pp. 861–879). Burlington, MA: North Holland.

Rasinen, A. (2003). An analysis of the technology education curriculum in six countries. *Journal of Technology Education*, *15*(1), 31–47.

Roberts, D. A. (1982). Developing the Concept of “Curriculum Emphases” in Science Education. *Science Education, 66*(2), 243–260.

Ropohl, G. (1997). Knowledge types in technology. *International Journal of Technology and Design Education*, *7*, 65–72.

Scriven, M. (1988/1962). Explanations, predictions and laws. In J. C. Pitt (Ed.), *Theories of explanation* (pp. 51–74). New York: Oxford University Press.

Sjöberg, S. (2004). *Grundbok teknik* [First book technology]. Stockholm: Natur och kultur.

Skolverket (2011a). *Curriculum for the compulsory school*, *preschool class and the leisure-time centre 2011*. Stockholm: Skolverket [The Swedish National Agency for Education]. URL http://www.skolverket.se/publikationer?id=2687. Accessed January 21, 2012.

Skolverket (2011b) *Kommentarmaterial till kursplanen i teknik* [Comments to the syllabus in technology]. Skolverket [The Swedish National Agency for Education]. URL http://www.skolverket.se/publikationer?id=2568. Accessed January 21, 2012.

TIMLOTO [Technische Informatica Motorvoertuigen Leerweg Open Technisch Onderwijs] (2007). URL http://www.timloto.org/pictures/motor_wout3.gif. Accessed January 21, 2012.

Vaesen, K. (2008). *A philosophical essay on artifacts and norms.* Doctoral dissertation from Eindhoven University of Technology.

Vermaas, P. E. (2010). Focussing philosophy of engineering: Analyses of technical functions and beyond. In I. van de Poel & D. E. Goldberg (Eds.), *Philosophy and engineering* (pp. 61–73). DOI 10.1007/978–90-481–2804-4_6. Dordrecht, The Netherlands: Springer.

von Wright G. H. (1971). *Explanation and understanding*. Cornell University Press, Ithaca, NY.

Wash, R. (2010). Folk Models of Home Computer Security. Conference paper from the *Symposium on Usable privacy and security*, Redmond, WA. URL http://prisms.cs.umass.edu/cs660sp11/papers/rwash-homesec-soups10-final.pdf. Accessed January 21, 2012.

ANNA STENKVIST

4. PICTORIAL REALISM IN GEOMETRIC IMAGES AND TECHNICAL DESIGN

Technology is highly dependent on mathematics. In engineering education, a strong grounding in mathematics is a cornerstone (and sometimes unfortunately a stumbling block). Currently, attempts are being made in many universities to integrate mathematics better with the engineering disciplines. This is also one of the aspects that should be covered in technology studies at all levels of education. Specifically interesting is geometry, since it allows for a variety of representations that can be used in design. Students will understand both mathematics and technology better if they discover how geometry can help them to illustrate technological constructions and to choose the representations that mimic both appearance and their function. This chapter compares structural properties of pictorial representations based on geometry with other pictorial representations used in technology education. In particular it investigates what it means for a geometric image to be pictorially realistic. The discussion is exemplified through illustrations of, among others, a pinhole camera.

Previous definitions of pictorial representation systems in aesthetics are analysed (Goodman, 1976; Kulvicki, 2003). One issue treated in this text is how the properties of pictorial representation systems should be counted and compared. Another issue is how the projective transformation between the depicted subject and the picture is regarded. Some examples are mentioned wherein representation systems are shown to be pictorial in an intuitive sense, but where the conditions for those systems are not fulfilled according to previous definitions stated by Kulvicki (2003) and Goodman (1976).

Here, an image is said to be pictorially realistic if it both pictorially represents and *visually* resembles the depicted object. It is proposed that the picture only represents the original to the extent that it visually resembles it, in some relevant aspects (Sartwell, 1994) and to a certain limited degree.

The significance of pictorial details is treated in a separate section. It is noted that a realistic picture of a high resolution is no guarantee for a more veridical impression.

Throughout the text, examples are used that link to technical application.

INTRODUCTION

Images consisting of geometric figures can be illustrative and at the same time correspond to a symbolic mathematical language. These unique characteristics

I.-B. Skogh & M.J. de Vries (Eds.), Technology Teachers as Researchers, 53–75.

make geometric images especially suitable in conveying technical information. The function of a technical artefact often needs to be demonstrated through sequential pictures, which are manufactured and transformed through calculations. At the same time, there are other requirements of technical illustrations such as visual resemblance with the depicted subject—a technological construction—for instance. Maps, depictions of technical products in design and handbook illustrations are all examples of pictures relating to physical reality. But what does it mean for a geometric image to be pictorially realistic? This text tries to contribute to finding an answer.

Geometric Pictures

By *geometric pictures* we will here mean two-dimensional pictures as representations or signs[1] of mathematical objects such as points, lines, curves, planes, spheres and combinations of these objects[2].

The use of these representations requires knowledge in mathematics and calculations. Practical examples when mathematics is needed are in designing pictorial applications and tools in computer programs. Knowledge in mathematics and geometry also helps in reading and understanding the geometric pictures.

A problem is that performance and interest in mathematics among many categories of students is decreasing in many countries (TIMSS, TIMSS Advanced, 2008). It is of course a complex and, moreover, important task to find out what different causes there are for this insufficient knowledge, but for the purpose of this text it is enough to state that one critical aspect is the handling of all kinds of representations in mathematics (Duval, 2004, 2006; Fischbein, 1993; Lesh, Post, & Behr, 1987; Niss, 2002). It includes geometric pictures and concerns deeper comprehension at all levels of mathematical learning. This applies to work within a certain representation system, including for example geometric pictures, and is also true when one representation is transformed to another with the same content, for example when a geometric representation of a line is transformed into an equation representing the same content (Duval, 2004, 2006).

Pictorial Realism

Apart from the connection to mathematics, geometric pictures have a natural connection to visual art. Pictorial realism, or just Realism, often refers to the artistic movement that began in France in the 1850s and pitted itself against the prevalent Romanticism. An ambition in Realism at the time was to depict reality objectively instead of expressing emotions, which was a characteristic feature of Romanticism. According to the painter Courbet (1819–1877), who was a driving force in the movement of Realism during the 19th century, Realism was to observe reality and never remove or add anything in the manufacturing of the picture (Paulsson, 1962–63). Pictorial realism was also, according to him, to choose a specific motif: "...a motif from reality which is brutal, cruel, indigestible…" (Paulsson, 1962–63, p. 294).

The meaning of the concept of Realism in visual art has been varied and much debated since then. An enduring property is however that the picture somehow shall look like the physical reality. An issue often discussed has been, what is it that makes us believe that pictures resemble the depicted original (Newall, 2011)? Simplifying greatly, one could say that there have been two major streams in aesthetics during the past decades that have prevailed when it comes to resemblance. On one side are the defenders of a natural resemblance between picture and the depicted matter (Gilman, 1992; Gosselin, 1984; Sartwell, 1994). For them, cultural factors are secondary to perceptual, biological and psychological considerations, regarding our tendency to find realistic resemblance. On the other side, there are conventionalists who claim that conventions, cultural factors and habits are decisive regarding our classification of pictures as realistic (Goodman, 1976). According to this view, realism is foremost contextual and relative to the current system.

Outline

In this text, a picture *p* is said to be *pictorially realistic* if and only if it both *pictorially represents* and *visually resembles* an object *o*. The meaning of "pictorial representation" and "visual resemblance" will be discussed in the following sections. In the text, the theories are discussed in relation to illustrations of a pinhole camera. Special attention is given to those illustrations that are *geometric*, and it is investigated how they deviate from other pictures.

Most of the text proceeds from Goodman's (1976) work on *representation systems* and alterations of his requirements for such a system to be *pictorial*, stated foremost by Kulvicki (2003). Special attention is given to the conditions for a pictorial representation system to be *relatively replete* and *transparent*. One of the issues treated here is how *relative repleteness* should be interpreted, specifically how the number of properties in different representation systems should be counted and compared. Another issue is how the condition of *transparency* can be applied without considering contextual aspects such as the angle between the gaze of the observer in relation to the depicted original.

Being pictorial, according to Kulvicki, is also valid for "audio pictures" such as tape recordings. But pictorial realism, as the term will be used in this text, is restricted to the *visual* resemblance between pictorial representations and the objects they denote. It is therefore argued that a picture is realistic only to the extent that it visually resembles the physical object it depicts (Sartwell, 1994). It is further argued that visual resemblance only concerns some measureable aspects shared by the picture and the subject. It is shown that if several pictures depict the same object realistically with given constraints, then the pictures also must resemble each other to some extent.

The human perceptual system is of course a very important factor of resemblance and realism, but in this text it is not the focus. Instead, the structural conditions for pictorial realism apart from the human factor have been analysed. When discussing resemblance, an almost machinelike registration of the picture and visible object has been presupposed. Besides the biological factors, there are of course also social considerations depending on the prevailing society and culture, which are not considered here either.

REPRESENTATION SYSTEMS

Geometric representation systems discussed in this text are parts of a hierarchy of *representation systems* (Goodman, 1976; Kulvicki, 2003). A representation system in general consists of pairs of a *representation* and an *object*. The representation in each pair denotes the object in the pair and here it is equal to a physical sign. Examples of representations are instances of letters, words, figures and pictures manufactured on paper, whiteboard or screen. We say that *r represents o* if and only if *r* stands for or denotes *o*.

Syntactic Classes

A representation, or physical sign, belongs to —a specific *syntactic type*. An example of a syntactic type is the class of all instances of the letter "a". For the sake of simplicity, in this text we will assume that each representation in a representation system belongs to only one syntactic type and stands for only one kind of object. A *syntactic class* is then a class of *syntactic types*, which belong to a certain representation system (Kulvicki, 2003, p. 324).

Semantic Classes

The semantic object, or the content, of a sign in a representation system belongs to a *semantic class*. For the purpose of this text, it is reasonable to break down semantic objects into different types. There is by no means a consensus on how this division shall be done, but for the purpose of the present text, it is enough to differentiate between four main types: *bodies*, *abstract objects*, *semi-abstract objects* and *imagined objects*.

Concrete objects or *bodies* belong to the physical world. They are sensible and spatial. In this text, bodies are also assumed to be visible to the human eye, even though a common view is to include invisible particles in this category as well. In many school subjects such as biology, the objects of a study can be discerned as concrete and visible matters. A field study of a certain bird for instance can bring new knowledge through direct observation. Empirical knowledge about the perceived bird requires the ability to visually recognise or remember perceptual patterns (von Glaserfeld, 1995). There are, of course, other ways to achieve knowledge about the bird and other ways to represent it, but just to watch and depict it is one possible way.

Abstract objects are often defined as objects lacking certain properties that concrete objects possess (Rosen, 2012). These objects can be characterised as being non-sensible, non-physical, non-spatial etc., which separates them from the concrete, being sensible, physical and spatial. A line-picture represents for example an abstract object in Euclidean space. The line-picture does in this sense not correspond to anything in the physical world but rather to all lines with a certain inclination and position relative the origin.

There are different philosophical views on whether abstract mathematical objects exist at all. Plato (424 BC–348 BC) for example claimed that abstract mathematical objects existed as ideas independent of man, while other philosophers, from Ockham (1288–1348) to modern philosophers such as Field (1946-) and Goodman (1906–1998) have rejected any man-independent existence of abstract and mathematical objects (Rosen, 2012; Shapiro, 2000).

Contemporary researchers in education today do not normally consider knowledge in geometry as the knowledge of existing abstract objects but as the mastering of representations of them, whether or not we believe that these objects exist. In other words, one could say that representations in mathematical activity in general are not primarily regarded to stand for mathematical static objects, but to be handled operatively (Radford, 2002; Duval, 2004, 2006; Lesh, Post, & Behr, 1987). The representations are manipulated as though they were the objects themselves (Otte, 2006).

A hybrid between bodies and abstract objects is a class of theoretical objects (Shapiro, 2000) that might share some properties of concrete objects but might lack others. We will call them *semi-abstract* objects. The centre of Earth would be such an object. It has location but lacks extension.

Finally, another category of semantic objects is called *imagined objects*. These are mental constructs that might or might not correspond to objects in the physical world. Commonly, when a depicted object is not physically present, the creator has to rely on previous experience and memory in the manufacturing process. When any other than the creator inspects a picture after its creation and talks about its degree of realism, the picture is presumably compared with such an imagined object.

PICTORIAL REPRESENTATION SYSTEMS

Pictorial representation systems consist of pairs of pictures and other objects. In this section, conditions of pictorial representation systems are analysed. The conditions are however not enough to specify *visual pictorial realism*, and therefore visual resemblance is also considered later in this section.

Conditions for Pictorial Representation Systems

Structural conditions of pictorial representation systems have been stated by Goodman (1976) and later been modified, complemented and sometimes completely changed by others. Here, the conditions given by Kulvicki (2003) are primarily discussed and sometimes compared to Goodman's counterparts. Kulvicki (2003, p. 324) writes:

> The following explicates four structural conditions that are necessary and sufficient for a representational system to be pictorial: relative repleteness, relative syntactic sensitivity, semantic richness, and transparency.

It is clear from the context in Kulvicki's article that the expressions *relative repleteness* and *relative syntactic sensitivity* mean a comparison between representation systems, and accordingly each representation system is pictorial to a certain degree. The following modification of Kulvicki's definition is therefore suggested:

> A representation system is pictorial insofar as it is replete, syntactically sensitive, semantically rich and transparent.

Syntactic sensitivity. A representation system is *syntactically sensitive* if a sign belonging to the system easily changes identity, that is, when the constitution of the sign is changed. Pictures are for instance commonly *more* syntactically sensitive than written letters. For example, a serif added to a letter does not change its syntactic identity. However, the same degree of pictorial change in a drawing, for instance, affects its meaning. The drawing is thus more syntactically sensitive than the letter.

Semantic richness. A representation system is *semantically rich* when there are at least as many denotations as there are *syntactic types*. A representation system that is not semantically rich would be one in which the semantic class is smaller than the syntactic class.

Repleteness. The syntactic types of representation systems possess a number of distinctive properties significant to their meaning. Repleteness refers to *the number* of properties that are relevant to specify the syntactic types of a specific representation system (Kulvicki, 2003). It is not always clear however what Kulvicki means by the concept *property*. Sometimes he exemplifies it by a specific colour, *red* for instance, and sometimes he exemplifies it by a more general term such as *colour*. In the first case, *property* refers to something *observable*, and in the second case it refers to a *class* of observable properties. In this text, it is often more reasonable to talk about general classes of observable properties, since it is clearer for the purpose to find fundamental characteristics differentiating pictorial representation systems from others.

Repleteness also has a comparative aspect. Kulvicki (2003) and Goodman (1976) deviate in how they define the relation *more replete than*. Kulvicki uses the conception *syntactically relevant properties*, which are the properties differentiating the syntactic types. The conception appears in the definition of the relation *more replete than* below.

According to Kulvicki, a representation system R_1 is *more replete than* another representation system R_2 just in case the syntactically relevant sets of properties, S_1 belonging to R_1 and S_2 belonging to R_2 relate to each other in such a way that:

1. $S_1 \cap S_2$ is not empty
2. The cardinality of $S_1 - (S_1 \cap S_2)$ is greater than that of $S_2 - (S_1 \cap S_2)$

Any pair of representation systems sharing at least one syntactically relevant property can be compared on the basis of their relative repleteness given the definition above. Say for example that R_1 and R_2 both have syntactic classes consisting of syntactic types that are different kinds of line-pictures. Further, if the set of syntactically relevant properties S_1 of the syntactic types—here different line-pictures—belonging to R_1 contains thickness, inclination and colour, and another set of properties S_2 of the line-pictures belonging to R_2 contains inclination and position, then R_1 is *more replete than* R_2 according to the definition above.

Goodman's original definition (1976) of the relation *more replete than* differs from Kulvicki's (2003). In Goodman's notion, a set of syntactically relevant properties S_2 must be a proper subset of S_1 in order for R_1 to be *more replete than* R_2. For example, a representation system of signs belonging to certain syntactic types, say line-pictures, differentiated by colour, inclination and position is *more replete than* one where only position and inclination are syntactically relevant. In other words, according to Goodman, one representation system R_1 is *more replete than* another R_2, just in case R_1 represents objects with the same properties as the ones of R_2, plus one or more additional ones. Or, expressed in a third way, according to Goodman, a representation system R_1 is *more replete than* another representation system R_2 if the syntactically relevant sets of properties S_1 belonging to R_1 and S_2 belonging to R_2 relate to each other in such a way that $S_2 \subset S_1$.

Example 1: A pinhole camera. The following example illustrates and compares the repleteness of different representation systems. The semantic classes of these representation systems seem at first sight to coincide and be identical—a class of visible bodies. However, it turns out to be less obvious. It is also shown that there exist representation systems, which are more replete than others but that might nevertheless be regarded as less pictorial.

A pinhole camera, or camera obscura, works in principle as an ordinary camera, except that it has no lenses[3]. In practical terms, the pinhole camera in this example is constructed of a white paper box. The interior is painted with black, non-reflecting paint. A small hole with a diameter of less than 0.5 mm is made in the middle of one of the box's sides. When the camera is not used, the hole is covered. Finally, a light-sensitive film is attached inside the box, opposite the hole.

Four representations of the camera are shown in Figure 1. The photograph 1a belongs to a pictorial representation system where the syntactic types are different photographs. A syntactically relevant property of such a system is, for example, lightness. It is also possible to count direction, mutual position and mutual proportion

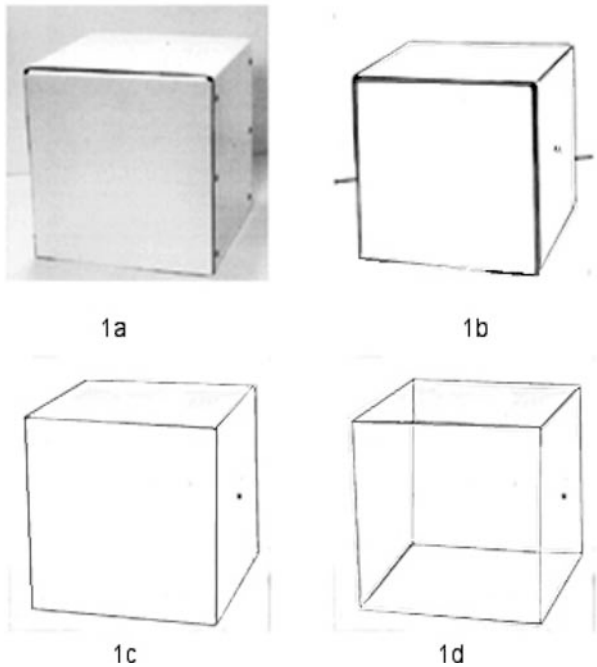

Figure 1. In the figure, four representations of a pinhole camera are shown. Each picture belongs to a different representation system. Picture 1a in the top left corner is a photograph, 1b in the top right corner is a sketch, 1c in the bottom left corner is a geometric picture and finally 1d in the bottom right corner is another geometric picture.

of separate figures as syntactically relevant properties of the photograph. The border between two areas of the photograph might be discerned and interpreted as line-pictures. In the photographic representation system, the width of these line-pictures is also a syntactically relevant property.

Further, say that the sketch 1b is a representation that belongs to another pictorial representation system. It has the same syntactically relevant properties as the photographic representation system, except for the more subtle, lightness. In this example, the set of syntactically relevant properties of the sketch constitute a subset of the photograph's syntactically relevant properties. The representation system that the photograph 1a belongs to is accordingly *more replete than* the one that the sketch 1b belongs to, both pursuant to Goodman's (1976) and to Kulvicki's (2003) definitions of being *more replete than*.

Picture 1c is a geometric picture. It belongs to a representation system with a set of fewer syntactically relevant properties than the sets of properties discussed so far. For example, the line-breadth is unnecessary to differentiate between two representations of the system that 1c belongs to, but it is necessary for the representation system of 1a and 1b. A concrete example is that the narrow area where two sides of the box meet does in some parts of the sketch 1b correspond to a broader stroke if there is a wider slot between the sides and a finer stroke if there is a thinner slot or no opening at all. Variable width means that different subjects are depicted. The corresponding representations belong to separate syntactic types.

However, here it is questioned that if a representation system is *more pictorial than* another then is it necessarily *more or equally replete* than the other. It is presupposed that pictorial means that the representation to some extent *looks like* the depicted body.

First, consider picture 1d. It is a geometric picture but belongs to another representation system than 1c. The semantic classes are different. The one related to 1c consists of *visible bodies* and the one related to 1d consists of *semi-abstract* objects. In 1d the camera is drawn in cross-section so that the interior of it is exposed, a feature of the picture that is not shown in the original subject. The positions of the areas, which in reality are invisible and covered, are syntactically relevant properties in addition to the syntactically relevant properties of 1c. In this case, the properties *invisible position* and *visible position*, for instance the visible/invisible position of the joint of the box's sides, are distinct and syntactically relevant. Accordingly, the representation system of 1d bears more information about the camera's constitution and has more syntactically relevant properties distinguishing the syntactic types. It is *less pictorial* but *more replete* than the representation system of 1c. This contradicts the notion that if a representation is more pictorial than another then it is more (or equally) replete.

There is a second argument against the assertion that more replete representation systems necessarily are more pictorial, since some syntactically relevant properties might be more important for a pictorial impression than others. Consider for example the *line-breadth* and *line-colour* of a contour. These properties might both be syntactically relevant in one representation system but not in another. Say instead that the *relative position* of the lines is syntactically relevant. The position seems to be much more important for a pictorial impression than line-breadth and line-colour taken together. If the shapes were to be placed at random on the pictures' surface, the image would be impossible to read. A representation system having the property *relative position* is thus intuitively more pictorial but less replete than a system having the syntactically relevant properties *line-breadth* and *line-colour.* This kind of problem appears only in Kulvicki's definition of *more replete than*, but not in Goodman's, since, according to Goodman's notion, a set of syntactically relevant properties in a more replete representation system is just an extension of the corresponding set in a less replete one.

There is a difficulty with both Kulvicki's and Goodman's definitions concerning how syntactically relevant properties shall count when optical effects occur. It is for instance well known that the lightness of different parts of a picture, such as the background and foreground, can interact, so that the impression of the picture as a

Figure 2. The square on the darker background to the left appears to be lighter than the square on the lighter background to the right[4].

whole is experienced differently than each part alone. In Figure 2, the figure at the centre of the leftmost rectangle appears lighter than the figure at the centre of the rightmost rectangle, even though locally they have the same lightness.

This distinction between local and experienced colours gives rise to a third example where one representation system is more pictorial yet less replete than another. In the following example *property* refers to an observable property, the colour *red* for instance, and not a general class of observable properties, such as *colour*. Say that in the first representation system only the local colours of the middle figure are syntactically relevant. The problem arises if the lightness of the surroundings is *not* syntactically relevant but differs among the pictures. Say for instance that the backgrounds are of three possible shades in the first representation system. Then there are three possible *experienced* shades of the figure at the centre of the rectangle but only one *local* shade. There are in other words three possible ways to pictorially mimic the shades of an object. Say that in another representation system there are two local colours of the middle figure which are syntactically relevant. In this representation system too, only the local colours of the figure at the centre are syntactically relevant, but in contrast to the first system there is only one possible shade of the background. The first system, having a greater number of experienced shades, is intuitively more pictorial than the second one and yet the first system, having a fewer local shades—i.e. syntactically relevant properties—is less replete.

Transparency. The properties relative syntactic sensitivity, semantic richness and relative repleteness presented so far are not sufficient for a representation system to be pictorial. An example of Goodman's (1976) shows the insufficiency. Imagine a visible scene depicted according to the perceived colours and the laws of the linear perspective. Then imagine another picture depicting the same scene according to an algorithm, wherein complementary colours are used instead of the perceived ones and the perspective is reversed, so that for instance a small shape looks big and vice versa. The two representation systems to which the pictures belong are syntactically

Figure 3. Draughtsman making a perspective drawing of a woman, *Albert Dürer*, *etching from 1525 AD.*

sensitive, semantically rich and replete to the same extent, even if only the first one is intuitively depicting the object, at least in any veridical way.

Another lucid example is the depiction of squares and round shapes in a black and white line drawing. In one representation system, the perceived figure is drawn. In another representation system, a square-picture is drawn if a circle is discerned and a circle-picture is drawn if a square is discerned. In this case, the first representation system is intuitively more pictorial, even though both systems are equally replete, syntactically sensitive and semantically rich.

By introducing the property *transparency*, one can structurally distinguish pictorial representation systems from others (Kulvicki, 2003, p. 330):

> A representational[5] system *S* is *transparent* just in case for any token representation, *R*, in *S*, any representation *of R* in *S* is of the same syntactic type as *R*.

It is easily verified that neither the colour complement system nor the reversed perspective introduced by Goodman's example above straightforwardly satisfies transparency, and neither does the representation system where every other picture is a square-picture and every other picture is a circle-picture. Kulvicki develops reasoning about non-transparency when complementary colours replace perceived colours. Here it is presupposed that there are at least two syntactic types: green objects and red objects (Kulvicki, 2003, p. 334):

> Create a picture of a picture of a green object and the result is a (green) picture of a red object, and so on. In this scheme, a picture of a green object cannot also be a picture of a red object. Therefore, the fact that a picture of a picture of a green object is itself a picture of a red object indicates that the picture of a picture is not syntactically identical to its object and transparency fails.

Examples of transparent representation systems are the ones based on the so-called linear perspective. In Figure 3, a draughtsman depicts a woman. The physical plane between the man and the woman represents the so-called picture plane, or projective plane, orthogonal to the man's gaze. It is an imaginary plane, but here it has a physical form, working as a tool for depiction. A fictitious vanishing point is situated on the crossing between the man's gaze if he looks straight ahead with one eye, and there is an imagined horizon line faraway and parallel to an imagined line between his eyes. All the perceived line-like objects of the scene, which in reality are parallel to the direction of the man's gaze, meet in the picture plane at the vanishing point on the horizon line. The man can transfer what he is seeing through the picture plane to the picture's surface on the table. He can also use geometrical rules of plane projection to construct the picture based on what he is seeing.

What does it mean then in practical terms for a representation system based on the linear perspective to be transparent? First, consider a representation system consisting of the syntactic types ellipse-pictures and circle-pictures and a semantic class consisting of ball-shaped bodies, ellipse-pictures and circle-pictures. A globe depicted under the linear perspective is then likely to be represented by a circle-picture, but the depiction of the circle-picture in the same manner might both be a circle – and an ellipse-picture depending on the angle between the depicted picture plane and the gaze of the draughtsman. Since the depiction of the circle-picture, one syntactic type of the system can result in an ellipse-picture; in the case of another syntactic type, the corresponding representation system is not transparent. This contradicts Kulvicki's notion that all representation systems based on the linear perspective are transparent.

The problem would be avoided if the depicted picture always were parallel to the fictive plane between the draughtsman and the object. Kulvicki (2003) does indeed bring up that there is nothing in the linear perspective itself, which requires that the two planes have to be parallel (Kulvicki, 2003, p. 332). Still, he argues that representation systems based on the linear perspective are transparent. This is possible, according to him, if the syntactically relevant properties are conceived as *invariants under projective transformation*. This statement can be interpreted as if the syntactically relevant properties are generated by projective transformation *between planes*. In this sense, all the invariant geometric features of the depicted picture plane in a *two-dimensional space* are mapped to corresponding parts of the pictorial representation. Point-pictures are mapped to point-pictures, line-pictures to line-pictures, angles between lines of the depicted original picture to angles in the pictorial representation and so on.

Note that the concept *object* of a depiction as per the linear perspective has a specific meaning in the transformation from the scene to the picture. Instead of a physical finite body, it is *a whole scene*—an infinite and continuous space. Panofsky (1927/1991) wrote about the ways and means of using the central perspective in the 15th century. It was revolutionary at the time since earlier perspectives had no idea of an infinite space and even less of how to represent it pictorially. Panofsky argues that the linear perspective preceded mathematical inventions and formalisations of infinite space and presumably was a source of inspiration for those inventions, for instance the infinitesimal and differential calculus of Leibniz (1646–1617) and Newton (1642–1727).

The definition of the linear perspective that Kulvicki presupposes is, as it seems, an unnatural limitation considering how it is actually used in visual art. The depicted subject in art is a three-dimensional scene from the creator's *point of view* rather than a transformation between two picture planes where coordinates are transferred. Each pictorial representation in art is instead a projection of a three-dimensional space to the two-dimensional picture plane. As we have seen, generally such a system is not transparent.

VISUAL RESEMBLANCE IN REALISTIC DEPICTION

Apart from the difficulties above, there is another issue that makes Kulvicki's definition (2003) too wide when applied to pictorial realism based on vision. Kulvicki does himself point out that it is not possible to distinguish between *different kinds* of pictorial representation systems given his conditions. For example, a representation system that is pictorial in a visual way is not distinguishable from one that is "audio pictorial". Tape recordings of ambient sounds do for example belong to a representation system, which fulfils the pictorial requirements. The audio pictorial representation system is also relatively syntactically sensitive, semantically rich, relatively replete and transparent. Yet, it is not visual. To establish pictorial realism, *visual resemblance* is a necessary ingredient.

Figure 4 represents pairs consisting of a picture *p* and another object *o*. Through the following examples based on Figure 4, it is shown that visual resemblance is neither a sufficient nor a necessary condition to establish pictorial representation. It means that neither does pictorial representation imply visual resemblance nor does resemblance imply representation.

A fragment of a scene, let us say an apartment building, might be represented by a stylised block drawn in perspective in a part of a picture. The block does not necessarily resemble the scene but it is still a pictorial representation. Therefore, the block-picture in the pair with the scene belongs to field 1.

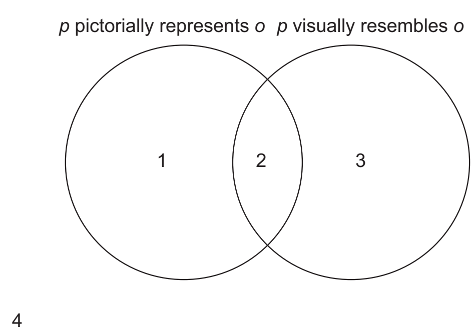

Figure 4. Let p be a picture and o another object distinguished from p. The numbers 1–4 refer to fields in the diagram. The numbers denote the following possible relations between p and o: (1) p pictorially represents o, but p does not resemble o visually (2) p pictorially represents o and resembles o visually (3) p does not pictorially represent o but resembles o visually (4) p neither pictorially represents o nor resembles o visually.

An example of an item belonging to field 3 is given by Putnam (1981; Brueckner, 1986). An ant leaves traces in the sand that accidently look like Winston Churchill, but since the likeness is not the ant's intention, the picture does not pictorially represent Churchill.

Field 4 corresponds typically to all pairs of pictures and objects that have neither pictorial representation nor visual resemblance between them. Every conceivable object, except for those where the picture represents or resembles some object, belongs to that set. For example a painting of Mona Lisa might represent and look like the person Mona Lisa, and maybe like some additional individuals, but *any other object* in pair with the painting Mona Lisa is an instance of field 4.

Field 2, the intersection between pictorial representation and visual resemblance, consists of pairs, each containing a picture and an object, where the picture in each pair *realistically* represents the object.

Visual resemblance in general. Usually, visual resemblance is reflexive, symmetrical and non-transitive. Reflexivity means that each object visually resembles itself. Symmetry means that for each pair of objects o_1 and o_2, if o_1 visually resembles o_2 then o_2 visually resembles o_1. Non-transitivity means that for three objects o_1, o_2 and o_3, it is not the case that if o_1 visually resembles o_2 and o_2 visually resembles o_3 then o_1 necessarily must resemble o_3 visually. Examples of resemblance between objects where transitivity is not obtained are shown in the examples below:

1. If some but not all aspects of the compared objects are similar. For example, if I resemble my mother in the aspects length and hair colour, and she resembles my grandmother in eye colour, then I do not have to resemble my grandmother in any of the aspects of length, hair or eye colour.
2. If one visible aspect is gradually changing in a sequence of compared objects. For example, if lightness is compared regarding visual resemblance in a sequence of photographs arranged by degree of light, two adjacent pictures might resemble each other while the ones at both ends can be each other's opposites with regard to lightness.

If resemblance between realistic pictures would allow non-transitivity, exemplified in (i) and (ii) above, it would be possible for two pictures to realistically resemble the same object even though they don't resemble each other. It is presupposed that the pictures are manufactured in the same medium, of the same object, seen from the same angle, in the same light, etc. The situation contradicts our intuition of what realistic pictures are. In the following section, a certain kind of situation is discussed—a situation in which several realistic pictures are compared to one and the same object that they all depict. Visual resemblance concerns specific aspects relevant for comparison. The aspects are also assumed to take on values within a certain range. It follows from this stipulation that realistic pictures of the same object must resemble each other to some extent.

Relevant aspects. One of Goodman's (1976) arguments against any natural resemblance between realistic pictures and depicted originals is that there are many visual aspects where they don't look alike. The appearance of a man for example is distinguished in many ways from a portrait of him, which is for instance flat, immobile and hangs on a wall, unlike the three dimensional man of flesh and blood. Realistic pictures look much more like other pictures than what they depict, Goodman claims.

But is it in this way that the concept of resemblance is used in Realism? Sartwell (1994) suggests that it actually is only the shared, visible aspects of pictures and their depicted originals that are regarded in pictorial realism. Further, he claims that it is aspects of the picture determined by the medium and manufacture process that naturally should be allowed for. A molecule depicted for instructional purposes by a computer program could for instance be manufactured both in 2D and in true 3D[6]. The two pictures are then according to Sartwell's notions not comparable regarding resemblance, even though the true 3D picture visually can be compared to the molecule in terms of more aspects than the 2D picture.

A proposed definition of pictorial realistic representation, including resemblance, is the following (Sartwell, 1994, p. 7):

> Given that a picture *p* represents an object *o*, *p* represents *o* realistically to the extent that *p* resembles *o* in all relevant aspects.

For clarity, it must be added that it is the *visual* resemblance that is assumed in the definition above.

Measurable values. Suppose that only one attribute is relevant for comparison. Let it be lightness as in (ii) above. Two adjacent pictures, in a sequence of gradually lighter pictures, which depict the same object, might then resemble each other, while the ones at both ends are each other's opposites with regard to lightness. Intuitively, for resemblance between realistic pictures, this situation is unreasonable. The realistic pictures depicting the same object under the same circumstances ought to resemble each other at least to some extent. Given a measured value of the lightness of the original and an allowed deviation from that value, the degree of resemblance can be decided.

Say that the measurable value of lightness for example is a number a for the picture and a number c for the depicted object. If then the distance between a and c is *close enough*, say less than a number d, the picture is said to visually resemble the object. Another picture of the same object, manufactured and looked upon under the same conditions, has a measured value, a number b, of the same aspect. If the two pictures realistically resemble the same object, then they must reasonably resemble each other to some extent. The distance between the values a and b is, in this proposed model, at the most *double the distance* of the admitted distances between a or b and c. The situation is illustrated in Figure 5.

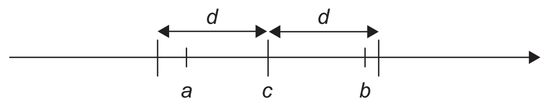

Figure 5. The distances between the values of the relevant aspects.

When more aspects are considered, the degree of resemblance can be expressed by a function measuring the distances between two arrays containing values of the relevant properties for comparison.

Example 2: Lines representing visible objects. To illustrate the notion of realistic resemblance just discussed, consider again Figure 1. This example illustrates the visual resemblance of the pictures to the depicted camera. The camera has to be imagined. Here, the conceived line-pictures of pictures 1a, 1b, 1c and 1d are discussed.

It is actually doubtful if anything at all in photograph1a could be called a line-picture. Everything in the photograph reproduces the reflected light of a scene. The joints where two edges meet are areas rather than line-like objects. The gradual change of lightness in the photograph mainly indicates that some edges are not sharp. The photo also shows darker, wider areas around the joints, indicating that some of the sides are not tightly connected. There are narrow openings between them. It is likely that the lightness of each pixel in the picture would come close enough to the reflecting light of the corresponding part of the depicted body. The areas in the photo corresponding to the joint where the edges meet resemble the depicted scene.

In the sketch 1b, the parts of the picture corresponding to the meeting of sides also has variable width like the line-pictures of the photograph. As opposed to the photo, the sketch only has black and white colour. A line-picture in the sketch might depict the light around the joints between the sides.

In the geometric picture 1c, the visual resemblance between picture and original is even less explicit. The line-pictures here are approximations of the narrow areas around the joints of the edges, but it is not perfectly clear how the approximations are made and what, more precisely, they stand for. They might be constructed by drawing evenly broad line-pictures between the middle points of the areas, corresponding to the corners of the camera. But the line–pictures might as well be constructed by drawing evenly broad line-pictures based upon some average function of the area comprising the edge between two sides. The methods will generate slightly different positions of the line-pictures. Besides the correspondence to the visible body, the line-pictures are approximating abstract mathematical lines, infinitely thin and representing the shortest way between two positions.

A detail of picture 1a is shown in magnification in photograph 6a of Figure 6.

Picture 6b shows how this part in a geometric picture, a magnification of 1c, alternatively can be represented with several lines, each line corresponding to the end of a side, commonly the edge between two sides.

Figure 6. Two different illustrations of a detail of a pinhole camera—to the left a photograph and to the right a geometric picture.

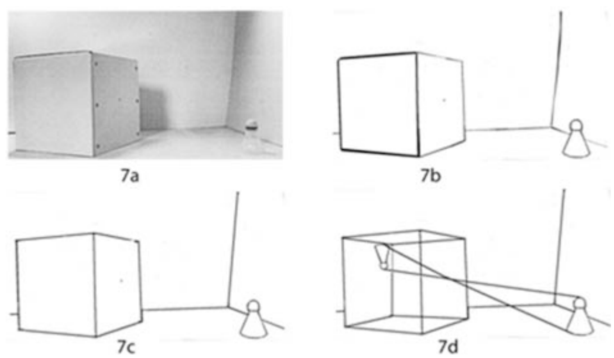

Figure 7. A pinhole camera. Picture 7a in the top left corner is a photograph, 7b in the top right corner is a sketch, 7c in the bottom left corner is a geometric picture and finally 7d in the bottom right corner is another geometric picture.

Finally, picture 1d contains pictorial information that is not visible. Picture 1d presumably resembles the subject to the smallest extent of the four pictures in Figure 1.

Example 3: Function or resemblance. In Figure 7, four different pictures illustrate a pinhole camera and the depicted object. To take a photo, the hole of the camera is uncovered so that light rays from the external world can pass through the hole. The scene is then projected on the film on the wall opposite the hole inside the camera. The picture will appear upside down and mirrored. After a quick exposure, the hole of the camera is covered again and later the film can be developed in a dark room.

In Figure 7 below, four different images are shown. Picture 7a is a photograph, 7b is a sketch and 7c and 7d are geometric pictures, each one belonging to a specific representation system similar to the representation systems of the pictures 1c and 1d in Figure 1.

Picture 7d differs from the others in a special way. Parts of the picture are *possible*, under specific circumstances, to discern by vision, such as the interior walls drawn in cross-section. Other parts depict semi-abstract objects. Here, those objects are light rays represented by line-pictures. Both the interior walls drawn in cross-section and the light rays are invisible, but for different reasons. The interior parts would have been visible if the camera had glass walls for instance or if it had been cut in two halves. The interior walls are physical bodies, but in the specific situation they are invisible to the observer and can then not be said to *visually* resemble the corresponding part of the picture. Unlike the interior walls of the camera, the light rays belong to a class of semi-abstract objects, invisible to the observer.

Further issues. How important is the amount of detail in a picture in order for it to resemble the original?

Take for instance a picture stored on a computer as a bitmap and a division of the picture into equal parts, each called picture elements or pixels. The number of pixels per area unit for a specific optimal picture size—or the resolution—is critical for the quality and the picture's number of visible details. A picture lager than the optimal size produces an image with low resolution and a smaller picture gives a picture with approximate or inaccurate pixel values. A high resolution is often a measure of the picture's quality and correspondence with the original.

Yet, there are a few deliberations considering high resolution as a criterion of more visual resemblance. If the difference between two pictures with different resolutions is not discernible to the human eye, it is of course doubtful if the picture with higher resolution should be considered as more realistic than the other. Further, might the high resolution of the picture distract the viewer and convey too detailed information in some parts of the image? For example, a photo or a painting that depicts a lake and reproduces every nuance of the reflecting water might be less distinct and discernible than a more schematically depicted lake. The combination of the pixels might not be understood as a lake, even though the information is detailed and each pixel resembles the reality. It is accordingly not obvious that such a picture is a more realistic depiction of a lake than a more distinct image with fewer details. The same phenomenon appears when an object is depicted in extreme close up or at an unusual angle. Even if it is an objectively correctly depicted human, for instance, it might not be possible to read the picture and recognise the depicted person.

Instead of using a bitmap, geometric computer images often store picture information in terms of control-points, known as vector storage. Combinations of such geometric images might represent and visually look like physical bodies. Imagine a depicted vehicle for example. All its parts—the wheels, the engine and the body—can be discerned as details of the picture, and each of them can in turn be broken down into smaller parts, mathematically describing the surface of the vehicle. Does then a picture with more depicted parts visually resemble the vehicle to a larger extent than another with fewer details? The question is to what extent the actual vision is involved here. It seems to rather be a matter of conceptual breakdown, and the appearance of the details is something that we *know* from previous experience but do not perceive directly.

CONCLUSIONS

The starting point of this text was that geometric pictures are powerful illustrations in education and technical applications. In this concluding section the role of geometric pictures is discussed a bit further.

Geometric pictures serve as links between mathematical and illustrative depictions, through their relation to both abstract objects and visible physical objects—rows 1, 2, 3c and 4 in Table 1.

Besides, there are geometric depictions of semi-abstract objects in natural science and technology—row 3a. Imagined objects—row 3b—are other types of objects that have not been the focus of this text, but are often represented by geometric pictures.

It is clear that geometric pictures can constitute syntactic classes of several representation systems. The variety of options for geometric images to stand for other objects indicate that they are useful in many contexts—especially technical ones where a lot of computation is needed. However, as a few examples were investigated in this text, it is now clear that there are a few matters to consider, especially if the geometric pictures must resemble reality.

The text here has focused upon pictorial geometric representation systems, foremost the depiction of visible bodies and semi-abstract objects. The following sections summarise partly to what extent geometric pictures are realistic and partly the difficulties found in previous definitions of pictorial representation systems.

Realistic Geometric Pictures

The diagram in Figure 8 illustrates the scope of realistic geometric pictures.

The instances of field 4 are pairs, each consisting of a geometric picture and another object, where the geometric picture neither pictorially represents nor looks like the object.

A geometric picture might look like a specific object even though it is intended to represent something else. For example, two straight parallel line-pictures drawn on a white board visually resemble each other even though they both are intended to represent an abstract line. The two parallel, physical line-pictures together constitute a pair and an instance of field 3.

Table 1. Representation systems

No.	*Representation system*	*Syntactic class*	*Semantic class*
1	Symbolic	Mathematical formulas	Abstract
2	Mathematical geometric	Geometric pictures	Abstract objects
3a	Pictorial Geometric	Geometric pictures	Semi-abstract objects
3b	Pictorial Geometric	Geometric pictures	Imagined objects
3c	Pictorial Geometric	Geometric pictures	Visible bodies
4	Pictorial (artistic)	Realistic pictures	Visible bodies

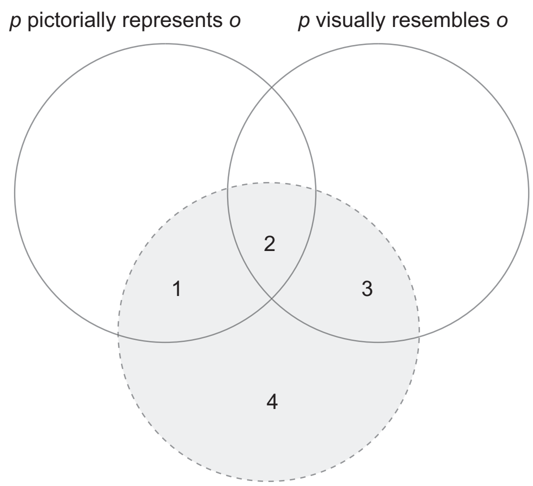

Figure 8. Let p be a geometric picture and o another object distinguished from p. The numbers 1–4 in the shaded area in the diagram denote the following possible relations between p and o: (1) p pictorially represents o, but p does not resemble o visually (2) p pictorially represents o and resembles o visually (3) p does not pictorially represent o but resembles o visually (4) p neither pictorially represents o nor resembles o visually. The rest of the figure contains all other pairs of pictures, apart from geometric pictures, and objects.

Geometric pictures might also pictorially represent objects without necessarily looking like them—as the instances of field 1. For example, a dashed line might on a map represent a road, but there is no obvious visual similarity between the line and the road.

Field 2, finally, corresponds to geometric pictures in focus here, which *realistically* depict physical bodies. A geometric figure, such as a drawn cube on a paper, might for instance pictorially represent a physical perceived paper box in a realistic way.

Figure 8 should however not be read too literally, since pictorial realism in this paper is a matter of degree. A picture is *more or less* pictorial and resembles the original object to *a certain degree*.

Implications of the Study

The focus in the text has been on pictorial representations, mainly geometrical, in technology, and visual resemblance, exemplified through illustrations of a pinhole camera. An issue has been to investigate the degree of realism of those illustrations.

The text started with an investigation of the structural conditions of pictorial representation systems given foremost by Kulvicki (2003) and Goodman (1976) to see if those systems could be used to compare the pictorial degree. The following definition, based on Kulvicki's concept (2003, p. 324), was investigated and discussed:

> A representation system is pictorial insofar as it is replete, syntactically sensitive, semantically rich and transparent.

Some shortcomings were found. It was shown that some representation systems that were intuitively more pictorial than others were still less replete or not transparent.

Repleteness was discussed both according to Kulvicki and to Goodman. If two otherwise equal representation systems are compared, it is the one with the most syntactically relevant properties—the most replete—that is the most pictorially representational. However, it was shown that it is possible to find representation systems where one is more pictorial than the other, in an intuitive way, without being more replete. For instance, when one syntactically relevant property in one representation system is more *pictorially* relevant than two others taken together in another system, the first one is intuitively more pictorial but less replete than the other.

Other cases when a representation system is more pictorial than another, without being more replete, were also mentioned, when some of the syntactically relevant properties were not visible. A pinhole camera drawn in cross-section, for instance, might belong to a representation system with more syntactically relevant properties than a representation system with representations only depicting the visible surface. Still, the last representation system is commonly regarded as more pictorial.

A third and last case in which one representation system can be more pictorial but less replete than another is when the optical values of the syntactically relevant local colours interact with the local colours of the background that are not syntactically relevant.

Another difficulty with Kulvicki's definition of pictorial representation systems is that transparency is not always fulfilled for representation systems, which traditionally are perceived as pictorial. Such systems are the ones based on the linear perspective. One interpretation mentioned in this text suggests that those systems are *not transparent*, and that transparency would *not* be a necessary condition for a representation system to be pictorial. The interpretation of the linear perspective that Kulvicki suggests, and which would allow transparency, is accordingly too limited.

Finally, the conditions for pictorial representation are applicable to representation systems, which do not presuppose vision, as Kulvicki (2003) himself pointed out.

Sartwell's definition of pictorial realism (1994, p. 7) was discussed as an alternative:

> Given that a picture *p* represents an object *o*, *p* represents *o* realistically to the extent that *p* resembles *o* in all relevant aspects.

It was argued that comparison of resemblance is only meaningful within the same representation system. The values of the same relevant aspects are then compared. In order for a picture to resemble an object or a scene, the difference between the measured values of the picture and the original in question cannot be too large. This implies that two pictures realistically depicting the same original under the same conditions also must resemble each other to a certain degree.

In practical terms, it has also been discussed that it is unreasonable to disregard the human ability to discern details when resemblance is considered. A high resolution of a digital picture is of less importance if no one can comprehend it. In the same manner, the amount of conceptual details in a pictorial construction presumably does not matter if the observer of the picture cannot read it.

This chapter shows the power and shortcomings of geometric realistic pictures as illustrations of technical objects. The example given (the pinhole camera task) highlights the structural differences between geometric and some other kinds of pictures. Hopefully such considerations may be useful in integrating mathematics and technology, which in my experience has proved to be a successful teaching strategy.

NOTES

1. The terms *representation* and *sign* in this text will be used synonymously to mean something standing for something else.
2. To avoid confusion between objects and their representations, for instance between a line and a picture of a line, the concepts *line-picture*, *point-picture* or *plane-picture* etc. will be used in this text, meaning the pictorial representation of the corresponding line, point or plan. In the same way, *line-like object* etc. will be used to distinguish objects of the physical reality that appear as approximations of lines from the abstract object *line*.
3. [Website] (n.d.) Retrieved December 23, 2012 from: http://www.pinholeday.org/support/faq.php
4. [Website] (n.d.) Laboratory of Dale Purves, Retrieved December 23, 2012 from: http://www.purveslab.net/resources/download.html#bcs
5. The terms *representation system* and *representational system* are in this text treated as synonymous.
6. A true 3D picture is created by a process known as stereoscopy, presenting two different pictures, one for the left and one for the right eye of the viewer, to create the illusion of depth.

REFERENCES

Brueckner, A. L. (1986). Brains in a vat. *The Journal of Philosophy*, *83*(3), 148–167.

Duval, R. (2004). A crucial issue in mathematics education: The ability to change representation register, *ICMI* (*International Commission on Mathematical Instruction)*, *The 10th International Congress on Mathematical Education*, *ICME-10*. Copenhagen, Denmark (2004).

Duval, R. (2006). A cognitive analysis of problems of comprehension in a learning of mathematics. *Educational Studies in Mathematics*, *61*, 103–131. doi:10.1007/s10649.006.0400-z

Fischbein, E. (1993). The theory of figural concepts. *Educational Studies in Mathematics*, *24*, 139–162.

Gilman, D. (1992). A new perspective on pictorial representation. *Australian Journal of Philosophy*, *70*(2), 174–186.

Gosselin, M. (1984). Conventionalism versus realism in pictorial art. Is perception basically particular or general? *Communication and Cognition*, *17*(1), 57–88.

Goodman, N. (1976). *Languages of art* (2nd ed.). Indianapolis: Hackett Publishing Company Inc.

Kulvicki, J. (2003). Image structure. *The Journal of Aesthetics and Art Criticism*, *61*(4), 323–340. doi:10.1111/1540–6245.00118

Lesh, R., Post, T., & Behr, M. (1987). Representations and translation among representations in mathematics learning and problem solving. In C. Janvier (Ed.), *Problems of representation in the teaching and learning of mathematics* (pp. 33–40). Hillsdale, New Jersey: Lawrence Erlbaum Associates, Inc.

Niss, M. (2002). *Mathematical competences and the learning of mathematics: The Danish KOM project*. (Technical report). Retrieved from IMFUFA, Roskilde University.

Newall, M. (2011). *What is a picture? Depiction*, *realism*, *abstraction*. UK: Palgrave Macmillan. Retrieved from http://kar.kent.ac.uk/id/eprint/31670

Otte, M. (2006). Mathematical epistemology from a Peircean semiotic point of view. *Educational Studies in Mathematics*, *61*(1–2), 11–38. doi:10.1007/s10649.006.0082–6

Panofsky, I. (1994), *Perspektivet som symbolisk form*. (S. Olsson, Trans.). Stockholm/Stenhag: Brutus Östlings Bokförlag Symposium. (Originally published in Vortäge Bibliothek, Leipzig & Berlin 1927).

Paulsson, G. (1962–63). *Konstens världshistoria*, *IV bandet*, *Från barocken till nutiden*, p. 294. Stockholm: Natur och Kultur.

Putnam, H. (1981). *Reason*, *truth and history*. Cambridge, UK: The Press Syndicate of the University of Cambridge.

Radford, L. (2002). The Seen, the spoken and the written: A semiotic approach to the problem of objectification of mathematical knowledge, *For the Learning of Mathematics*, *22*(2), 1–25.

Rosen, G. (2012). Abstract objects, *The Stanford Encyclopedia of Philosophy* (Spring 2012 Edition). In E. N. Zalta (Ed.), Retrieved from http://plato.stanford.edu/archives/spr2012/entries/abstract-objects/

Sartwell, C. (1994). What pictorial realism is. *British Journal of Aesthetics*, *34*(1), 2–12.

Shapiro, S. (2000). *Thinking about mathematics – The philosophy of mathematics*. New York: Oxford University Press.

Trends in International Mathematics and Science Study (TIMSS). (2007). Retrieved from http://nces.ed.gov/timss/

TIMSS Advanced 2008, Trends in International Mathematics and Science Study (TIMSS Advanced 2008). Retrieved from http://timss.bc.edu/timss_advanced/ir-release.html

von Glasersfeld, E. (1995). *Radical constructivism. A way of knowing and learning.* London: Falmer Press.

SECTION II

TECHNOLOGY EDUCATION RESEARCH

INGA-BRITT SKOGH

5. STUDENTS' ENCOUNTER WITH TECHNOLOGY EDUCATION

Testimonies from Compulsory School Technology Classrooms

INTRODUCTION

What do we know about what happens during technology lessons in school? Life in Swedish technology classrooms has been highlighted in several recent studies (Blomdahl, 2007, Bjurulf, 2008, Klassander, 2010, Svensson, 2011). In these studies issues like teacher's pedagogical approach, choice of subject content and, to some extent also teachers' work with assessment and evaluation have been examined from different perspectives and theoretical approaches. One common denominator for these studies is the focus they put on the teacher.

The approach to study teaching and learning in school from a teacher's perspective is neither new nor uncommon. As early as in the 1600s the Czech educator John Amos Comenius pointed out the importance of exploring teachers' efforts in the classroom (Didactica Magna, 2008). In all education, he says, teachers need to ask themselves three didactic key questions; what must be taught, how must it be taught and why must it be taught.

According to Comenius teaching and learning are complementary quantities. The question of how students perceive education (in this case technology teaching) therefore also needs to be explored. The task of capturing life in (technology) classrooms, based on statements from pupils and students, is of course not without problems. The reality that emerges is both based on and limited by students' memories and emotions. What students have actually done during technology lessons and what they remember from these lessons need not be (and probably is not!) the same. This is likely to also be true for teachers. What teachers think they have taught and what they have actually 'delivered' is seldom the same thing. In addition to this there is, of course, the uncertainty about to what extent students have apprehended and understood the information/instructions given by their teachers. Teaching (and learning!) truly isn't easy! The quote below by author Peter Englund conveys an important insight:

> Man's view of the world is in a way more real than reality itself, for it controls their actions. (Englund, 1993, p. 70)

In this chapter, unlike the studies mentioned above, life in elementary school technology classes is described from a student perspective. The text is based on

I.-B. Skogh & M.J. de Vries (Eds.), Technology Teachers as Researchers, 79–100.

findings in three studies/reports (Skogh, 1997, Skogh, 2001, the Swedish Technology Delegation, 2009[1]). The three studies provide a picture of how students in different age groups apprehend the technology education they have encountered in elementary school (primary school and secondary school). Since they are written at different times (1997, 2001, 2009) the studies convey images of technology education in Sweden at different time periods.

The purpose of this article is to give a voice to student's views on and experiences from technology education in compulsory school. The questions put forward to the students in the studies are linked to the very same didactic key questions (what, how and why?) that Comenius introduced in 1600s but now in the context today's technology education. The students were directly and/or indirectly asked about (1) what images of technology they had developed during technology education in school (What is technology?), (2) their attitudes towards/memories of technology lessons in school (How is technology taught?), and (3) what impact technology education has had on their own personal development (Why is technology taught?).

To give the reader information about the context from which the students (and their teachers) in the presented studies appear, this chapter starts with a brief presentation of technology education in Sweden during the past three decades. After this the studies and the views of the pupils are presented and discussed. The chapter ends with suggestions about how the findings (student definitions of technology, their attitude towards technology and gained [or not gained] technological self-confidence [techno-confidence] can be used in order to explain and understand students' willingness [or unwillingness] to engage in "technical" activities [i.e. activities that the students themselves perceive as "technical"]).

TECHNOLOGY IN SWEDISH ELEMENTARY SCHOOL – A BRIEF OVERVIEW

From Optional to Compulsory School Subject

Many of today's adult generation in Sweden lack schooling in technology. In the 1960–1970's, technology was an optional subject in secondary school. The course was vocational, with a view to industrial work and was chosen almost exclusively by boys. The traditional image of technology as a male area of expertise was well established in Sweden during this period, both within and outside the world of school. Women's and girls' absence in this sector can be described as built-in both in the cultural system and in the educational structure.

As a result of the intensive development of technology in society in the late 1900s conditions changed. The recruitment base for the technology sector (tech-savvy boys and men) needed to be strengthened and the potential of skills and talents in the large group of women and girls became more and more interesting. The decision to make technology a compulsory subject in primary schools in the early 1980s (Curriculum for primary school, Lgr 80, 1980) can be viewed in the light of this particular relationship. When technology was first introduced in 1982 however an additional argument in support of technology training was put forward. Technology, with its associated laboratory work was seen as a model for teaching in other subjects, in need of increased opportunities for practical work (Gustafsson, 1984, Elgström & Riis, 1997, Skogh, 2001). A document from the National Board of Education (1978) states:

> One of the main reasons to have all students meet elements of technological nature is that technology, as taught at the lower levels of education, provides unique opportunities to develop an active, exploratory and experimental teaching/learning approach in school. (In Gustafsson,1984 p.15. [Translated from Swedish]

Statements about the importance of teachers linking their teaching to students' own experiences show up periodically in the educational literature throughout history. Comenius (Lindström, 2007) argues that 'real' knowledge and understanding is based on students' own exploration, *'... on the students' own experience of the things themselves'*.

In 1762 Jean Jacques Rosseau (1977) declares that his imaginative pupil Emile is not to be taught science, *'... he must find it himself.'* The same ideas recur over a hundred years later in John Dewey's educational texts (Dewey, 1980). Dewey wants to bring education closer to pupil's social situation and is toning down the boundary between theory and practice:

> I believe that ideas (intellectual and rational processes) also are the result of actions. … Trying to develop common sense and discretion without regard to the selection and planning of practical action, is the main fallacy in our present methods to address this area.

Also Jean Piaget (Bringuier, 1980) points to the importance of students actively seeking knowledge:

> In every field action comes first, classification and conceptualization come later.

The same ideas have regularly returned in 'new bottling' throughout the years. Problem-based learning (e.g. Barrows, 1996, de Graaf & Kolmos, 2007, Schmidt G., Rotgans J., & Yew E., 2011) and Inquiry-based learning (e.g. Shymanski, Hedges & Woodsworth, 1990, Kirchner, 2009), are two recent applications of the same basic idea of students actively seeking knowledge.

Technology Education in Elementary School – Visions and Reality

The introduction of technology as a separate school subject in compulsory school in the 1980s was accompanied by high expectations from the national school authorities. Technology education in school was seen as both a model for, and an inspiration to more laboratory exercises in other school subjects. It was also seen as a gateway to higher education in technology (Elgström & Riis, 1990). Today, more than thirty years later, we now know that technology has not yet had the intended impact and effect. In many schools instruction in technology is still offered only during the latter part of secondary school and/or for a limited period (Fabricius et al., 2002, Teknikföretagen, 2005, Teknikdelegationen 2009).

Nor have the effects in terms of recruitment and gender equality developed as expected. According to statistics (Skolverket, 2011) under 10 % of all students in upper secondary school were following the technology program in 2010–2011 (upper secondary school year 1–3). Of the 20 600 students only twenty (20) percent were girls.

As for the vision of technology education in compulsory school promoting laboratory work in other school subjects, history has shown that the effect is not verifiable. The importance of laboratory work in school education has, from time to time, been highlighted during these past years by policy makers, educational researchers and teachers. However few would argue that this interest in laboratory work is primarily linked to work methods in technology education.[2]

The Question of Subject Content

When technology was first introduced in the 1980s it was included in the Science subject block. Its close link to the science subjects is still retained. Under current (and past) timetables a total of 800 hours (200 hours per subject) is devoted to instruction in the science subjects (physics, chemistry, biology) and technology years 1–9. The allocation of teaching resources for these subjects lies formally on the headmaster of each school but since there have been (and still are) few qualified technology teachers in Sweden and the other science subjects are often prioritized (Ginner & Skogh, 1999, Fabricius et al, 2002, Teknikdelegationen, 2009). Accordingly the content, and also the quality of technology education in schools, may have varied (and probably still does) not only from school to school but also from classroom to classroom.

What competences and qualities technology education in elementary school should result in according to governing documents during the years in which the pupils/students in the presented studies were taught technology, is not easily described. In the Curriculum for primary school, 1980 (Lgr 80), there was virtually no indication of what subject content should be addressed by the teachers. As a result, teachers had to design their technology teaching on ‘their own’. With few textbooks available the quality of the teaching depended heavily on teachers’ personal interest and knowledge in technology.

According to Riis (1989) the lack of definition could be explained in different ways. It could be seen as an expression of a political compromise or it could be seen as a result of a belief that schools/teachers could and should shape the content themselves; that the subject content should ‘emerge as a result of the teaching activity itself, guided by certain methodological requirements’. On the other hand Eriksson (1986) questions if the subject content had any significance at all. He argues that the introduction of technology as a compulsory school subject in Sweden may have been made for other than knowledge-related reasons:

> ... to interest children in science and technology may be expected to result in an impact on attitude attitudinal impact rather than an impact in strict terms of knowledge – we are talking about relatively limited and sporadic efforts. (ibid. p. 17) [Translated from Swedish]

In the 1994 curriculum (Curriculum for primary school, Lpo 94), teachers were obliged to link their technology teaching to five key perspectives (Development, What technology does, Construction and operation, Components and systems and Technology, nature and society). Which specific areas of technology and what operations to be included in the teaching were not specified thus leaving room for different interpretations of both substance and subject content. Among teachers a 'teaching tradition' however had begun to take shape. Sjöberg (1995) mentions solid mechanics, moving parts and mechanism, measurement and control, electromagnetics and parts of the history of technology as being 'core-elements' in this tradition.

Without a doubt, great demands have been put on teachers and students in Sweden during the last thirty years in relation to technology education. Teaching technology, in many cases without proper training and often with limited resources available, takes its toll. Learning technology, on the other hand, is not easy without a clear goal orientation (including subject definition/frames) and support from subject expert teachers.

ABOUT SELF-CONFIDENCE

The question of if the outcome (success or failure) of an activity (e.g. solving a task or assignment) is depending on the individuals' attitude and approach towards the task/assignment in question has, over the years, interested both teachers and philosophers. von Wright (1983) argues that an important prerequisite for us to want to deal with a task of any kind is that, within us, we make an assessment about the prospects of completing the assignment in question. If the prospects of success are too small it is, according to von Wright, likely that we will refrain from even trying.

> To have an intention to do something presupposes that the agent thinks, rightly or wrongly, that he can achieve the object of his intention. What he does not think he may accomplish, he will not attempt either. (ibid. p. 48)

How we perceive ourselves and our possibilities is, according to von Wright, vital as it affects both our experience of an activity and our ability to act. If we transfer von Wright's reasoning to the theme of this chapter, namely pupils' experiences and perceptions of technology education in school, the following relation can be formulated:

> Pupils with a sound confidence in their technical ability can easily be persuaded to take on a technical activity. This obviously leads to increased technical experience and increased technological skills/knowledge which, in turn, leads

> to increased confidence in her/his technical ability – a positive development spiral is created. Similarly, pupils with low confidence in their technological capabilities will, as far as possible, try to avoid situations where their technical skills will be put to test. This leads to little, if any, technical experience, which in turn leads to further undermined confidence in their technical ability – a negative development spiral is created. (Skogh, 2011, p. 112)

According to Ahlgren (1992) attitudes are based on both cognitive considerations and emotional experiences. An individual's self-evaluation (interpretation of reactions from the outside world) can be seen as a result of

> … how the individual interprets others' reactions towards their own behavior and the ambient value systems, individual goals, aspirations and previous experience and personal capacities (ibid. p. 39). [Translated from Swedish]

Under this reasoning, it is possible to accept one's own limitations without adopting a negative attitude to oneself – provided that one feels accepted by the environment. According to Ahlgren the reactions of others determines whether an individual perceives her/himself as successful or unsuccessful. By transferring Ahlgren's reasoning to the context of this chapter, pupils' self-evaluation of their own technical ability could be seen as a consequence of the following two conditions:

Functionality (cognitive stance) – It works /does not work.
Response (emotional experience) – 'Come and look – it works/does not work!'

The issue of proportionality between these two conditions is interesting. Are the two conditions (functionality and response) equally 'important', or is any of them more important for students when it comes to acquire (or not acquire) a technical self-confidence?

THE STUDIES

This article is based on findings from three studies/reports. The three studies are presented briefly in this section.

Teachers' and Teacher Students' Experiences from Technology Education in Elementary School. (Skogh, 1997) [Title Translated from Swedish]

This study is based on a survey performed in 1996–1997. A questionnaire was presented to 280 teacher students and in-service teachers at the beginning of the first lesson in a basic technology course at a Swedish Teacher Training University College. This technology course (15 credit points) was, at the time, mandatory to all teacher students studying to become teachers in science & mathematics in grades 1–7 or 4–9 in elementary school). The in-service teachers took a shortened version of the same course (7,5 credit points) transformed into a continuing professional development course.

The questionnaire (both multiple choice and open ended questions) covered the following issues; the concept of technology, gender and technology, own experiences from technology education in compulsory school, personal interests/ hobbies, what should be taught in technology (elementary school), personal reasons for choosing to become a science and technology teacher, their thoughts on at what age technology education should be introduced in school and finally their visions for technology education in school in the future. This article presents findings concerning three of these issues namely the concept of technology, experiences from technology education in elementary school and visions for future technology education.

Approximately 20–30 minutes was devoted to the survey. All students attending the first lesson of the course (offered once every semester) during 1996–1997 completed the questionnaire. At the time of the study the students were between 19 and 36 years old. Hence they had attended elementary school sometimes between the1980s and the early years of 1990s. The study has not been published but findings have been presented in other publications (e.g. Skogh, 2001, Skogh, 2011).

The World of Technology – The World of Girls. A Study of Young Girls' Encounter with Technology at Home and in School. (Skogh, 2001) [Title Translated from Swedish]

This is a longitudinal study where 26 girls (ages 7–12) were followed through their early years in elementary school. The aim of the study was to see, from the girls' point of view, how the girls experienced and apprehended their encounter with technology at home and in school. Three research questions were addressed: (1) how do the girls in the study speak of, think about, and feel about technology and technical education (2) why do the girls act as they do when faced with technical tasks and (3) how do the girls learn that they 'can' or 'cannot' deal with technology (having or lacking technical self-confidence).

Half of the girls in the study received instruction in technology once a week throughout the period during which the study was made. This school is referred to as R1-school. The other half did not receive an education in technology at all (referred to as R2 school). The girls in the R1-school were followed for five academic years (grades 1–5) and the girls in the R2 schools were followed for three academic years (grades 3–5). In accordance with the theoretical framework of the study (G. W von Wright's theory on logic of events) efforts were made to capture both the girls' inner lives as well as the external circumstances surrounding them. This was done through interviews/talks with the girls, informal talks with involved teachers, parents, and school administrators, questionnaires to the girls and their parents, observations of the girls and other data gathering (such as the girls' drawings and written/oral evaluations). Data from the entire period was considered in the study, but particular emphasis was placed upon girls' experiences of technology education in year 5.

This study is published as a doctoral thesis from Stockholm University, Sweden.

Is Technology Taught in School and is Math's Hard to Learn? This Year's Ninth Graders Responding (The Swedish Technology Delegation, Report 2009:2) [Title Translated from Swedish]

This study was performed in 2009 by Novus Opinion (a private consulting company) on behalf of the Swedish Technology Delegation.1 Web interviews with students in the ninth grade (15 years old) were conducted. The measurement covered 500 nationally representative recruited interviews. Of those interviewed, there were slightly more girls than boys (56 percent girls and 44 percent boys).

The purpose of the survey was to investigate the attitudes towards technology and mathematics among nine graders, and how this is linked to the students' choice of secondary school program and future plans (higher education, profession).

The study covers questions about (1) how important and fun the students find different school subjects (2) if mathematics and technology is perceived as hard or easy (3) if the students wants more math and technology in school (4) the students suggestions regarding how to make technology 'more interesting' (5) the students views on the usefulness of mathematics and technology education in elementary school (6) the students choice of upper secondary school program (a decision the students had to make shortly after the interviews) and finally (7) the students future plans (higher education, profession). As the focus of this chapter lies in technology education the findings regarding mathematics have been excluded.

With that the introductory background description is ended, and it is now time to reveal the pupils'/students' views on technology education in school. Let's start from the beginning with the youngest children in primary school (7–12 years).

PUPILS' EXPERIENCES AND PERCEPTIONS

Primary School Pupils about Technology Education

Teachers' ways of defining and presenting technology is important for how students' understand and define technology. In the longitudinal study of young girls (7–10 years) encounter with technology education in school (Skogh, 2001), this became obvious. As mentioned previously twenty-six (26) girls from two different schools with similar socio-economic background were studied (repeated observations, questionnaires and interviews). Only one of the schools provided instruction in technology on a regular basis. Of particular interest to the study was the question of how these young students perceived the concept of technology and, in the case of the students who received instruction in technology, their experiences from the technology education they had encountered in school (what had they learned and what had been fun).

The first time the girls in this study were asked to define the concept of technology (regardless of school affiliation) they were puzzled. Their perceptions of what the word 'technology' involves, seems initially rather blurred. Few associate spontaneously to something they've done themselves or to any particular person or business. Among R1-students ('the tech students') who every week received technology instruction, the image of what the technology 'is' gradually develops and is given a more precise meaning. Most young students perceive technology education in school as something positive. Some of them even claim that technology is their favorite subject:

> Technology is fun! (Student, Grade 3)

> Technology is in fact my best school subject (Student, Grade 5)

One of the students (in parenthesis said to be the most talented student in the class, according to the teacher) thinks differently:

> I think it [technology] has become more and more boring …

> I feel like I've outgrown it. (Student, Grade 5)

Despite this negative attitude the student expresses that there are certain elements of technology education that she likes:

> Some things are fun – it depends on what we do. Soldering is fun! But I don't like the part when the teacher instruct us and tells us what to do and why. I want to work in my own pace! (Student, Grade 5)

In year 3 the 'techno-students', with few exceptions, associate the concept of technology with the technical experiences made in school. The students mention primarily practical exercises and tasks they have been confronted with but also events like field trips and/or features from technological history. Hence their perception of the word 'technology' reflects both what they remember from technology classes and the feelings evoked. To many of them the concept of technology seems to be almost synonymous with "what you do in school during technology lessons" – an idea that they retain more or less intact for the duration of the study. However some are hesitant about if the technology they are doing during technology classes is 'real life' technology. What the students mean by 'real life-technology' is somewhat difficult to know. Maybe there is one kind of technology for children and another kind for adults?

> If what we do in school is technology, then it cannot be something adults are doing! (Student, Grade 1)

In year five (Figure 1) a majority of the R1-students ('tech students') in consistence with their previous answers in year 3, associate the concept of technology to the technology instruction they encounter in school. One of the students who, in contrary to the majority, describe technology in more general terms ('a bunch of cables, computers and TV-sets') clarifies her view by saying:

> It is my mother ... I mean that I think of my mother! She works with cables, computers and stuff.

	General statement	*Own experience*	*'Don't know'*
'tech-students'	Electrical things Wires and cables, computers and TV-sets. I'm thinking of spinning wheels and constructions.	Different things and that it is fun. Tuesday, when we may start with computer or things we've done before. Tuesday, when we have the technology That we do things. The school – not so fun. Connect and disconnect lamps … and soldering.	I don't know
'non-tech' students	Experiments … and computers. Some sort of experiment. Batteries and inventions. Machines, gears and inventions Computers, various technical jobs or to do something. Electronic stuff, resources and knowledge. To build, assemble and install things.	Something exciting that you come up with!	Nothing at all

Figure 1. Students (Year 5) answer to the question 'What comes into your mind when you hear the word technology'? (Skogh, 2001, p. 135).

Among the R2-students ('non-tech students') who, according to themselves and their teachers, did not receive any training in technology, the associations in relation to the technology concept are generally more generic. They do not, contrary to the 'tech students', consider technology to be a self-perceived activity. The 'non-tech student' primarily associates technology with objects or inventions (machines, or jobs as an electrician and inventor). But there are exceptions. One of the 'non-tech students' tells about a new invention. She has made a catenary structure that makes it possible to control the dustbin lid from the kitchen window. A much appreciated invention at home, she says. This student stands out from her peers. She's the only girl in the 'non-tech' school who spontaneously associates the word technology with something that can be perceived as personally experienced. And for her, technology is something positive:

> Something exciting that you come up with!

Regarding the inclination to engage in what the pupils consider to be 'technology related activities' this disposition is significantly higher among the students that had received technology instruction on a regular basis, than among those who had not. Recreational activities that only 'techno students' mention are construction activities (e.g. Lego, building cabins or rabbit cages) and 'experimenting' (e.g. exploring, unscrewing and assembling things like watches, toys and broken appliances). When 'techno students' in year 5 are asked if they can manage to set up a home video system (this was in the 1990s), nearly all of them respond 'yes'! One of them quickly adds:

> If there is an instruction manual! (Student, Grade 5)

The confidence reflected in the students' answers is worth considering. How and why did they obtain this 'techno-confidence'? The answer is surprisingly clear to the young 'techno students'. Technological self-confidence is, according to them, directly related to technical experience and the most important measure of if you are 'good' and able in technology is the outcome of technological activities (the results and performances achieved). If something is functioning ('works') you know you have succeeded. Then you know that you 'can' and that you are good at technology.

When asked about strategies for obtaining technological self-confidence the pupils also have an answer. According to them technological self-confidence will not come without efforts. There has to be opportunities to practice technology, a wish to engage in technological activities accompanied by the energy to actually do what need to be done and finally, the result of the activity should be successful – if not immediately at least at some point (ibid p. 245).

Secondary School Students

What about the somewhat older students? What do they think about the technology education they have encountered in school? With the help of two studies (the Swedish Technology Delegation, 2009 and Skogh, 1997) this will be illuminated.

In the Swedish Technology Delegation web survey study grade 9 students (15 years old) were asked about their views on technology education in school. A majority of these students (but not all!) stated that they had in fact received instruction in technology in school. Two-thirds say technology was taught as a separate subject and the rest state that they have received technology training as part of another topic or through thematic studies organized in subject blocks (mostly within the science block).

When asked about how they assess their ability to succeed in technology the answers vary. Between 10–15% of the students think that they succeed very well, hereby indicating a solid technological self-confidence. Just as many have opposite views of their technical ability and believe that they manage very poorly. The vast majority of students end up somewhere in between. They are not satisfied with their technical ability but also not completely dissatisfied (ibid, page 10).

In one of the questions the ninth graders were asked about the status of technology compared to other school subjects. Their answers are undoubtedly disturbing.

According to the students the core subjects Swedish, mathematics and English are perceived as key subjects. Technology, on the other hand, is ranked low. It is regarded as unimportant and not related to future higher education and career.

Regarding the issue of students' interest in technical education and a future profession in the technology sector, three response categories were identified (ibid p. 12):

- One fourth of the students are determined. Even in grade 9 they already know that they want to work with technology.
- About half of the students think that technology is important but that they do not want to work with it themselves. This response category is found among environmentally interested students and students interested in working with people.
- The remaining quarter of pupils do not want to work with technology and do not believe that technology is important. Girls are, according to the report, overrepresented in this group.

In grade 9 students in Sweden have to choose upper secondary school study orientation. This choice was made by the students in the study just prior to the study being performed. Approximately 7 percent of the ninth graders in the survey state that they have applied to the technology program in upper secondary school. Thus, a majority of the students, for various reasons, have chosen other programs. The most common – and most logical reason for this, according to the study, is lack of interest in technology. As much as 47% of students in the study state that they are uninterested in technology. Lack of interest in technology is however not the only reason for not choosing technology oriented studies. Few of the students seem to know what technology studies at upper secondary school really means. Of those who do think that technology is fun and important the most common reason for not choosing the technology program in upper secondary school is the fear of not 'fitting in' (ibid p. 13).

The report points to clear gender differences in attitudes to technology education. The boys in the survey in generally think that technology is more fun and more important than the girls. The boys also express that they are doing well in technology to a greater extent compared to the girls. The advantages that technology brings to individuals and society also seem to be of less importance to the girls. This 'not interested in-technology' attitude applies, according to the girls, to both everyday life technology and studies/training for future work (ibid. p. 10).

The teacher is an important person to the students. She or he has to be able to explain subject content and related activities in an effective but also 'fun' way." The teachers should, as much as possible, connect to the students' interests and experiences. To make technology more interesting the ninth graders also suggest more practical elements such as labs.

The idea of linking technology education in school to industry and business (often proposed by branch organizations) does not appeal to the students. Extramural activities in technology education are ranked low by most students, however, with one exception: the group of students who expressed that they feel that the subject technology is 'boring'. These students call for more instruction in environments outside school (field trips, museums, etc.). This might, according to the report, be a way of saying that teaching in the classroom is not stimulating. (ibid. p. 11)

Teachers' and Teacher Students' Experiences

In another study, in-service teachers' and teacher-students experiences and perceptions of technology and technology education in elementary school were studied (Skogh 1997). This study is, as mentioned previously, based on a survey performed in 1996–1997 (280 teacher students and in-service teachers).

When the teachers/teacher students were asked about their own experience from technology education in elementary school their recollections show great similarities. 201 of the 280 students reported that they had received instruction in technology in compulsory school. A majority of them had received instruction in technology only in secondary school (year 7–9). Almost exactly one-third of the students (68) were satisfied or very satisfied with the technology education they had received. The others reported either that they did not remember much of the technology education (many were unsure whether it was physics or technology lessons they remembered) or were negative or very negative about the teaching they had encountered.

The positive students are in a clear minority but their enthusiasm cannot be mistaken. Several of them give concrete examples on items or abilities that they have developed during technology lessons.

> We made an electric organ – great fun!
>
> Soldering was fun! I have taken advantage of this skill many times!

Students with a more negative attitude often described the feeling that technology education was forced on them. Ten years after finishing the last technology lesson in elementary school they still express strong feelings against the instructions given:

> Gray, dull premises smelling bad.
>
> Our teacher was an idiot!

It is evident that many experienced technology education in compulsory schools as being incomprehensible, and without any relation to the everyday life that surrounded them at the time.

> Boring – just the engines. Completely meaningless!

Several of the students indicate that these very negative experiences have followed them into adulthood:

> I learned nothing – except perhaps that I was no good at this. Since then I have kept myself away from technology as much as possible.

The technology lessons were, according to the teacher students, almost exclusively practice-oriented. The structure of a 'typical' technology lesson was, according to the informants, a short introductory phase when the teacher told the students what to do. The rest of the lesson the students were supposed to do just that. Few recall discussions with the teacher about why they should do what they were asked to do or being instructed individually about how to do overcome difficulties in solving a task.

The importance of sufficient input and support from the teacher is stressed by several students. Especially those who think that they did not receive the help they needed:

> The teacher only helped those who already knew what to do!

As examples of a typical technology tasks the student mention exercises with electricity (e.g. electrical connections, electric motor, battery tester, to mount switches, soldering), every-day technology exercises (e.g. wallpapering, pouring concrete and 'watching the teacher mend a puncture') and manufacturing of various items (Christmas goat in sheet metal2, corrugated box, and house models). Someone remembers the sheet metal goat in particular.

> There was hardly anyone in the class who had finished the goat when semester was over, so the teacher took all semi-finished Christmas goats, and completed them himself. You didn't learn much from that …

The teacher/teacher students were also asked about their opinion on what should be taught in the technology classrooms of tomorrow. In their answers few take example from the technology instructions they had received themselves. Instead of sheet metal goat decorations these students want their future pupils to do construction work, be familiar and comfortable with everyday technology, be aware of technological systems of various kinds and prepared to later be involved in environmental technology. Clarifying the close link between technology and society is also important according to the teacher students. Technological literacy for all students is a recurring thought.

To achieve this we need, according to the teachers/teacher students in the study, to demystify technology as a school subject, provide solid subject knowledge and, not least important, lay the foundation for a solid technological self-confidence among the pupils. One of the students quotes Sven Nykvist who, for many years, was world the famous film director Ingmar Bergman's main photographer. He is supposed to at some point have said:

> You have to know technology well to dare to ignore it.

CONSISTENT RESPONSES

The findings presented are results from three very different studies. The design of the studies differs, there are differences in relation to the aims of the studies, they are conducted at different times and there are obvious differences regarding the informants' age and experience. These circumstances are important to acknowledge. However, in spite of these obvious differences there are interesting similarities in the findings worth considering. It is possible to discern a number of common areas where the students' views show clear resemblance. The perceived prevalence of instruction in technology in elementary school is one of them.

Having or Not Having Received Instruction in Technology

In two of the studies this question is raised directly (Skogh, 1997 and Teknikdelegationen, 2009). In both studies there are a number of students who do not remember receiving any instruction in technology in school what so ever. Given the fact that technology is, and has been a mandatory school subject since the early 1980s, this is quite remarkable!

A majority of the students state that they did receive instruction in technology in elementary school. It needs however to be noted that these instructions, according to the students in the two studies, took place primarily in secondary school (year 7–9). This is also somewhat remarkable since technology instruction, according to regulations, should be taught throughout elementary school, including the primary years of school.

There are, in both studies, statements from students indicating uncertainty about if the instruction they recall from school was in fact instruction in technology or in something else. Many suggest that it probably could have been instruction in physics that they remembered. Some adding that they, at the time, had (and to some extend still have) difficulties to apprehend the difference between the two subjects.

The students' statements are consistent with the results of e.g. the previously mentioned studies by Fabricius et al, 2002 and Teknikföretagen, 2005 where it was found that technology education in elementary school often end up in the shadow of the science subjects. The statements are indeed also in line with the conditions laid by school authorities regarding technology education in elementary school (Elgström & Riis, 1997, Skolöverstyrelsen, 1980, Utbildningsdepartementet, 1994). Certainly, the students who suspect that they have received instruction in physics instead of technology can be quite right. The subject-specific content of technology has not been clear. We know that the responsibility for instructions in technology often has been laid upon the science or sloyd teachers (Fabricius et al., 2002, Teknikföretagen, 2005). The teachers concerned have had to deal with the situation to the best of their ability and knowledge. For any teacher given the responsibility to teach technology, the strategy of designing the teaching in accordance with her/his own knowledge and skills is understandable and, from the teachers' perspective, in fact even wise.

Depending on society's view on what technology education is (or ought to be) there are consequences to consider from these results. If we want our future pupils to develop certain technological skills and abilities in school this is what must be defined and taught in all schools and by all teachers.

The Teacher is Important

The teacher is a very important person to the students. To the very young pupils (Skogh, 2001), teachers' choice of subject content is of crucial importance for what the pupils' see as technology. Technology in school both symbolizes and embodies the whole concept of technology. If technology activities in school are 'fun and interesting' technology as a whole becomes 'fun and interesting '.

Also the ninth graders and the teachers/teacher students express similar views. Technology teachers should, according to them, as much as possible connect teaching to the students' interests and experiences and preferably, as the ninth graders put it, be able to explain things in a 'fun' way (the Swedish Technology Delegation, 2009, p. 11). Activities that, according to the many ninth graders who find technology uninteresting, would make technology more interesting are labs, field trips and museums. The students hereby connect to the pedagogical tradition of Comenius ('real' knowledge and understanding is based on students' own exploration … 'on the students' own experience of the things themselves') and his followers who stress the importance of learners being active.

The impact of the teacher is highlighted also by the teachers/teacher students (Skogh. 1997). What technology teachers said and did to the informants many years prior to the query is still influencing their feelings towards technology. The perception of teachers' expectations of their students seems to be of significant importance. If a teacher (intentionally or not) signals that a student is incompetent in technology, there is an obvious risk that this feeling of inadequacy in relation to the field of technology will live on within the student in question long after her/him leaving school (' I learned nothing – except perhaps that I was/am no good at technology'). The teachers who have expressed such negative comments are judged hard. Both the teacher her/himself ('our teacher was an idiot') and the situation surrounding the technology education ('grey, dull premises smelling bad') are condemned. To suggest that the same is true for teachers' negative comments in other school subjects as well is reasonable. Indeed a great responsibility is laid upon teachers!

Also other views regarding teachers' choice of work methods and teaching design are expressed by the students in the studies. One of the younger students (Skogh, 2001), is displeased with the teachers' way of controlling the activities (… the teacher instruct us and tells us what to do and why. I want to work in my own pace!). However the opposite (the lack of such instructions) is perceived as a serious problem among the teachers/teacher students (Skogh, 1997). They call for visible and understandable goals and objectives in technology teaching (… the teacher took all semi-finished Christmas goats, and completed them himself. You didn't learn much from that). Similar experiences of lack of purpose and meaning in elementary school technology education are indirectly expressed also by the ninth graders (Technology Delegation, 2009). Technology is ranked low and is regarded as unimportant and not related to future higher education and career.

So far, primarily very negative statements from the students in the studies have been reproduced and referred to in relation to student's views about instructions received. It is however important (and interesting) to acknowledge that the statements from students who express positive views about the technology education they have encountered in school essentially send the same message. The teacher student (Skogh, 1997) for example, who remembers learning soldering (Soldering was fun! I have had the advantage of this skill many times!) is in complete agreement with her more disaffected peers. Technology education should be meaningful and provide useful skills and knowledge, and at the same time, be experienced as interesting and enjoyable.

Images of Technology

To the youngest students in particular, but to some extend also to the older students, the technology taught in school embodies the image of what technology 'is'. The impact of teachers' ways of defining technology in school (as a subject area and as an area of expertise) may of course be perceived as a problem. Too unilaterally subjective content limits students' opportunities to a variety of technical experiences and also of alternative views on what technology 'is'. To students who perceive the selection of technology tasks/exercises in school as uninteresting as expressed by the teacher students, the findings point to a possible or even substantial risk that this negative attitude will cover not only the technology education they encounter in school, but also technology studies as a whole – an idea that can be very difficult to change.

Among the young 'tech students' in Skogh (2001) who received technology education in school on a regular basis, the imprint of the technology concept to which they have been exposed in school does not seem to have caused any limitation in their views on technology. The findings rather show the opposite. The fact that a majority of the 'tech students' say that they think that technology is 'fun' points, in this case, against the presumption that school's way of defining technology is limiting students' views, at least for the duration of the referred study.

The 'non-tech students' in this study (who did not receive regular technology instruction in school) define, as mentioned before (Figure 1) technology in more general terms without a clear link to their own world of experience. Perhaps this lack of technological experiences in school could be a contributing factor to why many students distance themselves from technology and/or technological activities?

Although in both groups of students ('tech students' and 'non tech students') there are examples of students who do not associate according to their group membership, one can say that the results from this study suggest that there is a correlation between students' experience of technology and the image of technology that students carry with them. If the image of technology presented in school does not agree with the students' view of what is interesting and important, the consequences are likely to follow the pattern described in the Swedish Technology Delegation report (2009) where technology is opted out by a majority of the students in favor of other study paths.

Attitudes and Confidence

The question of attitude and approach towards technological tasks and assignments was raised in the studies. In accordance with von Wright (1983) many of the students directly or indirectly express that feelings of confidence towards a task or an assignment will influence the outcome of the activity in question. The teacher student (Skogh, 1997) who was told by his technology teacher that he was not 'good enough' *(I learned nothing – except perhaps that I was no good at this. Since then I have kept myself away from technology as much as possible)* lost faith in his technological ability and did his best to avoid activities related to technology both while in elementary school but also long after leaving school.

Among the ninth graders (the Swedish Technology Delegation, 2009) the perceived feeling of self-confidence in relation to technology vary. About 10 % of the students express a solid 'techno-confidence'. About the same number express the opposite. To them technology is perceived as difficult and something they are not fit for. The share of technology-confident pupils could of course have been greater but, on the whole, these results are not unforeseen or surprising. It is rather the great majority of pupils who are in between these two extremes that need attention and intervention. To these students technology and technological activities are not experienced as a deterrent but neither apprehended as a realistic option. It is indeed problematic that half of the ninth graders have passed nearly nine years of elementary school without gaining enough interest in technology to see technology as a possible study path. It is also disturbing that a majority of the students in this study have vague ideas about what technology education in upper secondary school is and express feelings of doubt regarding their ability to manage studies within this program *(fear of not 'fitting in')*. Another disturbing issue is the fact that among students expressing lack of interest (and also lack of self-confidence) in technology, girls are in majority. The vision of technology as a subject for both boys and girls expressed in curricula (Skolöverstyrelsen 1980, Utbildningsdepartementet, 1994) has, at least not among these students, been materialized.

Perhaps we can learn from the younger students (Skogh, 2001) and their recipe on how to achieve technological self-confidence?

> The feeling of knowing that you 'can' is a result of the opportunities you get, the desire you have, what you actually do and what one achieves when.

The connections these young students make (they are 11–12 years age at the time) between attitudes, action and results are remarkably insightful. There is however one aspect these young pupils do not mention. According to Ahlgren (1992) an individual's self-evaluation includes an interpretation of reactions from the outside world, from significant 'others'. It is interesting that the pupils' recipe exclude this aspect. The reason for this one can only speculate about. One way of explaining the absence of 'others' in the recipe might be that these techno confident pupils subconsciously perceive feedback from 'others' as natural and implied and therefore not worth mentioning.

In accordance with Ahlgren's' reasoning, two conditions of significance for obtaining technological self-confidence were suggested in one of the introductory sections of this chapter: (1) a cognitive stance where functionality is stressed (something works or do not work) and, (2) the individuals 'emotional experience ('look – it works/does not work!'). The issue of proportionality between these two conditions needs to be commented on. In the case of the young 'tech students' (Skogh, 2001) functionality is undoubtedly considered to be the most important contributing factor. With regard to the students in the other studies, (Skogh, 1997, Swedish Technology Delegation, 2009) the picture is not as clear. Functionality is mentioned by some of the 'older' students. This is (indirectly) noticeable in e.g. the teacher students' statement about the perceived lack of teacher support (few recall being instructed individually about how to do overcome difficulties in solving a task). Among the 'older' students however emotional experiences seem to dominate their recollection of technology education in elementary school. There seem to be what could be described as 'reversed conditions' among the students in the three studies. It is the youngest students, those with few years of experiences from technology education, who primarily reflects interest and curiosity in technology and relates these experiences to technological activities. Many of the older students who, at least in theory, have nine years' experience from technology and technological activities, seem to have lost track of the purpose of the teaching and are left with feelings of inadequacy and disappointment. The question of which condition (functionality or emotional experience) the students in the three studies consider to be most important in order to achieve technological confidence is not fully clarified. Perhaps the relationship presented in Figure 2 (below) can be of help in understanding the mechanisms behind successful and sustainable technology education.

The Important Technology Definition

The views on science and technology in society have concrete implications for how technology teaching is organized and presented. What teachers teach and what

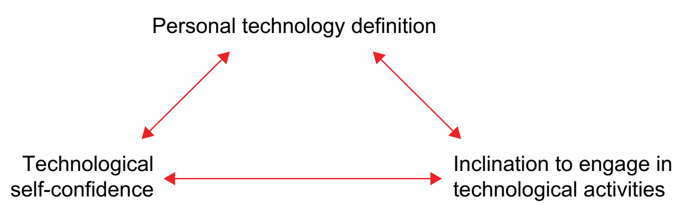

Figure 2 The relation between technology definition, willingness to engage in technological activities and perceived technological self-confidence.

students learn during technology lessons depends on and reflects these views (e.g. status, resources available and subject boundaries).

Personal technology definition

Technological Inclination to engage in

self-confidence technological activities

It is in everyday life that the concept of technology takes shape. The image of what technology 'is' emerges in the interaction with people surrounding us. The technology definition we choose both depends on and reflects our previous technical experiences (or our lack of such experiences). It reflects our attitude towards technology and hence our propensity to engage in technical activities. Figure 2 is an attempt to schematically describe this relationship.

Insight about the ambiguity of the concept of technology is important for everyone teaching technology at any level in the educational system. If teachers and educators are able to link teaching material to students' experiences (and definition of the technology concept) this will increase the possibility to arouse (and retain) students' interest in the subject. Also those who, from an external perspective (parents, business, and society) are assessing and evaluating technology education in school, need insight about this concept ambiguity and about the ongoing development of technological knowledge. We all have to deal with the fact that technology education in school cannot, and need not be the same as it was when the engineers of today went to school.

CONCLUSIONS

Three questions, all linked to Comenius didactic questions, were put forward to the students in the three studies. The pupils were asked about what images of technology they had developed during technology education in school, about their attitudes towards and /or memories of technology lessons in school and what impact technology education has had on their own personal development. So, what then have we learned?

In relation to the question of how the students define technology, we can conclude that there is no trace of a uniform, general definition of technology presented to the students. We can also conclude that teachers' different ways of defining technology have a significant impact on how the students themselves define technology.

Regarding the issue of students' attitudes and memories of technology education in school we can conclude that students, who feel that technology education in school is linked to their own personal experiences and interests, experience instruction in technology as interesting, useful and 'fun'. For those who experience the opposite the attitude towards technology is, not surprisingly, the opposite. They want to avoid activities related to technology while in school and, according to quite a lot of them, also after leaving school.

The last of the didactic key questions concerns the question of the students' views on why technology has been taught in school. What impact has instruction in technology had on them? The answers vary. The 'already converted' acknowledge the importance and usefulness of the technical knowledge and experiences offered in school. The uninterested remain uninterested or, in worst case scenario, develop enhanced aversion against technology.

So what can we learn from these results? Looking at the students' reflections an element of determinism can be detected. Students who, within or outside school, has developed an interest in technology seems to be 'the winners'. They are, according to the presented results, gaining most from technology education in school. Those who need technology education the most seem to gain the least from this teaching. It shouldn't be like that and, above all, it must not stay that way.

NOTES

1 In 2008 a governmental committee (The Swedish Technology Delegation) was appointed by the Swedish Government (ToR 2008:96). The Committee was mandated to promote greater interest among children and young people in mathematics, science, engineering and ICT (Information and Communication Technology). The members of the committee were selected from the business community, higher education and other stakeholders. Between 2008 and 2010 the Delegation conducted outreach work, implemented a campaign, published background reports, organized conferences, wrote articles and took part in debates. Its final report (SOU 2010:23) was presented to the Minister for Higher Education and Research in April, 2010.

2 A new curricula and new syllabuses in all school subjects, including technology, have been introduced recently in Sweden (Curricula for primary school, Lgr 2011). The effects from these changes lie in the future and therefore outside the limits of this article.

REFERENCES

Ahlgren, Rose-Marie. (1992). Jag – en social varelse. I: *Individens samspel med miljön.* (Red.) Pia Björklid & Siv Fischbein. Stockholm: HLS.

Barrows, H. S. (1996). Problem-based learning in medicine and beyond: A brief overview. In L. Wilkerson, & W. H. Gijselaers (Eds.) *New directions for teaching and learning* (No. 68*). Bringing problem-based learning to higher education: Theory and practice.* San Francisco: Jossey-Bass

Bjurulf, V. (2008). *Teknikämnets gestaltningar. En studie av lärares arbete med skolämnet teknik*. (Karlstad University Studies 2008:29), Doktorsavhandling, Karlstad: Karlstad universitet.

Blomdahl, E. (2007). *Teknik i skolan: En studie av teknikundervisning för yngre skolbarn* (Studies in Educational Sciences, nr. 99). Doktorsavhandling, Stockholm: Stockholms universitet.

Bringuier, J. C (1980). *Conversations with Jean Piaget*. London: Univ. of Chicago Press.

Bourdieu, P. (1991). *Kultur och etik*. Göteborg: Daidalos.

Dewey, J. (1980): My pedagogic credo. I: *Individ*, *skola och samhälle*. Stockholm: Natur och kultur.

Elgström, O., & Riis, U. (1990). *Läroplansprocesser och förhandlingsdynamik: Exemplet obligatorisk teknik i grundskolan*. (Linköping studies in arts and science, nr. 52). Linköping: Linköpings universitet.

Englund, P. (1993). *OfrEds.r*. Stockholm: Atlantis.

Eriksson, K-H. (1986). *Barn – ungdom – naturvetenskap – teknik*. Vol. 2: Undervisningsmål-yrkesföreställningar-könsroller-begreppsbildning. Översikt och problemorientering. Linköpings Universitet, Institutionen för pedagogik och psykologi. (Rapport – Institutionen för pedagogik och psykologi, 107)

Fabricius, T., Malm, I., & Pisilä, S. (2002). Skolinspektörernas årsrapport 2001/2002: *Grundskolan* (Utbildningsförvaltningens rapportserie, nr. 2002:5). Stockholm: Utbildningsförvaltningen.
Ginner, T., Skogh, I-B (1999). *Hur står det till med tekniken*. Linköping, CETIS. [Opubl.].
Gustafsson, C. (1984). Teknik och teknologi i grundskolan. Plan för utvecklingsarbete. Uppsala Universitet, Pedagogiska institutionen. (*Barn och teknik* 4).
de Graaff, E., & Kolmos, A. (2007). History of problem-based and project-based learning. In I de Graaff, E., & Kolmos, A. (red.), *Management of change: Implementation of problem-based and project-based learning in engineering* (s. 1–8). Rotterdam: Sense Publishers.
Kirchner, P. A. (2009). Epistemology or Pedagogy. In Tobias, S., & Duffy, T. M. (Eds.), *Constructivist instruction – success or failure?* New York: Routledge.
Klasander, C. (2010). *Talet om tekniska system – förväntningar, traditioner och skolverkligheter* (Studies in Science and Technology Education, nr. 32). Doktorsavhandling. Linköping: Linköpings universitet.
Lindström, L. (red), Comenius, J. A., Laufhütte, H., & Leinonen, M. (2006). *Orbis Sensualium Pictus*. Stockholm: Stockholms universitets förlag.
Lindström, L. (2007). *Läkekonsten – didaktikens barnmorska*. Programskrift vid konferensen Didaktiken 350 år, Lärarhögskolan i Stockholm.
Lärares utbildning och undervisning, Statskontoret 2007:8.
Riis, U. (1989). *Teknik – för alla?* Linköping, Univ., Tema. (Tema T, rapport 19)
Rousseau, J. J. (1977). *Emìle 1*, *eller Om uppfostran*. Göteborg, Stegeland.
Rätt utbildning för undervisningen. Riksrevisionen 2005:19
Schmidt G., Rotgans J., & Yew E. (2011). The process of problem-based learning: what works and why. *Medical Education 2011*, *45*(8), 792–806
Shymansky, J. A., Hedges, L. V., & Woodworth, G. (1990). A reassessment of the effects of inquiry-Based science curricula of the 60's on student performance. *Journal of Research in Science Teaching*, *27*(2), 127–144.
Sjöberg, S. (1995). Tankar om teknik. I: *Tekniken i skolan*, nr.1,1995. Linköping, CETIS.
Skolinspektionen, *Kvalitetsgranskning*, Rapport 2009:2
Skogh, I-B. (1997). *Studenters tankar om teknik.* Stockholm: Lärarhögskolan i Stockholm. [Opubl.]
Skogh, I-B. (2001). *Teknikens värld – flickors värld: en studie av yngre flickors möte med teknik i hem och skola*. (Studies in Educational Sciences, 44). Doktorsavhandling. Stockholm: HLS Förlag
Skogh, I-B. (2011). Elevsynpunkter på skolans teknikundervisning*.* I: Hansson, S-O., Nordlander, E., & Skogh, I-B. (Red.) *Teknikutbildning för framtiden*. Stockholm: Liber.
Skolverket. (2000). Grundskolan: *Kursplaner och betygskriterier*. Stockholm: Skolverket.
Skolverket. (2011). *Skolverkets lägesbedömning* 2011. Del 1. Beskrivande data. Skolverkets rapport nr 363. Stockholm: Skolverket
Skolöverstyrelsen. (1980). *Läroplan för grundskolan.* Allmän del: Mål och riktlinjer, kursplaner, timplaner Stockholm: Skolöverstyrelsen.
Svensson, M. (2011). *Att urskilja tekniska system – didaktiska dimensioner i grundskolan*. (Studies in Science and Technology Education No 33). Doktorsavhandling. Linköping: Linköpings universitet.
Teknikdelegationen. (2009). Finns teknik och är matte svårt?" Årets niondeklassare svarar. En webbundersökning av svenska niondeklassares intresse för matematik och teknik inför gymnasievalet 2009. *Rapport 2009:2.* Stockholm: Teknikdelegationen
Teknikföretagen. (2005). *Alla barn har rätt till teknikundervisning*!: En rapport om teknikämnet i dagens grundskola. Stockholm: Teknikföretagen.
Utbildningsdepartementet. (1994). *Kursplaner för grundskolan.* Stockholm: Utbildningsdepartementet.
von Wright, G. H. (1983): Determinism and the study of man. In von Wright, G. H (Ed.), *Philosophical papers of Georg Henrik von Wright* (Vol. 1). Practical reason. Ithaka, N. Y: Cornell Univ. Press.

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6. THE NOBLE ART OF PROBLEM SOLVING

A Critical View on a Swedish National Test

INTRODUCTION

Problem solving is the fundament of all applied disciplines in Science and Technology, where theoretical understanding is necessary for knowledge progression and systematic structuring of a task is the key to how to solve the problem. In ancient cultures, *e.g.*, the Babylonian, the Egyptian, and the Greek, a great interest in problem solving evolved (Encyclopedia Britannica 2011; Stanford Encyclopedia, 2011). Later on, the same interest was adopted by philosophers in India and China as well as in the Middle East, and they all had in common to think that problem-solving ability was a goal to strive for. Also in modern times, problem solving is the approach to scientific and technical development. As a result, problem solving is payed great attention in the Swedish school curriculum. Thus, the current Swedish elementary school is supposed to promote the students' learning to listen, discuss, argue, and use their knowledge to

– Formulate and test assumptions and solve problems,
– Reflect on experiences, and
– Critically examine and value statements and relationships

(Skolverket, 1994a, p. 12)

as well as to ensure that each student masters basic mathematical principles and can apply them in everyday life. The same applies to upper secondary school (Skolverket, 1994b, p. 9). Hence, the Swedish school system shows an outspoken ambition to improve the problem-solving ability of the students.

Nevertheless, problem solving is considered by many students as a difficulty that needs to be overcome by memorizing. Students want to compensate the lack of understanding by memorizing rules and procedures and by trying to learn models and patterns (Idris, 2009; Bergsten et al., 1997; Malmer, 1990). They try to find procedures and algorithms and substitute numerals to a formula they learn by heart in order to reach the solution without understanding the real mathematics that is lying behind (Gordon, 1997; Miller, 1992; Hiebert & Lefevre, 1986).

"Show me all the formulas and how to do it. Then I do not need to understand!" This attitude can be described as an algorithmic approach to learning and has very little to do with problem solving. It relies on the idea that repetition of recipes should

I.-B. Skogh & M.J. de Vries (Eds.), Technology Teachers as Researchers, 101–117.

give equally good results regardless the character of the problem, and that tools such as calculators, computers, and handbooks, will solve the problem through magical power. Another behavior that occurs in the context of problem solving is "piloting", where students try to realize how a task is designed in order to find an answer without understanding the real content of the problem (Löwing & Kilborn, 2002). For those students, it is more important to reach an answer by putting together many operations using symbols without a deep understanding of the mathematical task (Oaks & Rose, 1992).

Curcio (1987) gives an anecdote about this.

> One of my favorite anecdotes [...] is a "typical" quotation from a school child to his father: "You see, Daddy: I am very good in arithmetic at school. I can do addition, subtraction, multiplication, division, anything you like, very quickly and without mistakes. The trouble is, often I don't know which of them to use." (Curcio, 1987, p. 39)

Curcio (1987) wants to prevent an algorithmic approach to problem solving by implementing a strategy to improve the problem-solving ability of students. They should rather understand 'why it should be done' than 'what to do'. Several authors (*e.g.*, Curcio, 1987; Bergsten *et al.*, 1997; Hagland *et al.*, 2005) have tried to emphasize the importance of students' capability of interpreting the problem and use various forms of expression. The use of different forms of expression may be a way to overcome the difficulties that students experience in the translation of a mathematical problem from an everyday language into mathematical symbols and reasoning. Other authors (*e.g.*, Pólya, 1957; Malmer, 1990 and 1999; Emanuelsson *et al.*, 1991, 2000; Birch *et al.*, 2000; Sarrazy, 2003) present strategies to facilitate students' work in problem solving. One of the most well-known strategies is found in the classical book by Pólya (1957) "How to Solve It."

The question is whether theoretical approaches to problem solving are easily accessible for teachers or students. There should be an easy method for the noble art of problem solving – a structural method that all students can embrace. In the past, structuring a problem was considered an indispensable prerequisite for success in solving it. This was valid for any problem of mathematical character, regardless of whether it was a purely mathematical task or an application in science, technology, or engineering. It is not absolutely certain that school children or college students of the past agreed with this, but they had no other choice but to abide by their teacher's instructions.

In current Swedish school, the requirement of structuring a problem seems to be outdated. This applies not only to the compulsory school system, but also to college and university education. Many students seem to believe that it is enough to produce a reasonably correct answer to a problem, without actually describing how to get there. Their minds are shifted from the essential task of mathematics, which is reasoning and thinking, to be focused only on producing a solution. Consequently, they give more significance to the answer and not to the process itself (Feinstein, 2006).

Some students also believe that an incorrect reasoning, or reasoning with incomplete or even inaccurate justification, can be considered acceptable as long as the answer is correct.

> Many learners, either naturally or through conditioning, tend to get "obsessed" with the answers to a problem. This can happen to such a degree that the actual process involved in obtaining that answer can begin to seem irrelevant […] when the teacher does not give the student full credit, it may be confronted with a confused look and a response of, "why didn't I get full credit, I got the right answer?". (Feinstein, 2006, p.302)

The question is whether such an approach is acceptable. Teachers need to shift the attention of the students from this algorithmic attitude to mathematical thinking. As a result, students will become "less preoccupied with finding the answers and more with the thinking that leads to the answers" (Anthony & Walshaw, 2009; Fraivillig et al., 1999).

In applied subjects relying on mathematical reasoning, such as science or technical subjects, a theoretical understanding is the absolute basis for knowledge progression. One area of a subject is strictly based on another, and weak basic skills in one area will inevitably lead to failure in the following. Often the reason for an inadequate knowledge base is that the student did not understand what reasoning led to the answer to a question – the main thing seems to be that the produced answer is consistent with the answer given at the end of the text book (Feinstein, 2006).

To systematically structure the task is the key method for a student to sort out what the task is about, what theoretical reasoning can be applied, how to solve the problem based on these theoretical grounds, and, finally, solve the problem in a trustworthy and descriptive way. A good idea is to imagine somebody trying to follow the reasoning without any help other than the description/solution produced by the student. An even better idea is to assume that the reader should be able to repeat the exercise based on the methodology provided in the description by the author. Usually, this is a requirement for the content of scientific articles in science and engineering, *i.e.*, they must be possible to repeat. So why not teach students at an early stage to relate to problem solving in the same way?

TO TELL A GOOD STORY

Most people are fascinated by a good story. Nothing can capture a young child's attention as when someone is telling a story. With sparkling eyes the child falls into the story and eventually becomes a part of it in his own imagination. When the story is over, the call *Again! Please*, *again!* or *One more time!* from the child is inevitable. And if the narrator does not repeat the story word by word, sharp criticism is directed from the young listener.

All educational activities are based on this effect. It is a task for the teacher to capture interest by presenting knowledge in narrative form in an understandable, methodically structured, and trustworthy way. Moreover, if it is possible for the teacher to dress the concept in a fascinating costume, the educational foundation to open the door of learning is obtained.

Knowledge of mathematical or applied nature can also be described for students in this way. It is precisely this ability that characterizes a good teacher! Mathematics and its applications have the advantage of being structured in a logical manner. This feature provides the tools to present problem solving as a good story.

What is Characterizing a Good Story?

Every good story is logically structured in order to gradually capture the interest of the reader and engage the imagination. A good story can be divided in four essential parts: the preamble, the plot, the building of tension, and, finally, the resolution. In addition, two more parts may be added to brighten up the narrative: the prologue and epilogue. Now it is time to connect storytelling to problem solving of a mathematical task. Exactly the same reasoning can be performed in any mathematical application subject in science, technology, or engineering. Let us begin with the four necessary ingredients of a good story.

The preamble. The preamble consists of a narrative interpretation of the task using the problem description. Often it can be a rather wrapped-up task – a task where the key issue and input data are mixed with irrelevant or less important facts. Such descriptions are not unusual in an engineer's everyday life, particularly in consultative work. Generally, a customer or client cannot resolve the core issue, but gives all known facts in an unsorted way. It is thus expected of the consultant to be able to sift data and other information, in order only to use facts that are important and give up irrelevant information. In the preamble, also a discussion of what is relevant and needed to solve the problem is necessary. Irrelevant information is confusing, but one can seldom assume that a task only contains facts essential for the solution of the task.

The plot. The plot is an examination of the information extracted in the preamble. This includes the application of theories – mathematical theories if the task is a purely mathematical task, or science or technical theories and their underlying mathematics if the task is of applied nature. The plot also contains the theoretical/mathematical solution of the problem with all assumptions, statements and disposition.

The building of tension. In order to increase the tension, in the hope of soon being able to see the result of previous intellectual effort, the story now turns into a phase of utilizing the given data. Possibly, additional data have to be retrieved, however not from the problem description but from common sources such as tables and handbooks, manuals, or other publicly available sources. Numeric values are now processed according to the theoretical plan that emerged in the plot. At this stage, there is a risk for many mistakes, which is considered to be part of the tension.

Numerical processing of data may also involve digital tools for the calculations, e.g., calculators or computers. However, the result is never better than the way in which relevant data are processed. To avoid careless behavior and fribble in this process is a challenge many students appreciate. A heartfelt desire to perform correct numerical processing of the data is a great way to increase the tension in this good story.

The resolution. Now to the final touch, i.e., the very resolution of the story. The answer to the mystery is presented and clarified. It is not only to get to the end of the numerical calculations, but also to provide the reader with information about what really is the answer to the problem. The answer should be given with emphasis to the problem by repeating the main issue and giving the answer in that context. Without this punch, the story will lose value and ends up in a haze. The reader should not be forced to scroll back in order to recall the main issue.

Now the story is basically told, but a for quality improvement, two additional steps could be added without much effort: the prologue and the epilogue. The more important of these two steps is the epilogue.

The epilogue. The epilogue is a pure control function. Now the answer should be checked to be reasonable with respect to the main issue of the problem. For example, in a science task a calculation of the size of a germ or a microbe can hardly correspond to the distance between the Earth and the Sun. Without this assessment of reliability in the result of the problem, mistakes will not be discovered by the problem solver and storyteller, but will probably have the reader to ridicule the whole story. Verification of the answer as reasonable for the problem is a fairly simple task that students rarely understand the importance of, or at least use very sparingly. In the epilogue, the storyteller should also ensure that the answer is representative for the problem issued, and if everything that has to be considered is taken into account. This retrospect gives an opportunity for reflection.

The prologue. A prologue should naturally appear first in the story. Here, the task is repeated literally. By means of the prologue, the story not only becomes complete and independent of other texts, but the prologue will also be helpful in the preamble to interpret the problem and make a personal description of the task.

AN EXAMPLE FROM A SWEDISH NATIONAL TEST

In order to clarify the methodology proposed for the noble art of problem solving, an example is selected from a national test in Mathematics A, *i.e.*, the first mathematics course in Swedish upper secondary school. The selected national test is an open document as evidenced by the following statement:

> The Swedish National Agency for Education has decided in 2010–12-07 that Mathematics test A for the spring semester of 2010 will not be reused. (Skolverket, 2011a, p.1)

The test consists of two parts, Part I and Part II. Part I is a so-called calculator-free part with 14 tasks to be solved, of which 12 tasks only require answers without underlying calculations or analysis. The student has 90 minutes available to solve this part of the national test. As an example for the noble art of problem solving task number 14 was chosen, partly because it is text based and partly because it is the only MVG task in Part I. MVG is the highest grade given in the test corresponding to Excellent. Although Part I is called calculator-free, it is allowed to use a calculator when solving task number 14.

An important reason for the choice of task number 14 as an example in this article, is the mathematical character of the problem which is of great importance in most technical subjects. The problem is geometrical and concerns the volume of cylinders. Such a problem, and the methodology of solving it, is easily transferred as part of the content in general technology subject as well as specialized subjects, *e.g.*, mechanics, vehicles, energy systems, heat generation and distribution, water distribution and sewage, building construction, electricity, electronics, and many more. This transfer is even more obvious in university engineering programs.

The student is informed that task number 14 is an investigating task, which is presumed to take longer time than the other tasks of part I. In a box under the task itself in the test booklet, the student is informed about what the teacher must take into account in the assessment. Thus, the following is read by the student in connection with the mathematical problem of task number 14 (translated to English by the authors):

When assessing your work, the teacher will take into account

- what mathematical knowledge you have shown and how well you have performed the task
- how well you have explained your work and motivated your conclusions
- how well you have presented your work. (Skolverket, 2011a, p.2)

The Problem

Task number 14, entitled *The rolled paper*, is described in both text and figures. The text-based part of the task is the following (translated to English by the authors):

A rectangular paper can be rolled up into a pipe (a cylinder) as shown in the figure *(omitted here)*.

A pipe is made from a quadratic paper with the side of 10 cm.

- The pipe diameter becomes 3,2 cm, approximately. Determine the volume of the pipe (cylinder).
- Show that the pipe diameter is 3,2 cm, approximately, when the paper side is 10 cm.
- If the length and width are different in size, two different pipes (cylinders) can be produced depending on how the paper is rolled.

- Using rectangular papers of dimensions 10 cm × 20 cm, two different pipes are produced. Determine the volumes of the two pipes (cylinders).
- Compare these two volumes and determine the relationship between volumes.
- Examine the relationship between the cylinder volumes of papers with other dimensions of the sides. What affects the volume ratio between the high and low cylinder?
- Show that your discovery is valid for all rectangular papers.

(Skolverket, 2011a)

To this information some pictures are given showing different ways of rolling the paper.

Assessment Instructions

The assessment instructions for teachers (Skoverket, 2011b) state that task number 14 should be aspect assessed using a matrix. The starting point must be a positive assessment in which students receive credits for "the merits of the solution and not be penalized for errors and flaws" (p. 4). However, only answers without justification will not be given any credits.

Furthermore, the following guidelines (translated to English by the authors) for the assessment of task number 14 are given:

For full score, a correct solution with acceptable answer or conclusion is required. The presentation must be sufficiently detailed and articulated in such a way that the reasoning easily can be followed. A correct method or explanation of how the task can be solved will get credits, although followed by an error such as miscalculation. If the student also completes the task correctly, more credits are given. (*ibid.*)

Student Work G – A Pattern for Assessment

In the assessment instructions for teachers (Skolverket, 2011b) seven handwritten examples of students' solutions to task number 14 are given, indicating different levels of achieved quality levels. The solutions are named "Student Work" (followed by a subsequent letter of order) to emphasize that this is nothing else but realistic examples of how the solutions may look like. Hence, in this document Student Work A to Student Work G are found. The fact that real student solutions are chosen as examples in the assessment instructions could suggest that these examples do not necessarily represent an ideal image of the solutions for the Swedish National Agency for Education. Nevertheless, these are the only examples of guidance given to the grading teachers.

In this article we have chosen to focus on the student work that will reach the highest quality level and score the grade MVG (Excellent) according to the Swedish National Agency for Education, *viz.* Student Work G. In the following, the information in Student Work G is reproduced (and translated to English where necessary by the authors) (p. 16):

1. $\frac{10}{\pi} \approx 3{,}18 \qquad 1{,}59^2 \cdot \pi \cdot 10 = 79{,}42\,\text{cm}^3$

2. $\frac{10}{\pi} \approx 3{,}2$

3. $\frac{10}{\pi} \approx 3{,}18 \qquad 1{,}59^2 \cdot \pi \cdot 20 = 158{,}85\,\text{cm}^3$

4. $\frac{20}{\pi} \approx 6{,}39 \qquad 3{,}195^2 \cdot \pi \cdot 10 = 320{,}69\,\text{cm}^3$

5. $\frac{320{,}69}{158{,}85} = 2{,}0198\,(\approx 200\%)$

   One of the volumes is twice as large. (Small difference due to decimals)

   $$\frac{\frac{10}{\pi}}{\frac{20}{\pi}} = 0{,}5 \qquad \frac{\frac{20}{\pi}}{\frac{10}{\pi}} = 2$$

6. Paper 30×40 cm

   $\frac{30}{\pi} \approx 9{,}55 \qquad \left(\frac{9{,}55}{2}\right)^2 \cdot \pi \cdot 40 = 2865{,}21\ \text{cm}^3$

   $\frac{40}{\pi} \approx 12{,}73 \qquad \left(\frac{12{,}73}{2}\right)^2 \cdot \pi \cdot 30 = 3818{,}28\ \text{cm}^3$

   $$\boxed{\frac{2865{,}21}{3818{,}28} = 0{,}75 \qquad \frac{30}{40} = 0{,}75}$$

7. Paper $x \times y$

   $\frac{x}{\pi} \qquad \left(\frac{x}{2\pi}\right)^2 \cdot \pi \cdot y = \frac{x^2 y}{4\pi} = V_1$

   $\frac{y}{\pi} \qquad \left(\frac{y}{2\pi}\right)^2 \cdot \pi \cdot x = \frac{y^2 x}{4\pi} = V_2$

   $$\frac{V_1}{V_2} = \frac{\frac{x^2 y}{4\pi}}{\frac{y^2 x}{4\pi}} = \frac{x}{y}$$

   The relation between sides = the relation between volumes

DISCUSSION

Regardless of whether the solutions published in the assessment instructions are produced by students or not, one can conclude that these give signals to the grading teachers about how problems should be solved. The Student Work G is an almost unparalleled taciturn piece of art. This phenomenon is quite typical for students to transfer also to subjects using mathematics in application. In Student Work G, one can only with greatest effort follow the logical structure and reasoning that the student wants to communicate. However, it should be noted that some solutions in the assessment instructions for task number 14 are significantly more extensive in both running text and clarifying figures. Nevertheless, Student Work G should be discussed on the grounds that it is used as an example for the highest quality level by the Swedish National Agency for Education. There is no reason to doubt that the given solution of Student Work G is presenting the mathematical skills that are expected for the grade MVG, *i.e.*, Excellent. It is the communicative element in the student work that is criticized.

The assessment instructions for teachers (Skolverket, 2011b) are providing the following general guideline (translated to English by the authors):

> The report should be sufficiently detailed and articulated in such a way that the reasoning easily can be followed (p. 4).

Furthermore, the assessment instructions for teachers are stating as one of the MVG qualities that the student is presenting a well-structured solution using the correct mathematical language (p. 5). In the assessment matrix to task number 14, this is further emphasized through the following information on structure and mathematical language:

> How clear, precise, and complete the student's report is, and how well the student is using mathematical terms, symbols and conventions (p. 6).

Student Work G – as a Good Story

In the following, each part of the Student Work G is examined, based on the clarification above by the Swedish National Agency for Education, regarding how clear, precise, and complete the student's report is. Since the student has chosen to number the individual mathematical elements of task number 14, so will this analysis follow the chosen numbering. For the sake of clarity, also the original problem description is given element by element marked with the word Problem.

Problem #1:

A pipe is made from a quadratic paper with the side of 10 cm. **Prologue**
The pipe diameter becomes 3,2 cm, approximately.
Determine the volume of the pipe (cylinder).

Solution according to Student Work G:

$\frac{10}{\pi} \approx 3{,}18 \qquad 1{,}59^2 \cdot \pi \cdot 10 = 79{,}42\,\text{cm}^3$

Solution as a good story:

Calculate the volume of the cylinder. **Preamble**
The height of the cylinder = h
Quadratic paper => all sides are equal
The diameter of the cylinder = d, the radius = r

Theoretical expression for the volume of the cylinder: **Plot**

$$V = \pi \cdot r^2 \cdot h \qquad where \quad r = \frac{d}{2}$$

$$\Rightarrow V = \pi \cdot \left(\frac{d}{2}\right)^2 \cdot h$$

Numerically: **Building of tension**

$$d = 3{,}2\,\text{cm},\ h = 10\,\text{cm}$$
$$\Rightarrow$$
$$V = \pi \cdot \left(\frac{3{,}2}{2}\right)^2 \cdot 10 = 80\,\text{cm}^3$$

Answer: The volume of the cylinder is 80 cm^3. **Resolution**
Is the answer reasonable and representative for the problem? Yes! **Epilogue**
Is everything that should be considered taken into account? Yes!

Problem #2:

Show that the pipe diameter is 3,2 cm, approximately, when the paper side is 10 cm. **Prologue**

Solution according to Student Work G:

$\frac{10}{\pi} \approx 3{,}2$

Solution as a good story:

Show that $d \approx 3{,}2\,\text{cm}$ **Preamble**
if $x = 10\,\text{cm}$ (the side of the quadratic paper)
Theoretical expression for the periphery of the cylinder: **Plot**

$$x = \pi \cdot d$$
$$\Leftrightarrow$$
$$d = \frac{x}{\pi}$$

Numerically: **Building of tension**

$$d = \frac{10}{\pi} = 3{,}18 \approx 3{,}2\,\text{cm}$$

Answer: The diameter of the cylinder is approx. 3,2 cm. **Resolution**
Is the answer reasonable and **Epilogue**
representative for the problem? Yes!
Check: $3{,}2 \cdot \pi = 10$ (*cf.* $x = 10\,\text{cm}$)
Is everything that should be considered
taken into account? Yes!
Problem #3:
Using rectangular papers of dimensions 10 cm × 20 cm **Prologue**
two different pipes are produced.
Determine the volumes of the two pipes (cylinders).

Solution according to Student Work G:

$$\frac{10}{\pi} \approx 3{,}18 \qquad 1{,}59^2 \cdot \pi \cdot 20 = 158{,}85\,\text{cm}^3$$

$$\frac{20}{\pi} \approx 6{,}39 \qquad 3{,}195^2 \cdot \pi \cdot 10 = 320{,}69\,\text{cm}^3$$

Solution as a good story:

Two papers 10 × 20 cm makes cylinders A and B. **Preamble**
x_A = 10 cm, h_A = 20 cm
x_B = 20 cm, h_B = 10 cm
where x_A and x_B is the periphery of each cylinder.
Calculate V_A and V_B.
Theoretical expression for the volume of the cylinder: **Plot**

$$V = \pi \cdot r^2 \cdot h \quad where\ r = \frac{d}{2}\ and\ d = \frac{x}{\pi}$$

$$\Rightarrow V = \pi \cdot \left(\frac{d}{2}\right)^2 \cdot h \quad \Leftrightarrow \quad V = \pi \cdot \left(\frac{x}{2\pi}\right)^2 \cdot h$$

Numerically: **Building of tension**

Cylinder A: $V_A = \pi \cdot \left(\frac{x_A}{2\pi}\right)^2 \cdot h_A = \pi \cdot \left(\frac{10}{2\pi}\right)^2 \cdot 20 = 159{,}15 \approx 160\,\text{cm}^3$

Cylinder B: $V_B = \pi \cdot \left(\frac{x_B}{2\pi}\right)^2 \cdot h_B = \pi \cdot \left(\frac{20}{2\pi}\right)^2 \cdot 10 = 318{,}31 \approx 320\,\text{cm}^3$

Answer: The volumes of the cylinders **Resolution**
are 160 cm^3 and 320 cm^3, respectively.

Is the answer reasonable and representative for the problem?	Yes!	**Epilogue**
Is everything that should be considered taken into account?	Yes!	

Problem #4:

Compare these two volumes and determine the relationship between volumes. **Prologue**

Solution according to Student Work G:

$$\frac{320,69}{158,85} = 2,0198 (\approx 200\%)$$

One of the volumes is twice as large.

(Small difference due to decimals)

$$\frac{\frac{10}{\pi}}{\frac{20}{\pi}} = 0,5 \qquad \frac{\frac{20}{\pi}}{\frac{10}{\pi}} = 2$$

Solution as a good story:

Calculate the ratio between cylinder volumes, *e.g.*, $\frac{V_B}{V_A}$ **Preamble**

V_A = 159,15 cm^3 and V_B = 318,31 cm^3 according to Problem #3, taking the more precisely calculated values. **Plot**

$$\frac{V_B}{V_A} \approx \frac{318,31}{159,15} = 2$$

Building of tension

Answer: The ratio between volumes of the cylinders is 2, *i.e.*, one of the cylinder volumes is twice as large. **Resolution**

Is the answer reasonable and representative for the problem?	Yes! However, there is a small uncertainty due to truncated values.	**Epilogue**
Is everything that should be considered taken into account?	Yes!	

Problem #5:

Examine the relationship between the cylinder volumes of papers with other dimensions of the sides. **Prologue**

What affects the volume ratio between the high and low cylinder?

Solution according to Student Work G:

Paper 30×40 cm

$\frac{30}{\pi} \approx 9,55 \qquad \left(\frac{9,55}{2}\right)^2 \cdot \pi \cdot 40 = 2865,21 \text{ cm}^3$

$\frac{40}{\pi} \approx 12,73 \qquad \left(\frac{12,73}{2}\right)^2 \cdot \pi \cdot 30 = 3818,28 \text{ cm}^3$

$$\boxed{\frac{2865,21}{3818,28} = 0,75 \qquad \frac{30}{40} = 0,75}$$

Solution as a Good Story:

Choose some papers of other dimensions **Preamble**
and calculate the volume ratios of the cylinders.
What affects the volume ratio between the high and low cylinder?
Paper 1: 30 × 40 cm **Plot**
Paper 2: 30 × 50 cm

$$V = \pi \cdot \left(\frac{x}{2\pi}\right)^2 \cdot h$$

Numerically: **Building of tension**
Paper 1:

$x_{1,A}=30 \text{ cm},\ h_{1,A}=40 \text{ cm}$

$$V_{1,A} = \pi \cdot \left(\frac{x_{1,A}}{2\pi}\right)^2 \cdot h_{1,A} = \pi \cdot \left(\frac{30}{2\pi}\right)^2 \cdot 40 \approx 2865 \text{cm}^3$$

$x_{1,B}=40 \text{ cm},\ h_{1,B}=30 \text{ cm}$

$$V_{1,B} = \pi \cdot \left(\frac{x_{1,B}}{2\pi}\right)^2 \cdot h_{1,B} = \pi \cdot \left(\frac{40}{2\pi}\right)^2 \cdot 30 \approx 3820 \text{cm}^3$$

$$\frac{V_{1,A}}{V_{1,B}} \approx \frac{2865}{3820} \approx 0,75$$

Paper 2:
$X_{2,A} = 30$ cm, $h_{2,A} = 50$ cm

$$V_{2,A} = \pi \cdot \left(\frac{x_{2,A}}{2\pi}\right)^2 \cdot h_{2,A} = \pi \cdot \left(\frac{30}{2\pi}\right)^2 \cdot 50 \approx 3581 \text{cm}^3$$

$X_{2,B}$=50 cm, $h_{2,B}$=30 cm

$$V_{2,B} = \pi \cdot \left(\frac{x_{2,B}}{2\pi}\right)^2 \cdot h_{2,B} = \pi \cdot \left(\frac{50}{2\pi}\right)^2 \cdot 30 \approx 5968\,\text{cm}^3$$

$$\frac{V_{2,A}}{V_{2,B}} \approx \frac{3581}{5968} \approx 0,60$$

Answer: In cylinders made from different sized rectangular papers, the volume ratio between the high and the low cylinder is 0,75 for a 30×40 cm paper and 0,60 a 30×50 cm paper. It seems to be the same as the ratio between the length of the paper sides. **Resolution**

Is the answer reasonable and representative for the problem? Yes! **Epilogue**

However, the conclusion in the last sentence of the answer is somewhat vague, but is consistent with the answer of Problem #4.

Is everything that should be considered taken into account? Yes!

Problem #6:

Show that your discovery is valid for all rectangular papers. Prologue

Solution according to Student Work G:

Paper $x \times y$

$$\frac{x}{\pi} \qquad \left(\frac{x}{2\pi}\right)^2 \cdot \pi \cdot y = \frac{x^2 y}{4\pi} = V_1$$

$$\frac{y}{\pi} \qquad \left(\frac{y}{2\pi}\right)^2 \cdot \pi \cdot x = \frac{y^2 x}{4\pi} = V_2$$

$$\frac{V_1}{V_2} = \frac{\frac{x^2 y}{4\pi}}{\frac{y^2 x}{4\pi}} = \frac{x}{y}$$

The relation between sides =
the relation between volumes

Solution as a good story:

Show that the presumed conclusion in the answer of Problem #5, i.e., the ratio between volumes is equal to the ratio between sides, is valid for all rectangular papers. **Preamble**

Theoretical expressions: **Plot**

Paper x × y

$$V = \pi \cdot \left(\frac{x}{2\pi}\right)^2 \cdot h$$

$x_A = x,\ h_A = y$

$$V_A = \pi \cdot \left(\frac{x_A}{2\pi}\right)^2 \cdot h_A = \pi \cdot \left(\frac{x}{2\pi}\right)^2 \cdot y = \frac{x^2 \cdot y}{4\pi}$$

$x_B = y,\ h_B = x$

$$V_B = \pi \cdot \left(\frac{x_B}{2\pi}\right)^2 \cdot h_B = \pi \cdot \left(\frac{y}{2\pi}\right)^2 \cdot x = \frac{y^2 \cdot x}{4\pi}$$

The ratio between volumes:

$$\frac{V_A}{V_B} = \frac{\frac{x^2 \cdot y}{4\pi}}{\frac{y^2 \cdot x}{4\pi}} = \frac{x^2 \cdot y}{y^2 \cdot x} = \frac{x}{y}$$

Q. E. D. **Building of tension**

Answer: The proof is showing that the presumed conclusion made in Problem #5, i.e., the ratio between volumes is equal to the ratio between sides, is valid for all rectangular papers. **Resolution**

Is the answer reasonable and representative for the problem? **Epilogue**
Yes! The result is consistent with previous results.

Is everything that should be considered taken into account?
Yes! The proof is stringent.

CONCLUSION

The noble art of problem solving is similar to storytelling. In an educational situation where the teacher goes through a mathematical method or equivalent process of an application discipline in Science or Technology, the reader or listener should become mentally captured and gradually fascinated by the logical sequence which is such a delight in a good story.

In the best case, the storytelling in problem solving is divided into six steps:

- *The Prologue*: Recite the task literally.
- *The Preamble*: The storyteller's own description of the task. Discussion of what information given in the task is relevant for the solution process.
- *The plot*: The mathematical solution, with all assumptions, statements, and disposition, is presented.
- *The building of tension*: Numeric values are processed according to the preamble and the plot.
- *The Resolution*: The answer to the problem is presented and clarified.
- *The Epilogue*: The answer is checked to be reasonable and representative for the problem. A check if everything is taken into account that should be considered.

If this method is consistently practiced by teachers and students in mathematics education at all levels in the school system, it is easily transferred and utilized in any application subject in Science and Technology. In this way, problem solving will be more enjoyable for everybody, and the risk for mistakes in the process is minimized. Hopefully, the storytelling method in problem solving will lead to an enhanced interest among young people of higher education in Mathematics, Science, and Engineering.

REFERENCES

Anthony, G., & Walshaw M. (2009). Characteristics of effective teaching of mathematics: A view from the West. *Journal of Mathematics Education*, December 2009, *2*(2), 147–164.

Bergsten, C., Häggström, J., & Lindberg, L. (1997). *Algebra för alla.* Nämnaren TEMA. Gothenburg: NCM, University of Gothenburg.

Björk, L. E., Brolin, H., & Munther, R. (2000). *Matematik 3000 – Gymnasieskolan Grundbok*, *kurs A / Matematik tretusen*. Stockholm: Natur och Kultur.

Curcio, F. R., (1987). *Teaching and learning: a problem-solving focus; an anthology*. National council of teachers of mathematics. Reston, VA.

Emanuelsson, G., Johansson, B., & Ryding, R. (1991). *Problemlösning*. Lund : Studentlitteratur.

Emanuelsson, G., Wallby, K., Johansson, B., & Ryding, R. (red.) (2000). *Matematik ett kommunikationsämne*. Nämnaren TEMA, Gothenburg: NCM, University of Gothenburg.

Encyclopedia Britannica Academic Edition. (2011). *Problem solving in Egypt and Babylon*. Available: http://www.britannica.com/EBchecked/topic/14885/algebra/230957/Problem-solving-in-Egypt-and-Babylon.

Feinstein, S. (2006). *The Praeger handbook of learning and the brain* (Vol. 2). Greenwood Press, USA.

Fraivillig, J., Murphy, L., & Fuson, K. (1999). Advancing children's mathematical thinking in Everyday Mathematics classrooms. *Journal for Research in Mathematics Education*, *30*, 148–170.

Gordon, S. (1997). *Functioning in the real world: A precalculus experience*. New York: Addison Wesley.

Hagland, K., Hedrén, R., & Taflin, E. (2005). *Rika matematiska problem: Inspiration till variation*. Stockholm: Liber.

Hiebert, J., & Lefevre, P. (1986). Conceptual and procedural knowledge in mathematics. An introductory analysis. In J. Hiebert (Ed.), *Conceptual and procedural knowledge: The case of mathematics* (pp. 1–27). Hillsdale, NJ: Erlbaum.

Idris, N. (2009). Enhancing students' understanding in calculus. *International Electronic Journal of Mathematics Education*, *4*(1), February 2009.

Löwing, M., & Kilborn, W. (2002), *Baskunskaper i matematik för skola*, *hem och samhälle*. Lund: Studentlitteratur.

Malmer, G. (1990). *Kreativ matematik.* Solna: Ekelunds förlag.

Malmer, G. (1999). *Bra matematik för alla. Nödvändig för elever med inlärningssvårigheter*. Lund: Studentlitteratur.

Miller, L. D. (1992). Begin mathematics class with writing. *Mathematics Teacher*, *85*(5), 354–355.

Oaks, A., & Rose, B. (1992). *Writing as a tool for expanding student conception of mathematics*. Paper presented at the 7th International Congress on Mathematics Education. Working Group 7: Language and Communication in the Classroom, Quebec.

Pólya, G. (1957). *How to solve it*, Princeton University Press.

Sarrazy, B. (2003). *Le problème d'arithmétique dans l'enseignement des mathématiques à l'école primaire de 1887 à 1990*. Carrefours de l'éducation. n°15. janvier-juin 2003.

Skolverket (1994a). *Läroplan för det obligatoriska skolväsendet*, *förskoleklassen och fritidshemmet Lpo 94*. Stockholm: Fritzes.

Skolverket (1994b). *Läroplan för de frivilliga skolformerna*, *Lpf 94*. Stockholm: Fritzes.

Skolverket (2011a). *Gymnasial utbildning – Matematik A*. Available: http://www.skolverket.se/sb/d/2919/a/16428, redirected to http://www.prim.su.se/matematik/kurs_a/prov_vt2010/Del1.pdf.

Skolverket (2011b). *Gymnasial utbildning – Matematik A*. Available: http://www.skolverket.se/sb/d/2919/a/16428, redirected to http://www.prim.su.se/matematik/kurs_a/prov_vt2010/BedAnvDel1.pdf.

Stanford Encyclopedia of Philosophy (2011). *Aristotle and Greek Mathematics*. Available: http://plato.stanford.edu/entries/aristotle-mathematics/supplement4.html

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JOAKIM SVÄRDH

7. TO USE OR NOT TO USE A TEACHER SUPPORT PROGRAMME

A Study of What Characterises Swedish Schools that Apply the Inquiry-based Teacher Support Programme, *NTA*

INTRODUCTION

The use of inquiry-based educational programmes (IBSE) is a growing phenomenon in many western countries. There are a number of such programmes available to teachers/schools in the US and Europe. One European example is the S-Team project. This project promotes IBSE or 'investigative' methods when teaching science and was created to 'change the way science is taught in schools across Europe and beyond' ("S-TEAM Science Education," n.d.). In 1997, The Royal Swedish Academy of Sciences – KVA imported a similar development programme for primary and lower secondary schools from the US, called Science and Technology for Children Concepts Program (STC). The STC is an inquiry-based science education (IBSE) programme, encompassing both teaching materials and teacher training programmes. The general motivation for using STC and similar programmes is the idea that '*inquiry-based learning environment encourages opportunities for children to learn science*' (Cuevas, Lee, Hart, & Deaktor, 2005).

Together with the Royal Academy of Engineering Sciences (IVA), KVA developed a Swedish version of the STC programme, called Natural Sciences and Technology for All (NTA). The NTA participates in an EU-founded project called Fibonacci and also refers to their homepage for the scientific background of NTA. Fibonacci claim that IBSE help children: "The reason for emphasising inquiry-based education in the Fibonacci project is that, carried out effectively, it facilitates understanding" ("The Fibonacci-Project," n.d.). In spite of modest promotion and advertising, the NTA programme has spread widely across the country.

In the spring of 2010, NTA was used in about one third of Sweden's 290 municipalities, corresponding to 6700 teachers and 96000 pupils ("Naturvetenskap och teknik för alla – NTA," n.d.). As there are about one million pupils in compulsory school, this means that 10% of the pupils are participating in the NTA programme. The question posed in this article is whether the schools that have adopted NTA systematically differ from schools that have not adopted NTA and, if so, what the differences and possible implications of these potential differences are. The method used to address these questions is somewhat unusual in 'traditional' technology

I.-B. Skogh & M.J. de Vries (Eds.), Technology Teachers as Researchers, 119–142.

education research in Sweden (and possibly internationally). This is a quantitative study presenting findings based on collected data from official databases and a questionnaire (NTA coordinators).

Sweden has a long tradition of collecting information about its citizens. Already in 1686, a national provision for all citizens to be 'church recorded' was launched (Skatteverket, n.d.). A record of each individual's name, parents' and siblings' names, marital status, occupation, birth and death, baptism (including witnesses) and confirmation was to be recorded. Also, education-related data was recorded in the form of records of how the citizens performed in the examinations on parts of the Bible regularly conducted by priests. These early 'databases' are still available. Through the centuries, the collection of data on the population continued and we now, through the Statistics Sweden ("Statistics Sweden – SCB," n.d.) and other official databases, have worldwide unique access to information about almost everything that happens in the lives of Swedish citizens. Taking advantage of the rich information on individuals and groups that these data provide in an educational research project is the challenge that I have adopted in the present study.

AIM AND RESEARCH QUESTION

The use of inquiry-based educational programmes is a growing phenomenon in Sweden. In order to determine future initiatives in science and technology education (S & T), we obviously need to evaluate existing investments. Due to the relatively large number of NTA users, substantial resources are put towards this particular teacher support programme. Today we know very little about who the users are, what kind of schools has chosen to participate and what kind of schools have chosen not to. This paper aims at illuminating these questions. The following research questions are addressed:

1. What socio-economic indicators characterise schools using the NTA programme?
2. How is the spread of the NTA programme distributed (a) across the country and (b) within municipalities?
3. What implications may the answers to research questions 1 and 2 have on the use of NTA and similar educational programmes?

BACKGROUND

'Kit-based' Programmes in the US

In the US, there is a long tradition of inquiry-based educational programmes in science and technology. These programmes, also called 'kit-based programmes' (teaching material is provided in boxes with supplies and instructions for exercises and experiments), are based on constructivist theories. Schwartz, Lindgren, and Lewis (2009) describe constructivism as *". . . a theory of knowledge growth and life-long development built on a philosophy of pragmatism"* and in formal education it is often, *"used as a label for sense-making activities including discovery*, *inquiry*, *exploration and hands-on learning"*.

The first generation of inquiry-based programmes was developed in the 1960s and 1970s. The second generation has its origins in the National Science Education Standards (1996) developed in the US in 1995 by the National Research Council (NRC) and the American Association for the Advancement of Science (AAAS, the publisher of the research journal, *Nature*). The National Science Resources Center (NSRC) developed the Science and Technology for Children (STC) programme in order *'to improve the learning and teaching of science for all students in the United States and throughout the world'*.

The STC programme could be described as a system for school improvement. In addition to the teaching materials, it includes leadership support for school leaders, implementation of teaching materials support and teacher training. The programme/material is organised into two main parts. One part (Science and Technology for Children, STC) addresses teaching from pre-school up to the sixth grade (K-6), and the other part (Science and Technology Concepts for Middle Schools, STC/MS) addresses teaching in grades 6–8. The latter is supplemented with further reading material for K-8 and an instructional video for the teacher.

The STC boxes—32 altogether—are structured by subject in progressive order of age. The subjects are organised under the following themes/headings: 'Life Science, Earth Science, and Physical Science & Technology'. Since the STC programme is a commercial product, there are other similar competing systems running in the US, e.g. the Full Option Science System (FOSS) that was developed by Berkeley University. The STC programme has also spread to other countries. According to Sally Goetz Shuler (personal communication, September 10, 2012), Senior Advisor at Smithsonian Institution, STC has been officially used in Mexico, Chile, Panama, China, Thailand, Sweden and Germany. She claims that there are probably more countries that are using STC without having a signed agreement. Similar systems are reported to be in use in Finland, England and New Zealand (Sally Goetz Shuler, personal communication, September 11, 2012).

NTA—The Swedish Version of STC

The Swedish version of the STC programme, i.e., the NTA programme, is mainly used in primary and secondary schools. Just like the STC, the NTA programme is presented as a system for school improvement (teacher support material, teacher training, teaching materials/boxes) (Schoultz, 2012). Teachers can choose from 22 different themes. Each theme/box includes working materials and thematic instructions. Before using a box, teachers are required to attend a one-day training course regarding the use of the box in question, and afterwards there is a follow-up meeting. A box is commonly used in a class for a period of one semester. The responsibility for deliveries of equipment and supplies lies upon regional and local NTA coordinators working at the municipality level.

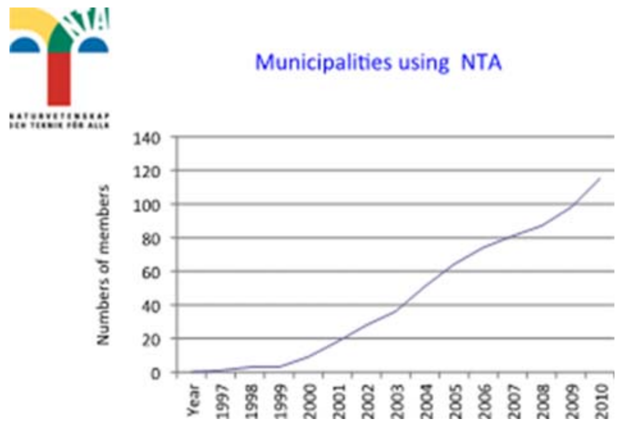

Figure 1. NTA municipalities' yearly growth (NTA, 2011).

The development and distribution of the NTA material is headed by the KVA, with support from the IVA. The KVA has translated the material and adapted it to the Swedish curricula. Today, NTA is increasingly used in municipalities and schools across the country. The average growth is about 10 municipalities and 10,000 pupils every year.

Joining the NTA Programme

Joining the NTA programme is a multi-step process. The first step is to decide whether to join the NTA organisation or not. This decision can be made by a municipality or by a private school.[1] Joining NTA requires an entrance fee of €1700. In comparison, no such entry cost is demanded in the US context. It should also be noted that while the entry cost is fixed in terms of Euro, the cost per school may differ. In a large municipality with many schools joining the NTA, the entry cost per school may be quite small, whereas a private school joining 'separately' will have to cover the whole cost by itself.

When a municipality joins the NTA, the next step in the process is to decide in which schools the material should be used (e.g., in all or only in some of the schools in the municipality). This decision could be made at the municipal level or locally by school principals or individual teachers. The use of each box/theme generates a fee of about €200 per box. In addition, a fee of about €2.5 is charged per student, semester and box. In some cases, the fees are paid by the municipality and in other cases by the local schools.

AREA OVERVIEW

There is extensive literature available about the use and effects of STC and its competitors. The STC homepage has a short list of research, but a more comprehensive updated list covering more topics (including STC) could be found at FOSS research database ("Research on FOSS and Ongoing Projects," n.d.). In comparison, the literature about the use and effects of working with the NTA programme are limited ("NTA – Rapporter och utvärderingar," n.d.). In line with the research question addressed in this article, the below overviews of research about the STC and the NTA programmes focus on *the users* of the respective programmes. Specifically, the characteristics of the users (schools) are contrasted with the characteristics of the non-users.

Research about STC in USA

Socio-economic and geographical spread. A number of documented attempts to apply STC in areas/schools with poor learning and teaching conditions can be found in the literature. For example, a five-year study describes how the Imperial Valley (a rural, low-income, immigrant-dense county in Southern California) managed to go from very poor performance to getting one of the highest test results in its annual "Achievement Test" through the consistent use of 'kit-based' education. The tests were conducted in year four and six with 1200 children participating in the study (Klentschy, Garrison, & Amaral, 1999). In a small experimental study, (Cuevas et al., 2005) similarly show how the gap between different social groups are smoothed out with the help of 'inquiry-based' teaching and in-service training. A pre- and post-test showed that the largest effects were found among traditionally low-performing groups. While the number of participants in this study was very low ($n = 25$), the results were confirmed by a large study—8000 pupils in grades 6-8—in Detroit's inner city schools with mostly poor and coloured pupils (Marx et al., 2004).

There is, unfortunately, not much information about how the use of STC and other inquiry-based materials has spread in the US. Numbers relating to geographical distribution and socio-economic characteristics of the users of STC are hard to find. Most reports do not concern the national level. Instead, they cover local initiatives, often aimed at bridging socio-economic gaps, at a state or district level. The yearly reports about STC on NSRC's homepage are not updated (the last one published is from 2007). While obviously selective, the examples provided on this homepage nevertheless indicate that the use of STC is quite extensive in some states ("NSRC Annual Reports," n.d.).

> Today, about 80% of Washington State students, 100% of Delaware public school students, and large percentages of Pennsylvania, Alabama, South Carolina, and North Carolina students are benefiting from research-based science education based on the NSRC leadership development programs and the applications of the NSRC Systemic Science Education Reform Model.

Whereas no study has directly addressed the question of why some states/districts have adopted the STC while others have not, discussions linked to possible reasons can be found in the literature. At a general level, (Schmidt, McKnight, & Raizen, 1997) point to poor curriculum structure, textbooks and instructional approaches as probable underlying causes. These conjectures are partially supported by a study of science teachers in eighth grade that reported that 54% of them rely primarily on texts (National Education Goals Panel, 1995). Furthermore, in another study, study, Wenglinsky (2000) ascertains that reading textbooks is the most frequent homework used 77% of the time.

Quality of teaching staff. The National Commission on Science and Mathematics Teaching for the 21st Century (2000) points at the quality of the teaching staff as an important reason for pupils' achievements in the S & T subjects. This problem is, according to Lee & Luykx (2006), aggravated by the educational system having difficulties in dealing with the diversity of the K-12 pupils. Some reasons for this are identified by Lynch (2000):

> The less skilled and experienced the teachers, the more they are likely to rely upon textbooks, and such teachers are concentrated in school districts where there is both more student diversity and poverty. Therefore, diverse learners are most apt to be at the mercy of poorly written texts and curriculum materials, and their teachers are least able to compensate for these weak materials due to lack of content knowledge and pedagogical skills.

Organisations like the NRC and the AAAS have been actively promoting the use of scientifically approved material and have encouraged the decision makers to take action against perceived achievement gaps. As a means to achieve this, they have published a number of books intended to help decisions makers to decide on what materials and methods to use. Some examples of such publications found on the National Academies Press homepage[2] are:

1. Expanding Underrepresented Minority Participation: America's Science and Technology Talent at the Crossroads (Committee on Science et al. 2011)
2. Ready, Set, SCIENCE!: Putting Research to Work in K-8 Science Classrooms Selecting Instructional Materials: A Guide for K-12 Science (Michaels, Shouse, & Schweingruber, 2007)

With respect to messages conveyed by these publications, and the spirit of the recommended, or promoted, approaches, Marx et al., (2004) note that:

> Science education standards established by American Association for the Advancement of Science (AAAS) and the National Research Council (NRC) urge less emphasis on memorizing scientific facts and more emphasis on students investigating the everyday world and developing deep understanding from their inquiries. These approaches to instruction challenge teachers and students, particularly urban students who often have additional challenges related to poverty.

Which schools choose kit-based programmes? Several studies (Bybee, 2003; Cuevas et al., 2005; Marx et al., 2004) suggest that the decision to join the STC programme is taken by the school boards at the district or state level. The STC material is sold by exclusive distributors in competition with vendors supplying similar products. The price for an STC theme, encompassing one class and one semester, varies between €220 and €1040. Subsequent themes are less expensive—about a third of the cost of the first theme. Thus, a large part of the STC activities are conducted on a commercial basis. In this respect, it differs from the corresponding Swedish programme, which is carried out by not-for-profit organisations.

Research on NTA in Sweden

According to Biriell & Josefsson, (1998), the introduction of the NTA programme in Sweden is a concequence of contacts between KVA and NSRC in the US. In 1992, information about the development of STC in the US reached the Information Secretary at KVA through personal contacts, resulting in KVA getting free access to the material. Early in this process, IVA was invited to join the project.

The early experiences of the NTA are described in several reports (Gisselberg, 2001; Schoultz, Hultman, & Lindkvist, 2003; Schoultz & Hultman, 2002). According to these studies, the participating teachers are mainly satisfied with the information and training provided and with the NTA organisation set up by the KVA. Pupils are, according to the teachers, perceived as enthusiastic about working with the boxes. In Schoultz et al., (2003) it is however noted that it takes dedicated and skilled teachers to exploit the development potential of the material.

According to Gisselberg (2001), many of the ‘first generation’ NTA teachers in his study state that they have sufficient content knowledge in biology to successfully instruct in the biology themes. Their confidence regarding content knowledge in the physics, chemistry and technology themes is considerably lower. The findings from this study indicated that minor adjustments to the material/boxes were required (e.g., simplifing experiments considered too complex). Findings also show that many of the early adopters of the NTA programme were teachers with some kind of scientific background.

In a survey of 700 teachers, Ekborg & Lindahl (2006) evaluated the teacher training parts of the NTA programme. The aim of this study was to explore possible differences regarding the use of NTA among teachers with different educational backgrounds. Findings show that teachers with less education in science tend to follow the provided instructions more thoroughly than their more experienced colleagues. The science and technology educated teachers also adapt to the themes more easily than the teachers lacking this background.

In an extensive study, Anderhag & Wickman (2006) evaluated in what way and to what extent teachers’ ability to support students’ conceptual understanding and language development is enhanced by the use of NTA. Findings show that the use of NTA increases students’ verbal linguistic ability and familiarity with scientific concepts. This study was followed up with a quantitative study (interviews with 80 students in grade 6) the following year (Anderhag & Wickman, 2007). Findings from this second study show that NTA students achieve a deeper knowledge in the science subjects compared to a control group. This was especially true for the low – and high-performing students. The results differ somewhat between the sexes in the sense that the boys reportedly perform better than the girls.

In a report from Teknikföretagen, (2005), the teachers (n = 354) are reported to have poor knowledge about the technology curriculum. Approximately 30% of the informants do not think that the demands put on them by the national school authorities regarding technology education are met at their 'own' school. The situation is increasingly worsening in the lower years of compulsory school.

There is no record of any previous study exploring the question of how NTA is distributed and spread across Sweden. The typical 'NTA user' has not been examined either. It is time to do so now.

DATA SOURCES AND METHODS

This is a descriptive statistical study. Data is compiled and analyzed based on descriptive statistical methods (Moore, McCabe, & Craig, 2007). Figures and percentages are accordingly the units in which the context studied is reflected and presented. Some people perceive statistical data as being both difficult and incomprehensible. To me, it is a powerful tool in my research. There are however issues to consider. One issue of importance is the question of how to present my research work and the research process (methods used, data collected, the analysis and the results) in an efficient way.

I have, after considerable consideration, chosen to adapt my presentation to the traditions of statistical research. Accordingly I have restrained myself from extensive philosophical reflections regarding how to explain and understand the findings. In the presentation of the results below, there is therefore a mix of methodical and analytical considerations presented together with reported results. I gently ask the reader to be patient with this untraditional (compared with 'traditional' quantitative educational research) attempt to make the presentation both readable and understandable.

Under the heading 'data sources and methods', this study therefore provides only brief information about these issues.

The empirical analysis in my study is based on two different kinds of data:

Survey. In the *first* phase of the study, a survey directed at the so-called NTA coordinators—one in each of the 96 municipalities that used NTA—which I conducted myself, was performed by mail or by telephone. The primary purpose of this survey was to establish which schools had participated in the NTA programme and to what extent they had used the NTA material.

Register data. The outcome of the classification (NTA or non-NTA schools) is matched with register data.

Two different public databases compiled by the state agency Statistics Sweden (SCB) have been used:

- The Swedish Association of Local Authorities and Regions (SALAR) database, which contains socio-economic data and school results at the *municipality level* (n = 290).
- The Swedish School Authorities tool for Local Correlation Analysis (SALSA) database covering variables with sociocultural information and subject grades at the *school level* (n = 1400).

Both of these sources originate from the census covering all Swedish schools and municipalities and are commonly used by policymakers, media and in educational research (Hansen & Lander, 2009).

The collected data has been organised by means of the database program FileMaker Pro and analyses were made with SPSS (Statistical Package for the Social Sciences). The analyses consist of comparisons of means and variation over time (five and 11 years) and across subjects.

Ethics. The study follows the ethical guidelines of the Swedish Research Council (Vetenskapsrådet). All numbers come from official sources available to everyone. The survey made with all of the NTA coordinators was sanctioned by NTA and therefore not really voluntary. The coordinators on the other hand seemed quite enthusiastic to participate. The single schools are not possible to identify. Due to the statistical nature of this study, findings will be reported in a slightly untraditional way, at least compared to most qualitative, educational research.

RESULTS

The results are organised in the following way: I start with the results from the survey of the NTA coordinators. This is followed by diagrams describing differences in the use of NTA, first at the municipality level and then at the school level.

Categorisation of NTA Municipalities and Schools

The categorisation of NTA municipalities and schools is a key aspect of this study. It makes it possible to conduct different kinds of comparative analyses. The categories themselves are dependent on my contacts with NTA and their coordinators. Their definitions are based upon what was believed possible to find out at that moment.[3]

The definitions are made at the municipality and school level. The binary category *NTA* or *not-NTA* at the municipality level was reported from NTA support organisation NTA Production and Service and is based on data from 2009. All of the 290 municipalities belong to one of the categories.[4]

To be able to describe the NTA at the school level, I had to know which ones had joined the NTA programme and how much they had used this education material. The best knowledge about this is found among the NTA support organisation, more specifically, among the NTA coordinators. The coordinators administer the schools in ‘their’ municipality and do all the practical and administrative work.

To get in contact with the NTA coordinators, I got help from the head of NTA production and service who kindly supplied addresses, mail addresses and telephone lists. The first contact with the NTA coordinators was made through an e-mail I sent with help from NTA production. In the e-mail, I explained what I wanted to achieve and I also attached a short survey form in which the coordinators filled in the names of 'their' schools and noted which of the five categories described below were applicable to their school/schools. They also answered a number of questions regarding self-selection and financing. The answers arrived mostly by e-mail but also as letters and occasionally via phone calls. It should be noted that the accuracy of the local and regional documentation regarding the use of NTA varies. The information provided from the NTA coordinators therefore may, to some extend, differ from the actual conditions.

NTA at the municipality level. Figure 2 illustrates the geographic location and numerical change of the NTA municipalities in Sweden from 1997 until 2011. The growth is about 10 municipalities each year. The maps clearly illustrate that the NTA is not evenly spread across Sweden. The use of NTA is concentrated around some of Sweden's bigger cities in the north. It is also quite clustered. It is not common in the most south and westerly parts of Sweden. The NTA programme has been employed in only one of the Swedish metropolitan areas—Stockholm. The other two—Göteborg and Malmö—are not represented (except for a handful of private schools).

Register Data

The first statistical source to be added to the data received from the survey was data from the Swedish Association of Local Authorities and Regions (SALAR). They

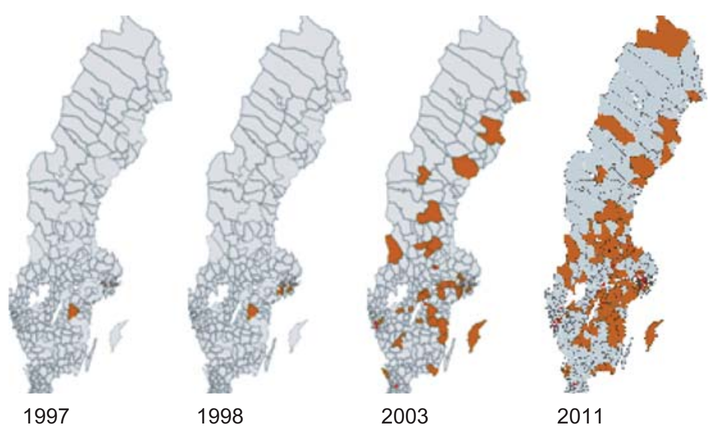

Figure 2. NTA municipalities (NTA, 2011).

publish a report series called “Open Comparison” in which they compare different aspects of municipalities. It contains several school variables aggregated to the municipality average. The information is available as PDF files on their homepage for the years 2007–2011. The underlying data is aggregated from Statistics Sweden (SCB) register data, covering all individuals living in Sweden.

The information in the SALAR data files was transferred to a database and combined with my categories of NTA users.

In SALAR, the 290 Swedish municipalities are divided into “nine categories on the basis of structural parameters such as population, commuting patterns and economic structure”. The categories are described in detail in Appendix 1.

Municipality key numbers. What characterises the NTA municipalities compared to the non-NTA municipalities? I will present both variables that show differences between the two groups, and other variables that point at no or small differences. The values are rounded off and they mostly refer to an average over at least five years.

The average NTA municipality has a population of 45,550 with 80% of the inhabitants living in the central town. The non-NTA has 26,700 inhabitants with 71% living in the central town.

The median net income over four years is different with the inhabitants in NTA municipalities earning 178,500 SEK, compared to the non-NTA inhabitants earning 172,700 SEK (see Figure 3).

The average NTA municipality spends about 72,870 SEK per student and year compared to the non-NTA that spends about 73,450 SEK.

Of all teachers, 86% take the university exams in both NTA and non-NTA municipalities. The number of children per teacher is also equal, about 9.5.

Performance. The report also contains results on different kinds of school tests and grades. The results come from the SALSA database (more about SALSA in *NTA at the school level*). Private schools are not included. The variables are extracted to municipality level.

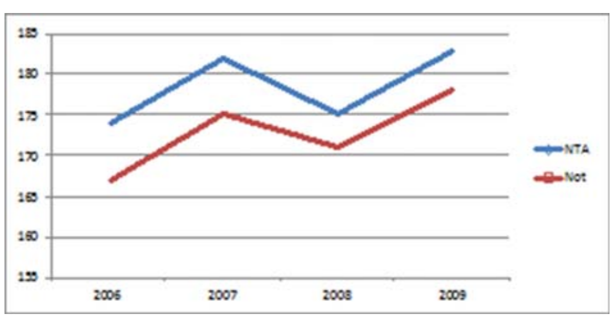

Figure 3. Median net income in thousands of SEK according to the SALAR database.

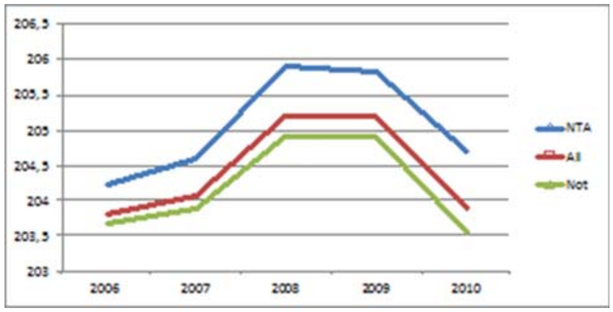

Figure 4. Merit value model calculated according to the SALAR database.

Merit value, model calculated. This diagram shows the average merit value for the municipalities that use NTA, the municipalities that do not use NTA and finally for all municipalities. It is the sum of every student's final grades divided by the number of students in the municipality. It is limited to the students that got their final grades in at least one subject. The maximum value is 320 points.

The values are controlled for sociocultural differences, the proportion of boys, parents' formal education and immigrant background. The differences between the groups are very small and almost constant over the years. While the differences are small indeed, it can be noted that when the controls are included, the average performance of NTA municipalities is consistently higher than that of non-NTA municipalities, which is not the case in the absence of the controls. This indicates that the NTA municipalities differ from the non-NTA municipalities with respect to the controls.

As a summary of these numbers, you could say that the typical NTA municipality is much larger in population and less rural, their inhabitants earn more but school spending is lower. The levels (86%) of the teachers' education are the same between the groups and so is the number of children per teacher (9.5). Grades expressed as merit values in year nine show very small differences.

The differences that can be seen are mostly connected to the differences between the cities and the rural part of the country. The majority of the NTA municipalities belong to the large cities and their suburbs. The non-NTA municipalities in general are located in the more rural part of the country.

Let us look at the next level: the schools. What is specific to the NTA schools?

NTA at the School Level

Sweden had about 4950 schools in 2009, of which about 1400 had children in the final year (year nine) of compulsory school (available data from SALSA concerns year nine, n = 1421). The numbers vary a bit over the years as some schools close down and new ones appear. The NTA groups from the survey of NTA coordinators are used to divide the 1421 schools as follows:

NTA groups definitions:

1. The school participated in the NTA programme with all of its pupils up to sixth grade, implying that the average pupil participated for three-four semesters
2. The school participated in the NTA programme with all of its pupils up to sixth grade, and also for some time when the pupils attended grades seven-nine
3. The school partly participated in the NTA programme, such that some pupils participated while others did not
4. The school did not participate in the NTA programme
5. No information about whether the school participated or not

The numbers of schools in each category are distributed in this way.

NTA group's distribution:

1. 72 schools	5.1 %	Uses NTA
2. 24 schools	1.7 %	NTA 7–9
3. 90 schools	6.3 %	Mixed
4. 1,133 schools	79.7 %	Not using
5. 102 schools	7.2 %	Unknown

First group (1)	schools that have used NTA "a lot" during several semesters, the devoted ones. The pupils in this group have used NTA for three or four semesters mostly in years one to six.
S*econd* group (2)	a small group of schools that use NTA in the same way as the first group but they also use NTA in years seven to nine.[5]
Third group (3)	a mixed group of schools for which the coordinator does not have information about the extent of the use of NTA, or where the students partly come from other schools, some of which have used NTA and some of which have not.
Fourth group (4)	schools that have *not* used NTA.
Fifth group (5)	schools that have no information about whether they have used NTA or not

The first groups, *one* and *two*, together contain 96 schools. They represented about 7% of the sample, and it is possible to compare them to non-participating schools both inside and outside of the municipality. They are named *NTA schools* in this paper.

The schools that did *not* use NTA made up the majority (1133 pcs or about 80% of the total number of schools). Of these 1133 schools, 256 were located in municipalities that had chosen to join the NTA programme. This sub-group makes it possible to conduct comparisons within the municipality, eliminating the need to control for differences between municipalities. They are named *non-NTA schools* in the SALSA comparison in Figure 7. About 190 schools, or almost 13.5%, had either a mixed or unknown "exposure" to the NTA programme and thus could not be used in this study.

The survey worked as a tool to divide the municipalities and schools into different groups. The groups will now be used to look at statistical data.

SALSA

The second statistical source with background information comes from the Swedish School authorities. Their SALSA-database covers variables with sociocultural information and subject grades at the school level. Both public and private schools are included. SALSA (School Authorities Tool for Local Correlation Analysis) is used for comparing school achievements with the possibility of compensating for sociocultural differences in children's environment. The information is published on their web page and covers data from the final year (15–16-year-old pupils) in all Swedish compulsory schools from 1998 to 2010. The SALSA-database makes use of aggregated data from Statistics Sweden's register data, covering all individuals living in Sweden. More details about their data and its limitations are described on their home page.[6]

Variables Predicting Scholastic Achievements

The following variables are published: proportion of boys, proportion of children born abroad, proportion of children with both parents born abroad while the child is born in Sweden, parents' formal education, the school's average of the merit values of its students and, finally, estimated merit values when controlling for the first four variables. These four variables seem to be some of the strongest predictors of scholastic success in several studies conducted by, for example, the Swedish School authorities and municipalities (*KOMMUT*, 2010; Skolverket, 2009).

NTA and Non-NTA Groups

The schools in the groups *NTA* and *non-NTA* are both situated inside NTA municipalities. This means that the two groups added together do not add up to *all schools*. The purpose behind this break-up is to conduct within-municipality comparisons, eliminating the need to control for differences between municipalities.

Parents' formal education. The first variable in comparing schools is parents' formal education. It is composed of the average of both biological parents' highest formal education. The maximum value is three. Value one corresponds to graduating from compulsory school, value two upper secondary school and three is at least one semester of university studies. The value is computed as the average from all the pupils' parents in the school.

The histograms below that cover the years from 1999–2010 show the NTA schools and *non-NTA schools* ***inside*** *the NTA municipalities.*[7] To the right, it shows *all the schools* in Sweden. The distribution for the NTA schools is more peaked and compressed; it has very few values above 2.5 (see the arrows in the diagrams).

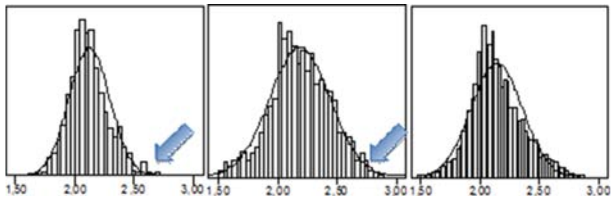

Figure 5. NTA schools Non-NTA schools All schools Parents' formal education distribution according to the SALSA database.

The non-NTA schools in contrast have a non-negligible share of schools where the average value of parents' education is 2.5 or higher.

The means, standard deviation and distribution are as follows:

Group	*NTA*	*Non-NTA*	*All*
N (schools)	1045	2637	15343
Mean	2.12	2.19	2.14
Std. Deviation	0.174	0.217	0.254

When the numbers are presented on a timeline, the differences are clear. The schools that are not using NTA clearly have a higher average of parents' formal education. The difference of about 0.07 (3.3%) is small but almost constant over the years. The overall level of education for all groups is rising slowly.

Merit values. The second SALSA variable useful for describing differences is the merit value, which is the school's average of the sum of the merit values of the students' grades. In each of the 16 best subjects, the pupils get points by grade. Pass (G) is 10 p, Pass with distinction (VG) is 15 p and Pass with special distinction (MVG) is 20 p. The maximum value is 320 p. Only pupils with at least grades in one subject are included. Both private and public schools are present.

The histograms below that cover the years from 1999–2010 show the *NTA schools* and the *non-NTA schools* ***inside*** *NTA municipalities.* To the right, it shows all schools in Sweden. The distribution for the NTA schools is more peaked and compressed; it has very few values between 250 and 300 p. The non-NTA schools' distribution is wider and they produce higher means with more values above 250 p (see the arrows in the diagrams).

The means, standard deviation and distribution are as follows:

Group	*NTA*	*Non-NTA*	*All*
N	1045	2637	15343
Mean	204	211	207
Std. Deviation	16.5	25.3	19.6

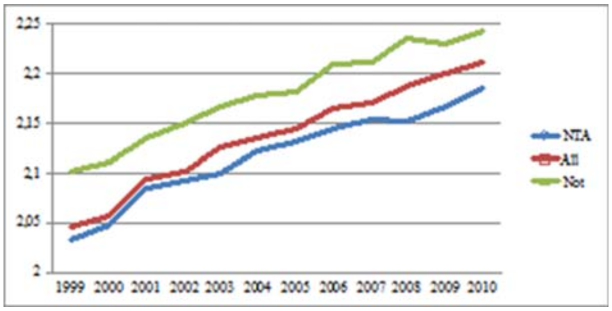

Figure 6. Parents' formal education.

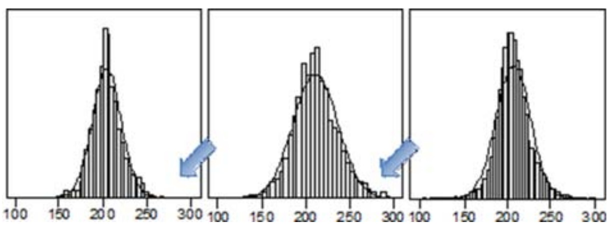

Figure 7. NTA schools Non-NTA schools All schools Merit value distribution according to the SALSA database.

The development of the NTA schools' merit value follows the same pattern as that seen above for parents' formal education. The distributions in the histograms almost look the same, with the NTA schools performing below average and the non-NTA schools performing better then average.

Merit value model calculated. This diagram shows the merit value controlling for socio-economic/cultural differences, the proportion of boys, parents' formal education and immigrant background. The difference between the groups is small but accelerating. The non-NTA schools perform about six points higher than the NTA schools in 2009.

Immigrant background. The difference in proportion of children with immigrant backgrounds between NTA schools and non-NTA school groups seems to be converging slowly. Initially, in 1999, the share in the non-NTA schools was about 4% higher than in the NTA schools. The gap by 2010 had decreased, and the difference is almost gone. The NTA schools are now very close to the average of all schools.

Proportion of boys. This last diagram shows some remarkable numbers. The proportion of boys differs by about 5% between the NTA and non-NTA schools. The difference seems to grow from 2007 while the non-NTA schools are closer to the average across all schools.

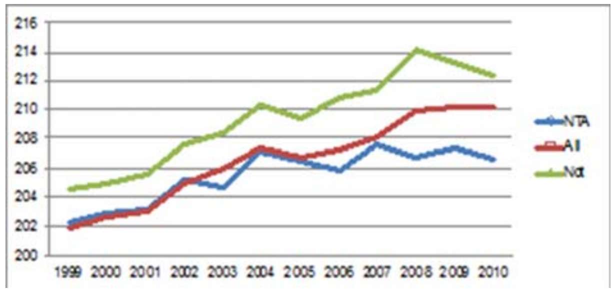

Figure 8. Merit value model calculated.

Figure 9. Proportion of boys.

COMMENTS ON THE DATA

The SALAR and SALSA databases are reliable, governmental sources. The underlying data is aggregated from Statistics Sweden (SCB) register data, covering all individuals living in Sweden. There is some missing data due to small groups and the fact that information about private schools is sometimes missing, but the quality is generally very good. Using 11 cohorts of SALSA data from 1999–2010, makes the small differences found more reliable when put on a time-line.

The categories of the different uses of NTA are defined by the knowledge of the coordinators. The coordinators administer the schools in "their" municipality and do all the practical and administrative work related to the programme. Their knowledge about the use of NTA varies due to for example how long they been working as coordinators and how much time they can give to the NTA administration. In some cases, I had to contact retired coordinators with better knowledge about the schools' use of NTA than their successor. In spite of this, I did manage to get in contact with all coordinators. In the cases of NTA coordinators expressing uncertainty about the use of NTA, the concerned school/schools were marked as 'non-responses'. These non-responses are not included in the comparison.

Table 16. SALSA values for 2009 including non-responses (Unknown).

2009	*NTA*	*Unknown*	*All*	*Not NTA*
N (Schools)	96	192	1421	256
Parents's education	2,166	2,183	2,198	2,231
Merit value	206,6	208,9	210,5	216,6
Merit value calculated	207,4	208,4	210,3	213,3
Born abroad	6,97%	6,80%	6,71%	8,41%
Born in Sweden	8,92%	8,41%	9,19%	13,67%
Proportion of boys	53,8%	51,8%	51,0%	49,7%

Non-response. The groups three and five (mixed schools and schools with unknown use of NTA) together consist of 192 schools and are thus quite large. Table 16 shows their main SALSA variables for 2009 compared with the other groups at the school level. Their values are positioned between the NTA group and all the schools. The non-NTA schools distinguish themselves with higher values. This indicates that the non-response group is composed of schools that behave more like NTA schools than non-NTA schools. This is expected since there are more mixed than unknown schools (definitions in section "NTA at school level") in the non-response group.

DISCUSSION

Three research questions have been addressed in this paper. The first question (Q1) focuses on the socio-economic indicators that characterise the schools that use NTA. The second question (Q2) highlights the spread of NTA distributed across the country and within municipalities. The third question (Q3) is about possible implications the findings (Q1 and Q2) might have on the use of NTA and similar teacher support programmes.

Regarding Q1 ***(socio-economic indicators),*** *the focus on supporting low-performing groups visible in the American studies (Cuevas et al., 2005; Klentschy et al., 1999) is not spelled out in the Swedish context. This study however shows that the same phenomenon (support for low-performing groups) is also found among the users of NTA. Looking at, e.g., Figure 5 (Parents' formal education) or Figure 12 (merit value, model calculated) the NTA group is clearly disfavoured.*

Based on the results from this study, there are reasons to believe that decision makers tend to promote the use of NTA in low-performing schools. The decision to join IBSE programmes seems similar in both the Swedish and the American context with the decision at state, municipality or school board level (Bybee, 2003; Cuevas et al., 2005; Marx et al., 2004).

Previous Swedish research has primarily been exploring participating teachers' experiences with working with NTA. However, Anderhag & Wickman, (2007) highlight the effects of NTA in relation to pupils' performance. According to them, positive effects can be demonstrated among both low and high performers. In this study, additional insight is presented.

The NTA schools are not geographically evenly distributed across the country (Figure 2). The more urban a municipality is, the more likely it is to have a culture that promotes education (including having parents with higher education) (Skolverket, 2009). This advantage is however not evenly distributed within each municipality. Some areas have inhabitants with higher incomes and higher education. To some degree, the variation between schools within the municipalities seems connected with socio-economic factors. Several variables indicate socio-economic advantages for non-NTA schools.

At the school level. Schools using NTA have been shown to differ from schools not using NTA in several ways. On average, parents' formal education is 3.3% lower among children participating in NTA, compared to the level of education among non-participants' parents (Figure 6).

The model calculated that merit values among NTA children were 2.8% lower in 2009 compared to the children in the non-NTA schools within the NTA municipalities (Figure 8).

In the early 2000s, the number of children with immigrant backgrounds in NTA schools was considerably lower than in the non-NTA schools. However, this difference had vanished by 2010. The 5% higher proportion of boys in NTA schools (Figure 15) is also interesting and needs further investigation. Both differences could, hypothetically speaking, be related to students'/parents' choice to attend a higher performing private or public school.

Regarding Q2 (The Spread of NTA Across the Country and within Municipalities)

The NTA programme is found to be most common in the big cities and in Stockholm. It is more common in the suburbs. The way that NTA is diffused (Figure 2) shows clustering in some regions with a lot of NTA usage. This is contrasted with very few (or no) NTA schools in other parts of the country. It is noticeable that the NTA organisation has not used frequent marketing to promote the programme. Instead, teachers involved in the programme seem to have 'spread the word' about NTA to friends and colleagues. This non-marketing strategy could be one possible reason for the geographical dispersion of the NTA schools. The discovered differences at the municipal level however primarily seem connected to differences between the rural parts of the country and the big cities. The administration and financing of NTA could demand a certain volume, which could have prevented small municipalities from joining the organisation. It should be noted that some municipalities share their coordinators and other resources with other municipalities. As pointed out above, there is not much information available about how the use of IBSE materials has spread in the US.

Regarding Q3: Implications of Findings

The American STC research indicates that more skilled and experienced teachers tend to choose to work at more prestigious schools (S. Lynch, Kuipers, Pyke, & Szesze, 2005). This effect combined with the fact that high-performing teachers and high-performing pupils tend to work at/attend the same schools, is of interest also in the Swedish context. The possibility to choose school (and to move away from low-performing schools) is now a reality in many cities in Sweden and the effects this has on performance is oft debated. There seems to be some consensus that these choices have made the schools more segregated (Hartman et al., 2011). The results from this study indicate that the choice to use or not to use NTA, to a certain degree, is dependent on this kind of clustering between low – and high-performing schools. The geographical clustering that can be seen in Sweden is not present in the American research but would be of interest when discussing which pupils tend to take part in IBSE.

One reason for looking closely at historical data is related to municipalities' reasons for joining the NTA programme. There are obviously various reasons for taking on the programme. Based on the findings of this study, several possible explanations emerge.

One possible reason for joining NTA is related to the reported lack of teacher's education in technology for the lower years (Gisselberg, 2001; Teknikföretagen, 2005). Measures need to be taken and the NTA concept is available. Similar reasons concerning the quality of the teaching staff could be found in the US context (the National Commission on Mathematics and Science, 2000).

Other possible reasons to join NTA found in the Swedish research literature is lack of time (Gisselberg, 2001), resources (Anderhag & Wickman, 2006) and teacher's education in science (Skolverket, 2005; Statskontoret, 2007). It is reasonable to assume that NTA, in this context, is considered to be an example of a 'tool of change'. Schmidt et al. (1997) points at similar reasons to join STC. The available American research focuses on the state level, and it lacks results for the national level. Is the easily available register data at the national level combined with the knowledge that the NTA coordinators possess about the participation unique for Sweden? Is similar information present in some other countries?

According to Schoultz et al., (2003), teachers wish to *'do more science and technology education*'. Several reports (Skolverket, 2005; Teknikföretagen, 2005) also indicate that the activity in S & T is not sufficient in the lower years. Here NTA could be seen as a 'catalyst' to enhance this work.

The active promotion of IBSE by American organisations (AAAS, NRC) seems to be in use in Europe as well by Fibonacci and S-Team. One question still to be answered is if the NSRC motto *'to improve the learning and teaching of science for all students in the United States and throughout the world'* has been successful.

In the American context, the use of STC as a tool to promote change in poorly performing districts and schools seems to be a more conscious decision than in the

Swedish case. The results of this study point in a similar direction as well. This is however not an official strategy of the NTA organisation or of the concerned municipalities. This raises questions about IBSE in other countries: what is the process to join a programme, which schools can join and who can afford to join?

Yet another incentive for municipalities and schools to join NTA is the introduction of a new curriculum in Sweden in 2011 (Skolverket, 2011). This introduction combined with the new demands for certified teachers (teacher legitimation), grades from year six and a central core curriculum in years one to three is inevitably increasing the pressure on schools to improve their performance in science and technology education. The use of NTA is by itself not enough to meet the lack of certified teachers.

The results from international measures like TIMMS and PISA also put pressure on countries to improve their science education.

To summarise:

- Joining the NTA is not a random process. This study indicates that NTA is seen as a possibility to compensate for disadvantageous conditions.
- High-performing city schools are less likely to use NTA.
- The NTA programme does not commercially advertise itself. Instead, teachers involved in the programme are ‘spreading the word’ about NTA to friends and colleagues.
- The NTA programme seems to be used to compensate for the reported lack of qualified science and technology teachers (particular in the early years of schooling)
- The NTA programme seems to be used to compensate for teachers’ lack of time and resources for S & T education
- Findings indicate that NTA is used as a tool to promote poorly performing districts and schools. This is however not the official strategy.

Final Remarks

The Swedish government is currently distributing money through the Swedish School Authorities designated to support the implementation of the NTA programme.

The findings in this descriptive study have, for the first time (in the Swedish context), drawn attention to the differences in background characteristics (such as geographic and socio-economic aspects) between NTA participants and non-participants. This new knowledge can hopefully serve as a basis for decision makers’ future efforts in supporting S & T education.

This present study has also shown that, in order to assess *the effects* of the NTA programme (which is *not* the purpose of the present study), there is a need to account for the lack of random assignment to the NTA programme. It is also necessary to have access to an instrument that can be used to measure statistically significant effects. Since 2009, such measurements—the national tests in science for year nine—are available. Such an analysis using the new tests constitutes the natural next step in the line of research commenced by this paper.

NOTES

[1] About 10% of the pupils in compulsory school attended private schools, in 2009.
[2] http://www.nap.edu/
[3] NTA production now has started work on standardising the collection of information to be able to do more precise evaluation in the future.
[4] *Some occasional private schools in the largest cities deviate from this pattern.*
[5] The NTA programme has the ambition to extend the use of NTA to a larger group of pupils and to higher levels of compulsory school. They also produce new material for themes that are appropriate for years seven to nine.
[6] http://salsa.artisan.se/beskrivning_datakallor.html
[7] *There are also other non-NTA schools in non-NTA municipalities that are not part of this group.*

REFERENCES

Anderhag, P., & Wickman, P.-O. (2006). NTA som kompetensutveckling för lärare. Utvärdering av hur lärares deltagande i NTA utvecklar deras kompetens att stödja elevernas begrepps – och språkutveckling. Stockholm. Retrieved from http://www.nta.kva.se/Om-NTA/Rapporter-och-utvarderingar/

Anderhag, P., & Wickman, P.-O. (2007). *Utvärdering av hur NTA hjälper skolorna att nå kursplanemålen för femte skolåret i naturorienterande ämnen*. Stockholm.

Biriell, F., & Josefsson, F. (1998). *Utprovningen av STC 1997/1998. Science and technology for children. Erfarenheter från de två första terminerna*. Linköping.

Bybee, R. W. (2003). *Science curriculum reform in the United States*. Washington, DC. Retrieved from www.nas.edu/rise/backg3a.htm

Committee on, U. G., the E. of the S., E. W. P., Committee on Science, E., P. P. P., G. A., National Academy of, S., National Academy of, E., & Institute of, M. (2011). *Expanding underrepresented minority participation: America's Science and technology talent at the crossroads*. Washington, D. C.: The National Academies Press. Retrieved from http://www.nap.edu/catalog.php?record_id=12984

Cuevas, P., Lee, O., Hart, J., & Deaktor, R. (2005). Improving science inquiry with elementary students of diverse backgrounds. *Journal of Research in Science Teaching*, *42*(3), 337–357.

Ekborg, M., & Lindahl, B. (2006). NTA som skolutvecklingsprogram. utvärdering av effekten av kompetensutveckling på lärarna och deras värderingar samt effekten på kommun – och rektorsnivå.

FileMaker Pro. (n.d.). Retrieved June 4, 2013, from http://www.filemaker.com/products/filemaker-pro/

Full Option Science System – FOSS. (n.d.). Retrieved June 4, 2013, from http://lhsfoss.org/index.html

Gisselberg, K. (2001). NTA-projektets tre första år – en positionsbestämning.

Hansen, M., & Lander, R. (2009). Om statens verktyg för skoljämförelser: Vem vill dansa SALSA? Pedagogisk Forskning i Sverige, årg 14, nr 1, *14*(1). Retrieved from http://www.ped.gu.se/pedfo/v14/n1.html

Hartman, L., Anell, A., Mörk, E., Vlachos, J., Hanspers, K., Lundin, M., Szebehely, M., et al. (2011). Konkurrensens konsekvenser. Vad händer med svensk välfärd? (p. 279). Retrieved from http://www.sns.se/forlag/konkurrensens-konsekvenser-vad-hander-med-svensk-valfard

Klentschy, M., Garrison, L., & Amaral, O. M. (1999). *Valle Imperial Project in Science (VIPS) Four – Year Comparison of Student Achievement Data 1995–1999*. Educational Research. Calexico, CA. Retrieved from http://educateiowa.gov/prodev/science/science_k-4_2.doc

Kommunal utvärdering av ungas livsval – KOMMUT. (2010). (p. 85). Retrieved from https://e264dc83-a-62cb3a1a-s-sites.googlegroups.com/site/kommutinfo/nyheter/Slutrapport100112_kommut.pdf?attachauth=ANoY7cpmUD1h-XywTKgyjl5LlFgDu1yZ9KncoZ9M-MJyqQ_WX7630nWBO19283zMHU6v7CGNBJs3S7AsekWMXV_h4zFMqxBHHYNswUhzaiJgW5qrn6oXImDL7fdpy_hBXZruu4Aqy-y_KB6P6Ms76qysVIMzOXSNqHuWVQ9vCo0GghxpFKMWqiXVvBwbPTJuPkVozeycaeR5tZjD_vYdxN2ZICYoCoAsCzRUYOVg9vr0a-SyA3LtZvM=&attredirects=0

Lee, O., & Luykx, A. (2006). *Science education and student diversity: Synthesis and research agenda*. Cambridge University Press.

Lynch, S. J. (2000). *Equity and science education reform*. Routledge.
Lynch, S., Kuipers, J., Pyke, C., & Szesze, M. (2005). Examining the effects of a highly rated science curriculum unit on diverse students: Results from a planning grant. *Journal of Research in Science Teaching*, *42*(8), 912–946. doi:10.1002/tea.20080
Marx, R. W., Blumenfeld, P. C., Krajcik, J. S., Fishman, B., Soloway, E., Geier, R., & Tal, R. T. (2004). Inquiry-based science in the middle grades: Assessment of learning in urban systemic reform. *Journal of Research in Science Teaching, 41*(10), 1063–1080. doi:10.1002/tea.20039
Michaels, S., Shouse, A., & Schweingruber, H. (2007). *Ready, Set, SCIENCE!: Putting research to work in K-8 Science Classrooms*. National Academies Press.
Moore, D., McCabe, G., & Craig, B. (2007). *Introduction to the practice of statistics w/CD*. W. H. Freeman.
National Education Goals Panel. (1995). Data volume for the national education goals report (vol. 1). Retrieved from http://govinfo.library.unt.edu/negp/reports/goalsv1.pdf
National Science Education Standards. (1996). Washington, D. C.: The National Academies Press. Retrieved from http://www.nap.edu/catalog.php?record_id=4962#toc
National Science Resources Center – NSRC. (n.d.). Retrieved June 4, 2013, from http://www.nsrconline.org/about_the_nsrc/index.html
Naturvetenskap och teknik för alla – NTA. (n.d.). Retrieved June 4, 2013, from http://www.nta.kva.se/
NRC National Research Council – NRC. (n.d.). Retrieved June 4, 2013, from http://www.nationalacademies.org/nrc/index.html
NSRC Annual Reports. (n.d.). Retrieved June 4, 2013, from http://www.nsrconline.org/publications/annual_reports.html
NTA – Rapporter och utvärderingar. (n.d.). Retrieved June 4, 2013, from http://www.nta.kva.se/Om-NTA1/Rapporter-och-utvarderingar/
Research on FOSS and Ongoing Projects. (n.d.). Retrieved June 4, 2013, from http://lhsfoss.org/scope/research/search.php
Research on STC. (n.d.). Retrieved June 4, 2013, from http://www.nsrconline.org/school_district_resources/research.html
Royal Academy of Engineering Sciences – IVA. (n.d.). Retrieved June 4, 2013, from http://www.iva.se/en/
S-TEAM Science Education. (n.d.). Retrieved June 4, 2013, from http://www.s-teamproject.eu/
Schmidt, W. H., McKnight, C. C., & Raizen, S. (1997). *A splintered vision: An investigation of U. S. science and mathematics education*. Dordrecht: Springer.
Schoultz, J. (2012). NTA och kompetensutveckling (p. 40). Stockholm: NTA Utveckling. Retrieved from http://www.nta.kva.se/Om-NTA1/News1/2012/April/NTA-och-kompetensutveckling/
Schoultz, J., & Hultman, G. (2002). Det är bra med NTA. Vi gör inte saker för att tråka ut oss utanför att lära oss. Utvärdering av elevers och lärares lärande och utveckling inom NTA-projektet.
Schoultz, J., Hultman, G., & Lindkvist, M. (2003). I början fick vi använda vår fantasi. Utvärdering av elevers och lärares lärande och utveckling inom NTA–projektet.
Science and Technology for Children Concepts Program – STC. (n.d.). Retrieved June 4, 2013, from http://www.nsrconline.org/curriculum_resources/stc_program.html
Science, T. N. C. on M. (2000). Before it's too late: A report to the nation from the national commission on mathematics and science teaching for the 21st century. Retrieved from http://www.ptec.org/items/detail.cfm?ID=4059
Skatteverket. (n.d.). Folkbokföringen i går och i dag. Retrieved June 4, 2013, from http://www.skatteverket.se/privat/folkbokforing/omfolkbokforing/folkbokforingigaridag/
Skatteverket. (2013). SALSA Betygsresultat för kommuner och skolor år 9. Retrieved from http://salsa.artisan.se
Skolverket. (2005). Undervisningen per ämne i grundskolan hösten 2002 – Resultat av en undersökning om lärares undervisning och utbildning i undervisningsämnet (pp. 29–31). Stockholm.
Skolverket. (2009). Vad påverkar resultaten i svensk grundskola? Kunskapsöversikt om betydelsen av olika faktorer. (p. 264). Retrieved from http://www.skolverket.se/om-skolverket/visa-enskild-publikation?_xurl_=http%3A%2F%2Fwww5.skolverket.se%2Fwtpub%2Fws%2Fskolbok%2Fwpub

ext%2Ftrycksak%2FRecord%3Fk%3D2260
Skolverket. (2011). Läroplan för grundskolan, förskoleklassen och fritidshemmet 2011 lgr 11 (p. 281). Retrieved from http://www.skolverket.se/om-skolverket/visa-enskild-publikation?_xurl_=http%3A%2F%2Fwww5.skolverket.se%2Fwtpub%2Fws%2Fskolbok%2Fwpubext%2Ftrycksak%2FRecord%3Fk%3D2575
Smithsonian. (n.d.). Retrieved June 4, 2013, from http://www.si.edu/
Statistical Package for the Social Sciences – SPSS. (n.d.). IBM Corporation. Retrieved June 4, 2013, from http://www-01.ibm.com/software/analytics/spss/
Statistics Sweden – SCB. (n.d.). Retrieved June 4, 2013, from http://www.scb.se/default____2154.aspx
Statskontoret. (2007). Lärares utbildning och undervisning, *Rapport, 2007*, 8 (p. 64).
Sveriges Kommuner och Landsting – SALAR. (n.d.). Öppna jämförelser. Sveriges kommuner och landsting. Retrieved June 4, 2013, from http://www.skl.se/vi_arbetar_med/oppnajamforelser
Teknikföretagen. (2005). Alla barn har rätt till teknikundervisning (p. 28). Retrieved from http://www.teknikforetagen.se/hem/publicerat/publikationer/alla-barn-har-ratt-till-teknikundervisning/
The American Association for the Advancement of Science – AAAS. (n.d.). Retrieved June 4, 2013, from http://www.aaas.org/
The Fibonacci-Project. (n.d.). Retrieved from http://fibonacci.uni-bayreuth.de/
The Royal Swedish Academy of Sciences – KVA. (n.d.). Retrieved June 4, 2013, from http://www.kva.se/en/
Vetenskapsrådet. (n.d.). CODEX – regler och riktlinjer för forskning. Retrieved June 4, 2013, from http://codex.vr.se/
Wenglinsky, H. (2000). How Teaching Matters: Bringing the Classroom Back Into Discussions of Teacher Quality (p. 36). Retrieved from http://www.ets.org/Media/Research/pdf/PICTEAMAT.pdf

GUNILLA ROOKE

8. CHALLENGE TRADITIONAL STRUCTURES

Ways of Building Gender Equality in Technology Education

INTRODUCTION

How come women are not equally represented in technology education? Although gender equality has been on the Swedish political agenda for many years, technology is still dominated by men (Skolverket, 2006; SCB,2013). Several and various reasons why women turn their back on technology have been discussed and lack of interest is one of them. Many attempts have been made to increase women's interest in technology and to change their attitudes (Hedlin, 2009; SOU, 2011:1). However, in spite of these attempts, today the interest in science and technology education in school among young people in general, and women in particular, is still very low (Schreiner & Sjöberg, 2008). The responsibility for this development rests heavily on the technology education carried out in schools since school is important environments where gender identity is developed (Lenz Taguchi, 2003). Choice of educational content is another reason, discussed and also carried out at several school levels, especially elementary and secondary school. Taking all this into account is necessary, but not enough.

To understand this further, male dominance in the structure must be challenged. Traditional structures prevail where men's advantage in positions of decision-making obstruct women from active participation. Even if women are not actively stopped by certain individuals, there are structures in society that contribute to women's subordination. To change these solid structures calls for extensive alterations within organisations—alterations that do not benefit everyone and therefore people are interested in keeping gender progress at a moderate level, not risking too much. To understand why women are still underrepresented in technology education, this study brings three questions into focus: What initiatives have been made? In what arenas do they take place? What feminist perspective can be traced in these efforts?

Several Swedish studies have been carried out showing attempts at recruiting more women into technology (Högskoleverket, 2000; Svantesson, 2006; Wikberg-Nilsson, 2008). To understand why women fail to enter, or are under-represented in many technology courses and programmes, these attempts must be analysed and discussed by structuralising them according to the social context in which they are taking place. This paper looks at the *action arenas*—a picture of what arenas are focused on and to what extent methods and power structures are challenged will

I.-B. Skogh & M.J. de Vries (Eds.), Technology Teachers as Researchers, 143–169.

be seen. This will also give an indication of the gender awareness of the players involved and clarify the feministic approach of the initiatives.

In the next section, I present a historical view of women's entry and persistence in Swedish technology education and how feminism suggests measures for gender equality within education. After that, I present and describe in what arenas campaigns and efforts to enhance gender equality in technology education have been made in upper secondary school and university during the last twenty years. Finally, I will, from a feministic viewpoint, make concluding remarks about what kind of actions must be taken for lasting changes towards gender equality.

The Basis of Feminism

Many men have, through industrialisation, secured a place in key technical positions (Wajcman, 1991). According to Wajcman, there are two dominating forms of masculinity in the technology world. One is connected to physical strength and practical hand-on skills. This can be seen in the industry workers' culture where it is important to manage both machines and mechanics. The other form is characterised by male experts, often found in decisive positions of engineering. In modern society, the engineer has become the personification of technical progress. This is also shown within the education system.

Women's access to higher education in technology was already debated in Sweden in the 19th century (Karlqvist, 1997). The barriers for female enrollment differ between countries, from socio-economical and socio-cultural norms to obstacles in qualification and institution. The most important arguments for getting more women into technology concern issues of justice, efficiency and the importance of not ignoring relevant experience (Haraway, 1988; Gemzöe, 2002; Faulkner, 2003).

Three feminist viewpoints. Feminism offers different approaches and explanations as to why technology education is unequal and how it must be changed. Depending on which feminist theory you subscribe to, the solutions vary. Also how you designate the different viewpoints vary. In this study I choose to use the political feminist designations for two reasons; school is steered by political decisions and feminist researchers in organisation use the same (for example Wahl, 2003). Three feminist views are brought forward: *liberal*, *radical/socialist* and *postmodern* feminism. These feminist directions all discuss education and how women can be drawn to male-dominated areas. The three viewpoints represent the "three feminist waves" (Gemzö, 2002). Historically, liberal feminism started in the 19^{th} century with for example women's right to vote, radical and social feminism grew in the 1960s and postmodern feminism was introduced in the 1980s. All forms of feminism are active today and depend on political standpoints.

The *liberal feminist* way to reach gender equality within education is by democratic reforms like counteracting prejudices, providing good examples, legalisation and arranging professional development courses. Discrimination of sex, they say, depends on ignorance, and if women were provided the same possibilities, gender inequality will disappear (Weiner & Berge, 2001). Within liberal feminism, technology is seen as neutral—the concern is the unequal relation men and women have to technology. Prejudices towards women have been revealed in textbooks and school material, and the domination of examinations favouring male thinking and acting has been disposed of with. This is supposed to be eliminated by providing more information (Egidius, 2002). Critics argue that liberal feminist campaigns hardly threaten the existing system and that the aim is to work within the current system rather than strive for change (Weiner, 1994; Leonard, 2003).

While liberal feminism appeal to reason for accepting changes, radical and socialist feminism do the opposite and point out to a fundamental power conflict between men and women (Gemzö, 2002). In this overview they therefore represent the second wave of feminism, even though their recommended solutions vary. In *radical feminism*, the concepts of patriarchy and power structure are introduced, explaining why men and women are not equal (Millet, 1970). Power structure is the social system that has permeated all aspects of society, where men are dominating women. Subordinate women give men an advantage, and that is why men lack interest in changing the system. Differences in power—physical, symbolic and structural—is revealed in technology education by the domination of men in writing textbooks, in teaching and in leadership (Egidius, 2002). Radical feminism raises criticism of "male" school subjects and examines the patriarchal process of schooling and power relations between the sexes in the classroom. The curricula, the education methods and the culture of education must be separated from the traditional concept of knowledge, i.e., male knowledge (Weiner & Berge, 2001) and questioned.

In *socialist feminism*, differences in class are focused on, and reforms for making studies possible are a key issue. Technology is both a cultural and historical construct that embodies both capitalistic and patriarchal values, which maintain the oppression of women. Socialist feminism also focuses on questions such as how education contributes to gender inequality, how gender and power relations are reproduced in schooling and how formations of gendered class groupings are made in the schooling context (Weiner, 1994). Much criticism from socialist feminists about analysing technology and gender is that issues such as class and race are often ignored. All three are varied and influence each other and they represent central factors that shape the relation between women and technology. Class, for instance, makes a big difference, and those Swedish women who are most willing to make gender-crossing choices come from middle and upper class families (Wernersson, 1991).

Postmodern feminism is an overall name for the youngest form of feminism and has several branches, e.g., post structuralism. Postmodern feminism challenges all general definitions of social relations and brings forward new analytic frameworks for explaining and exploring gender and social actions built on differences and varieties. In order to shift focus from "disadvantage", girls must be seen as not unambiguously powerless (Jones, 1993; Weiner, 1994). Language is one illuminated area that is socially produced and defines our subjectivity and our social organisation.

Therefore, it affects the intensions of curricula and how it is interpreted. Knowledge is another area that is situated and processed, and discusses whose knowledge is presented. According to Haraway (1990), the knowledge of the privileged (i.e., men) has been steered by their need for power.

Dividing lines in feminism. There are two fundamental differences among the feminist viewpoints above worth mentioning. The first is the levels at which changes must be made. *Liberal feminism* focuses on the individual level—what women themselves can achieve, women's possibilities, their skills and experiences and reforms to achieve equality without radical changes (Weiner & Berge, 2001). A different approach is offered by *radical*, *socialist* and *postmodern* feminism wherein social structures are emphasised (Henwood, 1996; Fox, 1998). Social structures are not eternal. They can be changed as well as the relations between them. However, gender patterns are complex and not pre-established. They are socially constructed and constantly negotiated.

The second key difference is the relation between men and women. *Radical*, *socialist* and *postmodern* feminism explain the social differentials by power structure, where men dominate over women, and therefore examines alternative measures that include female viewpoints (Scott & Sorenson, 1991; Weiner & Berge, 2001). The structural level is focusing on women's positions in working life, their representation in technology-based professions and their possibilities for education. For *liberal* feminists, there is no power relation between men and women (Ulmanen, 1998; Hirdman, 2001; Gemzöe, 2002). Both sexes have the same conditions and capacity when it comes to education and work. Women can change their lives if they want and if they are aware of their possibilities.

THIS STUDY

The aim of this study is to examine possible reasons why women are still unequally represented in Swedish technology education. Therefore, initiatives undertaken to improve gender equality in technology education have been explored. These initiatives concern engineering education at university and technological institutes and the Technology Programme for upper secondary school, which aims at engineering schooling. The initiatives studied are varied and include, e.g., campaigns for recruiting girls to upper secondary school and university, changes in the education structure and allocation by quotas. To develop an understanding of gender equality, the initiatives are looked upon also from the perspective of the chosen *arena for actions*, i.e., in what social context the attempt is made. These arenas and their corresponding initiatives are presented below This mapping of actions and arenas is thereafter discussed from a feminist perspective.

The initiatives studied were carried out during the last twenty years. There are several reasons for choosing this period. Gender equality became one of the key topics in Swedish school politics (Hedlin, 2009). The lack of engineers also became a problem for economic politics. Statistics showed a worryingly low interest in technology and women were still at a numerical disadvantage.[1] New actions for changes were about to be initiated, e.g., a new curriculum for compulsory school[2] and radical changes in the Technology Programme in upper secondary school (Fröberg, 2010). During this period, a number of targeted campaigns to increase women's interest in technology and recruitment of women into the technology sector were initiated.

Research question. In spite of numerous initiatives for change over a long time, women are still underrepresented in technology education. This situation raises issues. In this study, the following research questions are addressed:

What initiatives have been made during the last twenty years? In what arenas do they take place? What feminist perspective can be traced in these efforts?

Theoretical and methodical framework. Literatures consisting of academic theses on the subject, documents and official reports from Swedish authorities and universities have been studied. One of the central texts at the start of my examination was a thesis by Hedlin, which analyses the construction of gender in school political texts from 1948–1994 (Hedlin, 2009).

Official reports and documents have been researched primarily from the National Agency of Education and the Higher Education Authority (previous the National Agency for Higher Education), since they are political decision makers of school issues. Also, reports presenting projects carried out through governmental missions have been examined. In addition, documents from different universities and technical institutes regarding gender-oriented initiatives have been studied. A table view over initiatives, reports and documents is presented in the appendix.

Industry initiatives aimed at increasing interest in technology in schools or providing more engineers to the labor market have also been examined. Documentation regarding local initiatives in upper secondary schools (financed, documented and evaluated by the National Agency of Education, NAE) and statistics regarding female students' choice of specific educational programme (e.g., the number of female students in technology-oriented programmes and how female students finish in upper secondary school and university) are of particular interest to this study. Fortunately, this information is easily available from Statistics Sweden (SCB) and the National Agency of Education (Skolverket).

All initiatives studied have stated an explicit gender perspective in their policy statement or an intention to recruit more women in the technology sector. This mapping does not claim to be complete in the sense of mentioning every single campaign. However, the objective is to clarify in what arenas action is being taken. As mentioned previously, what arena the key players choose mirrors its feminist viewpoint. To identify and analyse actions taken and arenas chosen are therefore important steps in the process of understanding and explaining women's absence in the world of technology.

BACKGROUND

When the first female engineering student in 1915 was accepted in the Swedish Technology Institute, there were many obstacles for women trying to enter the technology arena (Karlqvist, 1997). Special demands for admission, like good grades in math and physics and having experience using the slide rule disqualified most women, since these skills were not taught in female grammar schools. When the first women pioneers broke new ground by taking on engineering studies, they were often seen as strong and striking. They were often regarded as the male students' mascots and called the "pride of the section" (Berner, 2003b). When the number of women gradually and slowly increased, they were laughed at, questioned and often seen as a threat. After graduating, female engineers often had to put up with the lowest paid and least qualified employment. At this time, this was not recognised as a problem of gender equality, since men and women often were considered to have different abilities and plans for their lives (Berner, 2003). During the '50s and '60s, in the shadow of space technology development around the world, technology became a priority, and the need for talented persons, male as well as female, increased rapidly. Taking measures to address the growing need for technological competence in society within the school system was seen as crucial. Women were now needed in the technology sector, and their interest in and attitudes towards technology had to change accordingly.

Gender becomes Political

Since the '1950s, it has been a goal of Swedish education politics to increase the number of female technology students. Technology has also been used in school politics for breaking gender boundaries (Hedlin, 2009). The political decisions have had an influence on both compulsory and non-compulsory school system. When introducing LpO 48, the Curricula for the Swedish Compulsory School System in 1948,[3] the idea was that girls and young women should learn to handle tools and electric equipment in order to reduce their dependence on men to manage everyday technological tasks. A key criticism of engineering education at this time was the male-dominated environment and the lack of human connections to technology (Berner, 2003b). Women seemed to turn their back on "plain technology subjects" in favour of technology that was more directly linked to the needs of humanity (Kvande, 1983). Now, a debate concerning whether the engineer should be a pure technical specialist or a technologist with a social responsibility was raised (Richardsson, 1987). Some technology institutes offered lectures in humanistic, psychological and social subjects under private management of humanities engineer groups.[4] However, it would be several years before the humanistic issues really became part of the study of technology.

Encouraging Gender Crossing Choices

In the 1960s, girls studying mechanical and other technical education served as models for making gender-crossing choices. As Swedish industry was growing, more employees were needed. In order to find the best talent to work with technology, women also became a resource. From the late 1960s to the middle of the 1970s, politicians struggled for a uniform compulsory school where boundaries between girls and boys would be broken by equality in education. Girls were encouraged to broaden their technical knowhow in order to have more professional freedom. During the second half of the ’70s, gender roles became central. Teachers and school leaders were educated in gender issues and student counseling played an important role in informing pupils about education and career choices (Hedlin, 2009).

Gradually, the focus was changed from convincing women to make gender-crossing choices to pedagogical issues. Women were no longer seen as the problem. Now education could attend to both men’s and women’s needs and interests (Lindahl, 2011). According to Lindahl, the idea was that a reformation of the content in the subject of technology would make women more willing to choose a technology-based education and career. However, in upper secondary school, young women were still under-represented—around 10% of the Technology Programme (Fürst, 1990). In the middle of the 1970s, the number of female engineering students in Swedish technology institutions was 13%. At one of the largest institutions, it was as high as 18%. Female engineering students were however not equally distributed among the programmes, e.g., architecture attracted 43% women (Karlqvist, 1997; Högskoleverket, 2008).

Focusing on Gender Differences

When introducing Lgr 80, the National Curriculum 1980, technology in compulsory school changed from being a vocational subject to a mandatory one.[5] In the middle of the ’80s, the number of students in upper secondary school and the programme for technology increased to the same level as natural science (Fürst, 1990; Fröberg, 2010). This was three times higher than ten years earlier, but the distribution of the sexes was the same. Gender differences were again in focus, for example by discussing how the hidden curriculum made girls less visible in the classroom (Einarsson & Hultman, 1984; Wernersson, 1985). The hidden curriculum is the implicit and unwritten rules in school culture, e.g., how you behave in the classroom and what pupils learn besides the content of each subject. Several governmental campaigns were once again directed at persuading women to make untraditional choices in their studies and professions. One of the main objectives was to make young women understand what was for their own good (Fröberg, 2010).

Technology for girls[6] was a governmental initiative introduced in 1985 (and still continues) for girls preferably in school years 7–9, which was often for a week during the summer vacation. The aim of this initiative was to increase girls’ interest in technology but also to change their attitudes by widening the technology content. An evaluation done by the NAE shows that a majority of the girls that took part in this course displayed an increase in their interest in technology and wanted to learn more about it.[7] Other studies have shown that although this initiative has had some positive effects, other projects are also needed (Svantesson, 2006). The interest from the labor market led to a recruitment campaign called *More women into the industry*[8] for engaging more girls in technical industrial work and, in the long term, stimulate girls to choose technology studies (Hedlin, 2009).

Looking for Other Pedagogical Methods

In the beginning of the 1990s, about 25% of the technology students in Swedish universities and technology institutes were female, but the distribution among programmes was still unequal.[9] Some institutes have reached a higher number of women—up to 30% (Karlqvist, 1997). Work for developing new curricula in upper secondary school started and the Technology Programme was about to be revised.[10] Technology now ceased to be an independent programme and became an orientation within the Natural Science Programme. The immediate effect was that the number of technology students decreased whereas more students enrolled in natural science. This was a big threat for future technology enterprises (Fröberg, 2010). Gender equality now once again became one of the key topics in Swedish school politics. So far, the measures taken to involve women in the field of technology had failed. Gender-coded areas were brought forward in discussions about the technology content in school. According to the political debate, the subject of technology should generate interest among continuing studies, broaden pupils' minds and, not in the least, be a basis for democracy. Critical voices were being raised with regard to how gender is understood and worked with. This criticism resulted in the government appointing a commission to clarify and formulate the gender equality goals for the Swedish school system and make them more concrete.[11] The government also initiated campaigns for recruiting more women to higher education in technology.

Still no Gender Equality in Technology

Today, Swedish upper secondary school is strongly gender segregated. Compulsory school shows gender awareness in technology education, but there have been great difficulties in realising the strategies and methods for gender equality. It often relies on enthusiasts, and strong support from the school leader is a crucial requirement to break gender boundaries (Rooke, 2012). Today, the Technology Programme has increased the number of first-year students since the reform (Skolverket, 2011b), but the percentage of female students compared to the last ten years has reduced (Skolverket, 2012). At higher levels of education, women dominate in general, but in technology there is an evident male dominance. Among technology researchers and professors too, there are few women. Women are "the leaky pipe-line" in the education system, here as well as in the rest of the EU (Högskoleverket, 2008). Campaigns for increasing women's interest in technology are now being questioned and more structural efforts are being brought forward.

The delegation for Gender Equality in Higher Education points out in their report the importance of local structural changes and long-term work (SOU, 2011.1). They suggest, for example, equality bonuses for gender-equal universities and special actions to make sure that female researchers are not treated unfairly. The Swedish National Agency for Education now has a governmental commission for gender equality in schools in the form of, for example, professional development courses for teachers in gender inclusive methods, the examination of textbooks and discussions about gender divided groups in school (SOU, 2010:99).

ARENAS FOR GENDER EQUALITY

In this section, a description of technology-oriented gender equality actions is made. They are presented alongside the arena they take place in. The arenas presented are the structuralised result of my data collection. To connect actions with arenas is a model showing the context of the initiative. The arenas are places where players from education meet incoming pupils and students. They can be physical or virtual, open to the public or only invited attendees. Every arena set the frame of a social structure—what is expected and how to act. The message given is also adjusted to the arena. To picture the levels, each arena is named after how far or close it is to the physical school building and also where it is located.

The following five arenas have been identified: the *square-*, *mass-*, *entrance –* *classroom –* and *boardroom arenas.* The *square arena* is located somewhere outside the school building and has no physical limitations. Information, often written or virtual, for potential female students is central and aimed to encourage interest and change attitudes towards technology studies. If you become interested, you can “take a step” to the *mass arena* to know more. The mass arena includes arrangements implemented in physical places, inside or outside the school building, like exhibitions, seminars and try-out days. The potential female students moving about here have made an active choice to see for themselves and get more information.

The *entrance arena* contains the educational structure, how you enter education and what programmes are on offer. Actions here can contain, e.g., names or structures of programmes and admission demands. The *classroom arena* focuses on education—what to learn, how to learn and whom to learn it from. It contains everything that happens in the classroom that affects your learning. This part exposes courses, content and textbooks as well as pedagogical methods. The *boardroom arena* includes school organisation among staff and school environment. Actions in this arena can be change of organisation as well as distribution of teachers and appointed managers.

The choices of actions and initiatives in the different arenas are made based on the focus of my study, to capture a pattern where actions and arenas will picture the work for gender equality in technology education. Not every action is mentioned, but a reasonable number of actions according to the type of work. Some campaigns must therefore represent similar actions. The number of actions I have come across in my study are mentioned here proportionally alongside each arena. In that way, it will be clear in which arena the most actions are being taken. The presentation of actions alongside each arena generally starts with upper secondary school and continues with university and technological institutes.

Square Arena

The *square arena* is open to everyone. Here, information is edited and schools advertise their educational programmes to attract new students. You find written media like brochures and catalogues, as well as virtual media like web sites and social media. These are open to everyone.

Catalogues, brochures and website information are basic media arenas for the recruitment of students into secondary school. Municipal schools often have a central administration for the design and editing of such media. Privately run schools on the other hand do their own publishing. Many schools send catalogues aimed at pupils in the age group. For pupils, it still can be difficult to get a full picture of schools available. A common regional website is one way to facilitate pupils towards making their secondary school choice.[12] Catalogues and brochures can serve to help go beyond gender, e.g., through the choice of pictures showing more girls in male-dominated situations.[13] Special editions addressed to only girls have not been found.

Universities use the same media to inform, attract and recruit new students. Catalogues and official websites are also platforms important to convey attitudes. Some institutes scrutinise the information and focus on what women want to know and show female role models[14] (Svantesson, 2006). *Think if…* is an information campaign for recruiting more women into education in energy technology at a Swedish technology institute. To reach female upper school pupils, they sent them brochures describing their technology education and also supplied an informational video to the student counselors. Neither the brochure nor the video had any measurable effect.

A TV serial sponsored by the industry (through Teknikföretagen) to increase interest in engineering and shown on Swedish television in 2010, showed the variety in an engineer's work by travelling around the world and meeting engineers in different countries.[15] The focus was to generally increase interest, but they were obviously trying to give a gender-neutral picture since for example four out of eight programmes showed a female engineer. The programme received much attention and was awarded by Reftec.[16] After the TV serial, a competition for young technology students to win a summer job at one of the biggest engineering companies was announced in Spring 2011 and attracted considerable interest.[17] Among the rewarded, there was an equal mix of young men and women. How this competition will affect the number of new students in technology universities is too early to say.

Another way of showcasing education is by arranging online voting of students' projects. One of the leading technology institutes arranged a competition for students, asking how they would like to present an engineer. Different technology projects were shown on the school's website and Internet visitors voted for the best project. The argument was that by using the students' own images of the engineer and making use of women's reflections, engineering studies would be more enticing.[18] The interest on the website was high, but effects on recruitment were not measured.

In order to broaden the recruitment of students for higher education, especially women, and enhance the quality of teaching, the Swedish government in 1993 invited Swedish technology institutes and universities to take part in a national competition. Five institutions with 14 projects were selected to realise their ideas (Wistedt, 2001). This campaign combined educational and institutional changes with information efforts. Some of them were rather traditional, such as information brochures, recruitment campaigns and weekend seminars for female students in upper secondary school. The information recruitments however did not yield the expected outcomes. One reason is that these efforts are dependent on long-term financial support and are therefore hard to manage for such a short period of time. More about this campaign is described in the *classroom arena* and *boardroom arena* sections.

Many local universities start *networks* for female students in order to give them technical knowledge and support in their everyday life (Svantesson, 2006). The network can grow from online contact to real-life meetings. Depending on the needs, the networks can for instance arrange seminars, offer meetings, visit companies and strike up acquaintance with female mentors. Networks are therefore in between the *square* and *mass arenas*. One example is *Geek Girl* located in several cities and co-operating with technology businesses and universities nearby.[19] They want to entice women into the technology arena, inspire them to study technology and serve as female role models.

There are also campaigns directed at the technology profession, often carried out by companies and organisations together. *Tomorrow's Engineer* (IVA, 2003) is an already finished two-year project initiated by IVA, the Royal Swedish Academy of Engineering Science, in 2002.[20] The objective was to promote the development of tomorrow's education for engineers, adjusted to the coming needs of students, society and professions. One outcome was quite a number of reports mapping actual recruitment campaigns, illuminating good examples examining engineer educations and describing images of engineers and engineering work. The final report verifies the present low number of female students and recommends universities and technology institutes continue trying to broaden their recruitment and their demands of pre-qualifications. The report also emphasises new education methods and invites a holistic, social and creative view to match the traditional method of analysing content.

Mass Arena

In the *mass arena*, you find exhibitions, open house arrangements, seminars and courses. Here, women are invited to see, experience and discuss technology education. The events can last from a single visit to courses over a few days. Seminars and courses can be public but also for special invitees.

Secondary school has a long tradition of offering "Open Houses" and "School Exhibitions", which present both programmes and school locations. These activities are also one way to attract more women towards technology education. Through personal invitations and arranged meetings between current and potential students, the female students can talk about what it is like to study technology and be role models for younger girls. The previous mentioned *Technology for Girls* was initiated in 1985 and is still drawing interest and serving as an inspiration for technology studies among young girls. Unfortunately, no evaluation has been carried out to measure how many girls and young women have chosen a technology programme or an engineering education after this course.

The *NOT-project* is an extensive governmental investment, including many and widespread projects, to bring about technical knowledge in general and increase recruitment in natural science and technology for primary and secondary school (Skolverket, 2004; Skolverket, 2005). NOT started in 1993 and lasted for ten years. One of the sub-projects called *KNOT* was explicitly focused on women and technology.[21] A seminar based on a new historical overview showed that Swedish women have made great progress in traditional male areas and prestigious educations (Stanfors, 2000). However, women's participation in technological education is still low and there are big differences between men and women in terms of choice of education. The NOT programme did very little targeted at girls and women. Afterwards, a plan of action for developing the subject area was formulated, for example, by supporting national conferences in technology, pilot projects in preschools and the translation of technology education material (Skolverket, 2004b). Today, the NAE arranges a conference series to ease the transition between upper secondary school and university. They also arrange teacher days together with academic organisations.[22] Furthermore, NAE now subsidises start-upsfor more KOM-TEK offices around the country—KOM-TEK works to increase interest in technology, especially among girls. Today, seven cities have their own offices, supporting schools with technology arrangements.[23]

On behalf of the government, one of the leading technology institutes in Sweden worked out a plan of action for increasing gender equality in the IT-sector (KTH, 2007). They emphasised the importance of cooperating with upper secondary and compulsory schools to raise awareness about IT and gender among teachers. In the summary, they suggest, e.g., increased networking/adopting activities for female students and information about learning outcomes for upper secondary schools with authorised education for qualification.

Open Houses are also used at universities and technology institutes. Several institutes arrange open programme seminars, but also send special invitations for pupils in secondary school third degree. A more direct informational activity is arranging courses for young women in universities. Some call it *Girls in Institute of Technology*, others *Girls' Courses* and *Girls' Days* (Högskoleverket, 2003; Svantesson, 2006; Ottemo, 2008). They all offer inspirational days when interested younger women are shown careers, life at university and also are given the opportunity to try out some labs and experiments. What impact these campaigns have had has never been analysed in terms of the number of applying students.

Some institutes of technology have a more frequent cooperation with upper secondary schools nearby. "Do as University Does" offers visits for study purposes, large scale lectures, special advanced courses in mathematics, sharing teachers with the university and arranging evenings for problem solving etc. All this gives the pupils an insight in the university world of technology and knowledge of different programmes. Through these activities, pupils from upper secondary schools increase their interest in technology studies, but how it affects the number of students who apply has not been measured (Skolverket, 2011).

Choose IT is another recruitment campaign from the profession to recruit more students, especially women, into the IT-sector.[24] The project was initiated by several technology universities and players in the technology arena. It started in 2009 and is still an ongoing project. One of its goals is reaching at least 40% female IT engineers in 2014. Increase in interest will be achieved by projects at the upper secondary school level, lectures from leading IT companies and an "e-skill week" during which the importance of e-competence is focused on. What the outcome will be is yet to be seen. *SuperMarit* is a three-year project aimed at involving women in game developing. By inspiring and teaching young girls to play and create games, students in engineering courses nearby increased from 6 to 16%.[25]

Entrance Arena

The *entrance arena* clarifies the programme structure, from names to subject combinations, and how one can enter them. This allows special start-years to prepare for an education or other special arrangements.

Since 2000, the return of the Technology Programme at the upper secondary school level is stimulating interest in technology and the technical education of youths (Fröberg, 2010). There are three evident structural strategies for the Technology Programme in 2000. The strategies were expected to automatically solve the recruitment problem of engineers. The first one, a broader pedagogical method for educating, is mainly focusing on more girls in technology. This arrangement is discussed in the next section, the *classroom arena*. The second and third includes programme structure and changes about entrance and exit. One of these strategies was broad and offered modern entry points into technology education. The old choices of technology-based professions like mechanics, electronics and chemicals have been closed down. Since no national orientations were decided, every school could make their own orientation according to interest and local conditions. Many new technology fields like environmental technology, design, IT and bio technology replaced the traditional fields. The other programme strategy was a broader way out from school to prepare for both higher education and working life. The independent Technology Programme with a dual purpose—preparing for both university and working life—was aimed to bridge the gap between vocational training and the Programme of Natural Science. One school running this programme saw an increase in the number of girls in the Technology Programme to 44% (Teknikföretagen, 2009). Since 2000, the number of female pupils in the Technology Programme increased from 10% (2000/2001) to 20% (2010/2011).[26] In the new curricula of 2011, some changes were made.[27] First year now has open entry including a general and basic technology course. Before starting year two, the pupils have to choose one of five national orientations.[28] The name and syllabus of the programme is decided by the government, but the school offers advanced courses within the profile from a national list. How this will affect the number of female pupils is too early to say.

Most projects to change structures are directed towards the outside structures such as the structure of a certain programme and its various entry points, e.g., how to plan and arrange an introduction year or a basic year. *Open entry* in university and in technological institutes is one example of a programme starting with an introduction year with more in-depth studies in each orientation of the engineer programmes and a possibility of getting to know the subjects before choosing the profile.[29] A male-dominated environment remains in many technology areas even if some of them are in the process of changing. Allocation for quotas is one example of radical actions, a discussion initiated already in the ’70s that has recurred (Prop. 1978/79:180; Hedlin, 2009). A successful project of the Information Engineer programme at one technical institute was the allocation of a 75% quota for women. Some years later, the programme was discontinued, the quotas were removed and the number of female students decreased dramatically from 52% to 26% (Högskoleverket, 2000).

Similar programmes are found at other universities. *Basic year* is one year of studies for undergraduates in science and technology. Most Swedish technology institutes offer a basic year. This is a governmental decision wherein funds from the labour market sector were transferred to higher education in order to increase interest in technology education. This has shown to have a strengthening effect on the recruiting base, especially among women (Högskoleverket, 1998). Most of the students finish off their studies and continue with technology studies as intended after the basic year. Also, the proportion of women continuing engineering education was higher from the basic year group compared to the group of beginners.[30] From 1997–98. having a basic year is voluntary for every university, but most of them offer it even though the volumes have reduced.

Besides the basic year, a special labour market effort called NT-SVUX has been initiated.[31] This is an opportunity for employees running the risk of losing their job. They have been offered the opportunity to study natural science and technology with special economic support based on their ordinary wages. Half of the students were recruited to do a Bachelor of Technology, while the others are distributed among education for teachers, a Master of Technology or other technical programmes.[32] Before starting, most women worked in health care and medical service, teaching or administration. An evaluation over the two first years shows that 26% of the students were women and the number of women increased with age (Högskoleverket, 1998).

Most of the five projects in "the governmental recruitment programme" of 1993 (see above under *square arena*) introduced new programmes.[33] During the measured time, 1995–2000, the proportion of female students varied substantially among the programmes. In 2000, three of the involved new programmes had as much as 40–50% female students, exceeding the recruitment goal of 30%. The dropout rates were evenly distributed between the sexes and the examination rates were high compared to other programmes. In the follow-up study, some successes was reported—open entries and new programmes (Wistedt, 2001). In programmes with open entries, the students get acquainted with various subject areas without having to choose one single subject from the start. They were also getting to know the areas through projects to work on in co-operation with peers and tutors. Changing existing programmes is difficult and the study shows that launching new programmes with new organisations in terms of structure and content is more successful. To achieve gender-inclusiveness takes more than modest changes in structure and content. This is not easy and it takes a strong internal culture of organisation. Strong cultures are easier to create if the project-groups are rather small. Another important factor is staff continuity. Mobility among tutors makes it hard to use the experiences during the project and make further development.

Changing only the name of a programme, (e.g. renaming it to "Design Technology" instead of calling it "Machine Technology"), is also used. This has proven to be no long-term solution. It usually works only for some years and after a while there are still few female students in the programme (Svantesson, 2006).

The campaign *Think if…*, which was described above (in the *square arena* section), did not succeed in their information strategy to recruit more women into the programme for energy engineers. Later, new combinations of courses were made by introducing biology and environmental courses in traditional energy education, only to attract women. Together with new content, the name was changed. When the first class started, it had enrolled 66% women. During the following years, the interest slowly reduced, but the share of women remained (Högskoleverket, 2000).

Classroom Arena

The *classroom arena* includes the students, the teachers and the interaction between them. Here, technology students have made their choice and expectations shall be fulfilled. The classroom arena can apply new and different pedagogical methods, working on the content of subjects, lectures and schedules.

The Technology Programme of 2000 in upper secondary school introduced a broader pedagogical method for educating that mainly focuses on more girls in technology. The pedagogical approach was that working in an interdisciplinary, comprehensive, problem – and project-based way would benefit girls. In 2007, the number of female pupils studying technology in upper secondary school had slowly but steadily increased and approached 20% (Skolverket, 2008). There has been an increasing interest from young women in some areas like design and architecture, while other areas have seen small changes. By using assignments close to everyday life, pupils would be given a comprehensive view of technology. This seems to have attracted girls. Today's reformed Technology Programme 2011 clearly mandates that interdisciplinary studies and a gender-inclusive approach are goals of the programme.[34] The new curriculum also emphasises the importance of teaching how traditions affect what is male and female in technology and how technical artifacts are gender marked. What impact this will have on the recruitment of female students into higher technology education is too early to say.

Also, universities and technological institutes have been implementing projects that are trying to break traditional working methods. In the "governmental recruitment campaign" 1993 described above (in the *square* and *entrance arena* sections), five development projects were singled out and one of the goals was enhancing the quality of learning by breaking away from traditional methods. Co-operative, problem-oriented forms of work and interdisciplinary studies were implemented—all believed to create a more inclusive educational environment. Pedagogical reform was very important according to the lecturers and the students, but modest changes have a minor impact. To succeed, it is important to prepare the teachers. Changes call for more time for teachers' preparation, contact with students and new forms of work. Two of the programmes in this study failed to keep up the good intentions and were "back to normal" already after one year.

A global initiative also implemented at the largest Swedish technology institutes is CDIO (Conceive Design Implement Operate). The initiative aims to change traditional education forms and intends to provide a more stimulating and motivating education to all students, adjusted to engineering work. The CDIO is an answer to the labor market's critics of engineers not being useful after education. It includes project-based work and practical experiences connected to theoretical studies (Crawly, Malmqvist, Ostlund, Brodeur, 2007). To implement the method, teachers in the schools are offered courses. However, no evaluation is done. Since other methods are used during the schooling—methods that have also been beneficial to women—an evaluation is needed to determine if this has had any impact on female students' recruitment or on preventing dropouts.

Interdisciplinary programmes aimed at new careers like industrial leadership and development assistant engineering combine technical courses with social science.[35] By introducing subjects in social science, engineering students also learn to relate technology to social life. This has proven to be very successful. One of the leading technology institutes offers courses in "Man-Technology-Society" as obligatory parts of the schooling.[36] This is a way to include other qualifications and areas of knowledge in engineering, comparable to the CDIO project mentioned above, which appeals to many women. Through the modernisation of education and cancelling courses not directly usable for future professions, adjustments for working life demands have been made. Several engineering programmes have moved the heavy technical courses from the earlier to the latter part of the programme, so as not to scare away the students.

Some universities work with generally *female-friendly-structures*, e.g., organising smaller seminar groups, having older students coaching younger ones in mentorship programmes and "math studios" where students are offered support and individual tutoring (Svantesson, 2006).

A different approach tried out at the university level is *gender scrutinising*. This means the teachers and students analyse the course content—from the teacher's treatment, seminars and textbooks to examinations—from a gender perspective. This analysis makes it possible to highlight and grasp the situation and suggest relevant changes. Reports show that structure in school becomes distinct and support for female students in their everyday life has been carried through (Svantesson, 2006). The effects are very much dependent on how the teachers and the leaders adopt the outcome and how willing they are to make far-reaching changes. One of the technology institutes has, after gender scrutinising some of the courses, decided to go a step further with a plan for gender equality integration (Mälardalens Högskola, 2011). The plan presents four goals that will impact all programmes, including key players in the decision-making and recruitment process, teachers and students. The goals are, for example, more women in technology education, open lectures in gender research, methods for a gender-equal education and development in interdisciplinary methods. Other universities have also rolled out plans for gender equality to integrate gender in education. One of them has decided that written examinations now shall be done without gender marking, which means the student marks the test paper with a number, not his or her name.[37]

Boardroom Arena

The picture of the boardroom arena illuminates the social structure in organisations, e.g., the hierarchy between teachers, professors, administration staff and leaders. Generally, staff in governing positions is more often men than women. Gender distribution among headmasters at both the upper secondary school level and university level is fairly equal. For higher positions, qualifications in economy and administration are demanded, which seems to be unfair to women. Inside the boardroom, the distribution looks the same: women's membership on boards is increasing while the chairman of the board is almost always a man (Högskoleverket, 2008). Gender patterns in the boardroom are a crucial factor for how and to what extent gender equality is given priority.

In upper secondary school, there are more administrators and economistssince the local government took responsibility in 1991. Each municipality has their own board and administration of education. Every school unit has their headmaster and chief of division. Local gender equality plans regulate, more generally, what goals to achieve in the area.

Different actions for supporting teachers and researchers take place at several universities. *Career planning* is a way to strengthen and support female researchers to take the next step in their academic career.[38] A female research school has been started to support the recruitment of pedagogues and researchers in technology.[39] There is also an example of active support for the recruitment of female professors.[40]

Several universities and technology institutes have now reached an agreement about letting gender permeate all activities and actions, so called *mainstreaming*. The expression is also used in politics, meaning, to integrate work for gender equality at all fronts of political actions (Ulmanen, 1998). For one of the universities, mainstreaming means courses in gender-inclusive education methods, positive special treatment and remuneration for students who write in a gender-neutral manner in their papers.[41] Gender equality policies are now a specific measure taken by several universities and include, e.g., active support to teachers forging a broader perspective in technology.[42]

DISCUSSIONS AND A VISION

The actions taken for gender equality in the Swedish school system and in technology education have been numerous and they still continue. Compared to many other countries, Sweden is far ahead, but not far enough. It seems like the proportion of women in engineering education should be held at a "large enough" level, not too low and not too high. Too low would lead to criticism that the school system is doing nothing. Too high would make the programme look less technological and by that lose prestige (Salminen-Karlsson, 1999).

As this study shows, actions are dominated by a liberal feministic perspective to inform and to change the attitudes of women towards technology education. However, interest and attitude are not the only decisive factors when choosing an education. Therefore, one of the weak points of these individual actions is that women become responsible for the fight against a power structure no one can change alone.

Today, we stand before the huge challenge of changing the structures of power. This doesn't mean that liberal feministic campaigns, e.g., the TV serial or voting campaign described in the *square* and *mass arena* sections must be closed down. Information, networking and seminars still have their rightful place. Also, other values in these campaigns can be worth achieving. *Girls for Technology* has a combination of content that is a value add. It also has elements of radical feminist strategies with single sexed groups, which gives an opportunity to try something new without being measured and having to prove anything. From a feminist perspective, it is a useful tactic to find non-threatening ways of improving your technological competence and be less dependent on men. In that sense, girls' courses can challenge stereotypes.

Interest is Not the Only Issue

Several studies show that choice of education is a choice of identity (Ottemo, 2008; Andersson, 2011). The environment and engineering culture in technology education is also considered "male" by several female students and can affect women who enter the institutes (Berner, 2003b).

Therefore, it is not women's lack of interest that causes the male dominance problem. In too many attitude campaigns, this ignorance is the base of the recruitment and therefore its weakness. The lack-of-interest viewpoint and the assumption that women make their choices based on wrong premises or antiquated gender roles has been criticized by several technology researchers. (Henwood, 1998; Berner, 2003; Salminen-Karlsson, 2003; Faulkner, 2003; Ottemo, 2009). According to Berner, Salminen-Karlsson and Ottemo, women are very well aware of technology structures, of how traditions and male structures permeate engineering education. I agree with this standpoint. Unfortunately, many campaigns also amplify gender structure rather than changing it. When women are encouraged to make untraditional choices in high-status arenas, the hierarchy with the male at the top is maintained.

Open entry and new programmes are tried out at both the secondary and tertiary level. At the university level, it seems to be a success according to earlier reports. Maybe younger students are more sensitive to finding the right place at once. A technology programme with local orientations showed that many girls joined the programme.[43] Furthermore, the proportion of girls increased in 10 years from 10% to 25%—a period that obviously increased interest among young women. They were enticed by local orientations such as architecture, design and biochemistry. In the new Technology Programme, some of the orientation names have been changed and some of the positive code words canceled. The orientation "Social Structure and Environment" is a political concession to the building industry and politicians in environmental issues, ignoring the experience of successful orientations.[44] The effect of today's open entry, new orientations with new names, is yet to be seen. Worrying signals from schools around the country indicate a backlash when it comes to recruiting girls to the new Technology Programme. The number of applicants for the first year shows that the proportion of women has decreased from 20% to 15.6%, even though the total number of technology students has increased by almost 40% compared to the year before (Skolverket, 2012). An evaluation of the new Technology Programme is therefore desirable.

Changing Power Structures

It is good news that changes in programme structure have been implemented in many universities and technological institutes. This also shows teachers and tutors are aware of the problem and take action where it is possible. Changes in methods are often carried out by enthusiastic teachers who are aware of gender inequality. This includes gender scrutinising at all levels in the *classroom arena*—textbooks, choice of literature and tasks. With supportive leaders, development in this area can be very fruitful and even profitable. The CDIO is another interesting way of changing education methods and exams. The new Technology Programme at the upper secondary school level includes implicit writings of CDIO in the curricula, which suggest methods more adjusted to engineering.[45] It would be of great value to implement the CDIO concept consistently at this level. Courses and guide books adjusted to technology subjects would be an effective contribution to its implementation.

However, power structure must include the *boardroom arena* for durable changes. Women's representation in leading positions is a requisite step towards gender equality. The pattern from industry boardrooms, when it comes to allocation, is therefore worrying. According to the common debate, allocation is too politically subversive since it presupposes an acknowledgement of the male-dominated power structure.[46] In this sense, educational boardrooms might have a huge gain by doing the reverse—equal representation in all boards. Among universities and technology institutes, there are good examples today of changes. The organisation for upper secondary school is however more ominous. Since the municipals now are economically responsible for the school area, many boards are filled with members qualified in economy and administration. This means more men at the top and pedagogical issues are economically subordinated. To find tools for changes, mainstreaming is maybe the best of all initiatives. Several of the joined universities and institutes are big, have authority and their technology education is highly regarded among students. Giving tools for gender awareness cannot be emphasised enough. It could be done by, e.g., open courses and internal continuing courses for the staff.

During the last ten years, new actions and new arenas have entered the recruitment scenery. Some of the universities and technology institutes are pioneers in challenging male power structure. The industry continuously appeals to interest and this is no surprise since more radical actions would challenge power among serious areas such as economy, manufacture and power of boardrooms. Therefore, the *boardroom arena* is the most important arena to impact.

Vision

What vision may evolve from the results of this study? The content of courses, what to learn and who's knowledge is chosen must be debated at all levels, from the profession to writers of the curriculum. At the national level, the new Technology Programme must be evaluated. What changes are seen in female representation? What impact has the open entrance had? The industry also has a responsibility to make sure traditional male environments in technology change and match the progress made by various education programmes.

The local level faces the greatest challenge. Reformation of methods, content and textbooks is central to achieve an equal technology education. The CDIO initiative is one good example of working methods adjusted to engineering studies that challenge various abilities and develop engineering know how. To spread it to all technology institutes and properly implement it through the Technology Programme would be great progress for engineering education. A critical examination of curriculum must be elaborated upon in order to formulate goals for knowledge provided for both male and female interests and vision. Gender scrutinising must be done of textbooks and course planning, both in choices of authors and content. However, not only what and how to mediate knowledge is crucial. Gender awareness among school leaders and tutors must increase. Scrutinising employment structure, e.g., who is in charge and what is rewarded for building a career can result in a visible imbalance of power. To point out how power shapes relations between men and women is essential in order to achieve gender equality. This also must include making the conflict of imbalance visible. When imbalance is visible, far-reaching changes can be made.

As long as inequality in power between the sexes continues, the gender gap within technology education will remain. The conditions of life for men and women are different; therefore, their own and others' preconceived apprehensions of what men and women can do must be attended to and critically examined by the teachers. Values and gender relations vary in time and space. This insight makes it possible, and gives the courage, to question and challenge existing structures. Unfortunately, the school system still amplifies stereotypes—girls and boys are socialised into traditional gender patterns. However, gender equality in general is strongly prescribed in governmental regulations. It is now up to the local members to realise it.

CONCLUDING REMARKS

The central issue of this study was to discuss why women still are underrepresented in technology education. Three questions have therefore been brought forward: *What initiatives have been made during the last twenty years? In what arenas do they take place? What feminist perspective can be traced in these efforts?* The study contains a mapping of actions for gender equality at the upper secondary school, university and technology institute level, since 1994. The actions have been presented in five arenas: *square arena*, *mass arena*, *entrance arena*, *classroom arena* and *boardroom arena*. The actions and their arenas were discussed from a feministic view.

To achieve gender equality in technology education, several measures have been taken during the last twenty years. The players are many and so are the arenas. Access and admission to the different arenas are dependent on the actor and what arena is chosen has impact on the long-term result.

Several actions in the *square arena* have not been measured or evaluated. The effect of information in brochures and websites is often hard to assess. Competitions like the web voting, a summer job and the TV serial showed wide public interest and engagement. New ways of reaching potential students and using media targeted at young people is probably two ways. Also, networks seem to be an important, engaging and no-demanding way to connect to each other. The *mass arena* gets closer to potential students, teachers or other interested parties. Seminars for teachers have received wide response and obviously fill a great need. Girls' courses in technology seem to have had some impact but need to be combined with other actions. These two arenas are built on interest and attitudes and include actions often initiated by liberal feminists, like awareness-raising campaigns and showing good role models.

The next three levels—the *entrance*, *classroom* and *boardroom* arenas—focus on changing structure in order to adjust to women. Structural changes are emphasised by radical, social and postmodern feminists. The *entrance arena* has shown many successful results. New programmes have had a great impact on more girls in the Technology Programme at the secondary school level during the last ten years. More women in programmes with a mix of subjects that offer a holistic view have an impact on recruitment. Open entries also attract women at least at the university level. The basic year has invited, and still does, more women to technology studies, and governmental financial support through the NT-SVUX has made it possible for economically vulnerable groups to enter. Allocation by quota has been successfully tried out for a period of time. The strategy is however controversial in political debate.

In the *classroom arena*, some interesting measures have been taken. Gender scrutinising has been tried out with good results when it is followed up properly. Working in an interdisciplinary fashion has been done in both secondary schools and universities. However, it is sometimes combined with other things and, therefore, it is hard to determine if it is this action or the combination of actions that has been beneficial. Actions in the *boardroom arena* expose several positive efforts, especially mainstreaming. How this comprehensive action will affect the school structure has not yet been seen. Still, there is a lot to do at this level.

In this mapping of actions for gender equality in technology education, we can see that the first two arenas—the *square* and *mass arenas*—dominate. Information campaigns have been created for a long time—only the media and the message is updated. These individual actions, like information campaigns and girls' courses in the *square* and *mass arenas*, fill a purpose but will not change the fact that many women turn their back on technology because of the "male-charged" school environment of technology universities and institutes.

In the three other arenas, *entrance*, *classroom* and *boardroom*, some actions from the government have been initiated. Structural actions like the basic year financial support for students and gender-inclusive projects take place within all universities. Change of programmes and structure in upper secondary school also has had a direct effect. However, many smaller universities and technological institutes are taking up the fight for more female students and have in many ways gained an advantage over the big and established educational institutions.

The findings from this study show that liberal actions dominate gender equality work in technology education (e.g., actions built on individual initiatives like information and role models). More radical feminist views are built on the power system and demand structural changes—changes that are politically debated and questioned. Structural changes are more often initiated by smaller and younger technology institutes and governmental initiatives dependent on the prevailing political situation. Gender equality is, although it has a long historical agenda, still a value-add. Women's underrepresentation in technology education is the result of many years of obstinate focus on a lack-of-interest viewpoint showed by actions in the *square* and *mass arenas. University environments continue to be male dominated.* However, there are exceptions. Some are about to change both programme structure and educational methods. This is shown in the *entrance* and *classroom arenas*, e.g., by allocation of quotas and gender scrutinising. The tardiness in the *boardroom arena*, with traditional hierarchy patterns and mainstreaming is one of the few good examples of changes, reflecting how traditional male power structure protects its advantages. From a feminist viewpoint, where power structure explains gender roles, this is the explanation of why changes take so long.

NOTES

1 Tabell 4.3A läsår 1994/95. Retrieved July 31, 2012 from: http://www.skolverket.se/statistik-och-analys/2.1862/2.4391/2.4392/skolor-och-elever-i-gymnasieskolan-lasar-1994–95-1.29631

2 Lpo 94. Läroplaner för det obligatoriska skolväsendet, Utbildningsdepartementet

3 In Swedish, "Läroplan för den obligatoriska skolan"

4 For example, "The Committee for Humanities in Technical Schools". In Swedish: "Kommitéen för humanistisk orientering vid teknisk utbildning"

5 Lgr 80 is The Curricula for Compulsory School from 1980. In Swedish: "Läroplan för grundskolan".

6 In Swedish, "Teknik för tjejer". A project initiated and financed by the government.

7 TheNAE is the National Agency of Education. In Swedish: "Skolverket". When the project started, it was led by the NAED—the National Agency for Education Development. In Swedish: "Myndigheten för Skolutveckling". Later, a separate agency 2003–2008, today a part of Skolverket.

8 In Swedish, "Fler kvinnor till industrin"

9 For example, Retrieved July 30, 2012 from: http://hsv.se/nu_jamyrk?struts.portlet.action=/nudev/urval&frageTyp=2&frageNr=230

10 LpF 94. Curricula for the Non-Compulsory School System 1994.

11 "We are all different". In Swedish, "Vi är alla olika". Utbildningsdepartementet (1994)

12 For example, Retrieved July 30, 2012 from: http://www.skanegy.se/

13 For example, Retrieved July 30, 2012 from: http://www.skelleftea.se/default.aspx?id=46853 and http://www.ed.edu.jonkoping.se/24/nyfiken-pa-ed/lar-kanna-teknik.html

14 For example, "Kvinna på teknis" (Wikberg-Nilsson 2006) and "womengineer" (http://www.womengineer.se)

15 Retrieved July 30, 2012 from: http://www.teknikforetagen.se/hem/Publicerat/Nyheter/Sandningsstart-for-Felix-stor-en-ingenjor/

16 Reftec is an association for Swedish technology students. In Swedish, "Sveriges teknologkårer"

17 6,600 students applied for 13 job openings at even number of companies. Retrieved July 30, 2012 from: http://www.teknikforetagen.se/hem/Publicerat/Nyheter/Har-ar-vinnarna-av-Sveriges-storigaste-sommarjobb/

18 Retrieved July 30, 2012 from: http://www.kth.se/kthpainsidan as one example from the Royal Institute of Technology

19 Retrieved July 30, 2012 from: http://geekgirlmeetup.com/

20 In Swedish, "Morgondagens ingenjör". IVA is an abbreviation for "Ingenjörsvetenskapsakademin". IVA is a network of technicians and economists from university, professions and administration.

21 KNOT is Women in Natural Science and Technology. In Swedish, "*Kvinnor i Natur Och teknik*".

22 See Skolverket (2009) and Retrieved July 31, 2012 from: http://www.skolverket.se/skolutveckling/amnesutveckling/nt

23 Retrieved July 31, 2012 from: http://www.skolverket.se/skolutveckling/amnesutveckling/nt/pagaende-insatser/stod-till-komtek-1.127088

24 In Swedish, "Välj IT". Retrieved July 30, 2012 from: http://www.valjit.se/website1/1.0.1.0/392/1/

25 Retrieved July 30, 2012 from: http://www.supermarit.com/index.php?option=com_content&view=article&id=57&Itemid=28

26 Table 6.3A year 2000/01. Retrieved July 31, 2012 from: http://www.skolverket.se/statistik-och-analys/2.1862/2.4391/2.4392/skolor-och-elever-i-gymnasieskolan-lasar-2000–01-1.29625 and table 4A year 2010/11 http://www.skolverket.se/statistik-och-analys/2.1862/2.4391/2.4392/skolor-och-elever-i-gymnasieskolan-lasar-2010–11-1.124788

27 Gy 2011. A reformation for Upper Secondary School.

[28] The five national orientations: *Design and Product Development*, *Social Structure and Environment*, *Production Engineer*, *Technical Sciences* and *Information and Media Technology.*
[29] In Swedish, "Öppen ingång" For example, retrieved July 30, 2012 from: http://www.kth.se/utbildning/program/civilingenjor/oppen-ingang
[30] In 1993–96: 37% women from the basic group and 18% from the beginners.
[31] NT-SVUX is an abbreviation for "Naturvetenskap och Teknik, särskilt vuxenstöd" In English: "Natural science and Technology, special financing for adults".
[32] In Swedish, "högskoleingenjör" and "civilingenjör"
[33] Scientific Problem Solving, The Project Programme, Reforming the Computer Science and Engineering Programme D++, The IT Programme and Women in Engineering Education. (Wistedt, 2001)
[34] Skolverket "Examensmål för Teknikprogrammemet" (2001). Retrieved July 29, 2012 from: http://www.skolverket.se/forskola-och-skola/gymnasieutbildning/program/nationella-program/teknikprogrammet/examensmal-och-programstruktur
[35] For example, retrieved July 29, 2012 from: http://www.liu.se/utbildning/program/industriellekonomi?l=sv and http://www.chalmers.se/en/education/programmes/masters-info/Pages/Entrepreneurship-and-Business-Design.aspx
[36] In Swedish, "Människa-Teknik-Samhälle". Axelsson 2009.
[37] Retrieved July 29, 2012 from: http://www.liu.se/om-liu/strategi/ett-liu-for-alla/genus/om-genuslektorerna/1.259064/HPLiTH.pdf
[38] Retrieved July 29, 2012 from: http://www.filfak.liu.se/filfakta/karriarplanering?l=sv
[39] Retrieved July 30, 2012 from: http://www.ltu.se/cms_fs/1.62658!/gin%20nr%202%202008.pdf
[40] Retrieved July 29, 2012 from: http://www3.lu.se/pers/Jamstalldhet/policy_jamst-likab-mangfald.pdf
[41] For example, retrieved July 29, 2012 from: http://www.lth.se/genombrottet/hoegskolepedagogisk_utbildning_kursutbud/kurser_av_andra_kursgivare/genuspsykologiska_aspekter_i_undervisningen_kvinnor_maen_och_teknik/
[42] For example, Liu "Equal terms" (in Swedish "Lika villkor"). Retrieved July 30, 2012 from: http://www.liu.se/om-liu/strategi/ett-liu-for-alla/lika-villkor/?l=sv KTH Policy and plan for gender equality (in Swedish: Jämställdhetspolicy och jämställdhetsplan). Retrieved July 30, 2012 from: http://www.kth.se/polopoly_fs/1.114788!/Menu/general/column-content/attachment/jamstalldhetspolicy.pdf
[43] See endnote xxvi
[44] Retrieved July 29, 2012 from: http://www.regeringen.se/content/1/c6/12/64/61/66728528.pdf
[45] Retrieved July 30, 2012 from: http://www.skolverket.se/forskola-och-skola/gymnasieutbildning/program/nationella-program/teknikprogrammet/examensmal-och-programstruktur
[46] For example, retrieved July 2, 2012 from: http://www.dn.se/ekonomi/kvotering-ar-inte-aktuellt

REFERENCES

Andersson, S. (2011). Identitesresan. In Skolverket *Fler som kan – Hur vi kan underlätta för ungdomar att läsa naturvetenskap och teknik?* Stockholm: Skolverket.

Axelsson, A-S. (2009). Bildning i den tekniska högskolan. In Å. Ingerman, K. Wagner, A-S. Axelsson. (Eds.), *På spaning efter teknisk bildning.* Stockholm: Liber.

Berner, B. (2003). Kön, teknik och naturvetenskap i skolan. In B. Berner (Ed.), *Vem tillhör tekniken? Kunskap och kön i teknikens värld.* Lund: Arkiv förlag.

Berner, B. (2003b). Kvinnor i ingenjörsarbete. In B. Berner (Ed.), *Vem tillhör tekniken? Kunskap och kön i teknikens värld.* Lund: Arkiv förlag.

Crawley, E., Malmqvist, J., Ostlund, S., Brodeur, D. (2007). *Rethinking engineering education, the CDIO approach.* New York: Springer Science Business Media.

Egidius, H. (2002). *Pedagogik för 2000-talet.* Stockholm: Natur och Kultur.

Einarsson, J., & Hultman, T. (1984). *God morgon pojkar och flickor, om språk och kön i skolan*. Malmö: Liber.

Faulkner, W. (2003). Teknikfrågan i feminismen. In B. Berner (Ed.), *Vem tillhör tekniken? Kunskap och kön i teknikens värld.* Lund: Arkiv förlag.

Fox, M. F. (1998). Women in science and engineering: Theory, practice and policy in programmes. *Signs. Journal of Women in Culture and Society*, *24*(1), 201–223.

Fröberg, M. (2010). *Teknik och genus i skapandet av gymnasieskolans teknikprogram.* Översättningar *och gränsarbete på tre nivåer*. Linköping: Linköpings universitet.

Fürst, G. (1990). *En ny gymnasieskola för flickor och pojkar. Jämställdhetsperspektiv på den nya gymnasieskolans linjestruktur.* Forskningsrapport nr 99, Göteborg: Sociologiska Institutionen, Göteborgs Universitet.

Gemzöe, L. (2002). *Feminism.* Stockholm: Bilda Förlag.

Haraway, D. (1988). Situated knowledge: The science question in feminism and the privilege of partial perspective. *Feminist Studies, 14*(3), 575–599.

Haraway, D. (1990). A manifesto for cyborgs: Science, technology and socialist feminism in the 1990s. In L. J. Nicholson (Ed.), *Feminism/Postmodernism*. New York: Routledge.

Hedlin, M. (2009). *Konstruktionen av kön i skolpolitiska texter 1948–1994 med särskilt fokus på naturvetenskap och teknik*. Doktorsavhandling nr 26 i pedagogiskt arbete. Umeå: Institutionen för matematik, teknik och naturvetenskap, Umeå Universitet.

Henwood, F. (1996). WISE choices? Understanding occupational decision-making in a climate of equal opportunities for women in science and technology. *Gender and Education*, *8*(2), 122–214.

Hirdman, Y. (2001). Genus, om det stabilas föränderliga former. Malmö: Liber.

Högskoleverket (1998). *Särskilda utbildningssatsningar – vad blev det av dem? Uppföljningsstudie av vissa särskilda utbildningssatsningar inom högskolan som finansierats med arbetsmarknadspolitiska medel.* 1998:4R. Stockholm: Högskoleverkets rapportserie

Högskoleverket (2000). *Goda exempel – Hur universitet och högskola kan arbeta med jämställdhet, studentinflytande samt social och etnisk mångfald*. 2000–9 R. Stockholm: Högskoleverkets rapportserie

Högskoleverket (2003). *Lärosätenas arbete med jämställdhet, studentinflytande samt social och etnisk mångfald – en uppföljning av Högskoleverkets utvärdering 1999/2000*. 2003:31 R. Stockholm: Högskoleverkets rapportserie.

Högskoleverket (2008). *Kvinnor och män i högskolan*. 2008:20R. Stockholm: Högskoleverkets rapportserie

IVA (2003). *Morgondagens ingenjörer: 59 goda exempel och några till… En kartläggning av pågående projekt i syfte att stimulera barns och ungdomars intresse för naturvetenskap och teknik.* Stockholm: Kungliga Ingenjörsvetenskapsakademien.

Jones, A. (1993). Becoming a 'girl': Post-structuralist suggestions for educational research. *Gender and Education, 5*(2), 157–166.

Karlqvist, A. (1997). *Från eftersatt till eftersökt. Om kvinnliga studeranden på Kungl Tekniska Högskolan.* Stockholm: Informationsenheten, Kungliga Tekniska Högskolan.

KTH (2007). *Jämställd IT-utveckling för ökad tillväxt.* Stockholm: KTH.

Kvande, E. (1983). Anpassning och process. *Kvinnovetenskaplig tidskrift* 1983, 3. Lund: Föreningen kvinnovetenskaplig tidskrift.

Käller, K. (1990). *Fostran till andrarang: en studie i dominansprocessen vid skolstart och via vägar genom utbildningssystemet ur ett kvinnovetenskapligt perspektiv*. Stockholm: Almqvist & Wiksell International.

Lenz Taguchi, H. (2003). Det finns inga naturliga kön. *Pedagogiska magasinet* PM, nr 4. Stockholm: Lärarförbundet.

Leonard, E. B. (2003). *Women, technology, and the myth of progress.* New Jersey: Prentice Hall.

Lindahl, B. (2011). Varför förstår de inte sitt eget bästa? In Skolverket *Fler som kan – Hur kan vi underlätta för Ungdomar att läsa naturvetenskap och teknik?* Stockholm: Skolverket.

Millett, K. (1970). *Sexual politics.* Stockholm: Rabén & Sjögren.

Mälardalens Högskola (2011). *Policy och handlingsplan. En jämlik högskola*. Västerås: Mälardalens högskola.

Ottemo, A. (2008). *Rekryteringsarbete och genusmönster i rekryteringen till Chalmers utbildningar på EDITZ-området.* Göteborg: Chalmers. Retrieved July 24, 2012 from: http://document.chalmers.se/doc/197.120.0964

Ottemo, A. (2009). Rekryteringsarbete: Rådande utgångspunkter och alternativa strategier. In *NORDTEKs Teknikdelegation*. Rapport. Stockholm: VINNOVA. Retrieved August 1, 2012 from http:// www.lth.se/fileadmin/lth/genombrottet/naturvkonferens2009/ proceedings/12Ottemo.pdf
Proposition 1978/79:180 (1978). *Om läroplan för grundskolan.* Stockholm: Ministry of Education.
Proposition 1992/93:160 (1992). *Högre utbildning för ökad kompetens*. Stockholm: Ministry of Education and Cultural Affairs.
Richardsson, G. (1987). *Tekniken, människan och samhället. Humanistiska inslag i 1940 – och 1950-talens tekniska utbildning.* Linköping: TEMA Linköpings Universitet.
Rooke, G. (2012). … när kommer tekniken? In S-O. Hansson, E. Nordlander, I-B Skogh (Eds.), *Teknikutbildning för framtiden.* Stockholm: Liber.
Salminen-Karlsson, M. (1999). Kvinnor och ingenjörsutbildning inför 2000-talet. In M. Fritz (Ed.), *Gnistor 2. Tjejer är inte som andra grabbar.* Stockholm: Tekniska museet.
Salminen-Karlsson, M. (2003). Hur skapas den nya teknikens skapare? Berner, B. (Ed.) *Vem tillhörtekniken? Kunskap och kön i teknikens värld.* Lund: Arkiv förlag.
Schreiner, C & Sjöberg, S. (2008). Sowing the seeds of ROSE. Background. *Acta Didactica* 4/2004. Oslo: Dept. of Teacher Education and School Development, University of Oslo. Retrieved August 1, 2012 from: http://folk.uio.no/sveinsj/ROSE-overview_Sjoberg_Schreiner_2010.pdf
Scott-Sorensen, A. (1991). Studies and education in Scandinavia: Results, problem and future directions. *Nordisk Pedagogik* 3. Oslo: Universitetsforlaget.
SCB (2013). *Ingenjörerna – en djupanalys av ingenjörsutbildade och personer med ett ingenjörsyrke.* Temarapport 2013:1. Stockholm: Statistiska Centralbyrån.
SOU 2010:99 (2010). *Flickor, pojkar, individer – om betydelsen av jämställdhet för kunskap och utveckling i skolan.* Slutbetänkande. Delegationen för jämställdhet i skolan, DEJA. Stockholm: Regeringskansliet.
SOU 2011:1 (2011). *Svart på vitt – om jämställdhet i akademien*. Betänkande av Delegationen för jämställdhet i skolan. Stockholm: Regeringskansliet.
Skolverket (1980). *Läroplan för grundskolan*, Lgr 80, SFS 1980:64. Stockholm: Fritzes. Retrieved August 1, 2012 http://www.riksdagen.se/sv/Dokument-Lagar/Lagar/Svenskforfattningssamling/Forordning-198064-om-mal-oc_sfs-1980–64/?bet=1980:64
Skolverket (1994) *Läroplan för det obligatoriska skolväsendet,* Lpo 94. Stockholm: Fritzes.
Skolverket (1994). *Läroplan för de frivilliga skolformerna* Lpf 94. Stockholm: Fritzes.
Skolverket (2001). *Examensmål för teknikprogrammet.* Stockholm: Skolverket. Retrieved August 1, 2012 from: http:// www.skolverket.se/forskola-och-skola/gymnasieutbildning/program/nationella-program/teknikprogrammet/
Skolverket (2004). *Här kan flickornas teknikintresse växa. En utvärdering av bidrag till sommarkurser i teknik för flickor.* Stockholm: Skolverket.
Skolverket (2004b). *Men till hösten så … Effektstudie av Skolverkets bidrag till kompetensutveckling i teknik (Tekniken lyfter)*. Stockholm: Skolverket.
Skolverket (2005). *KUL-rapport.* Stockholm: Fritzes.
Skolverket (2006). *Könsskillnader i måluppfyllelse och utbildningsval.* Rapport 287/2006. Stockholm: Fritzes.
Skolverket (2008). *Elever i gymnasieskolan 2007/08.* PM Dnr 71–2008–00004. Stockholm: Skolverket. Retrieved August 1, 2012 from: http://www.skolverket.se/polopoly_fs/1.79275!Menu/article/attachment/pm.pdf
Skolverket (2009). *Kompetensutveckling och andra utvecklingsinsatser inom naturvetenskap och teknik* (U2005/8130/S). Stockholm: Skolverket. Retrieved August 1, 2012 from: http://www.skolverket.se/polopoly_fs/1.82484!Menu/article/attachment/regeringsuppdrag_nytt_MNT.pdf
Skolverket (2011). *Fler som kan. Hur vi kan underlätta för ungdomar att läsa naturvetenskap och teknik.* Stockholm: Skolverket.
Skolverket (2011b). *Gymnasieskola 2011*. Stockholm: Skolverket.
Skolverket (2012). *Statistik och analys.* Tabell 9A. Stockholm: Skolverket.
Stanfors, M. (2000). Säkert och sakta. En kort historik över kvinnors intåg i naturvetenskaplig och teknisk utbildning. *NOT-häfte* nr 18, NOT 1104–8050;18. Stockholm: Skolverket.

Svantesson, C. (2006). *Tjejer till tekniska utbildningar eller tekniska utbildningar till tjejer. Projekt och initiativ med syfte att öka antalet tjejer inom tekniska utbildningar.* Tema T Rapport nr 45. Linköping: Linköpings Universitet.

Teknikföretagen (2009). *Visst går det-inspirerande teknisk gymnasieutbildning.* Stockholm: Teknikföretagen.

Ulmanen, P. (1998). *(s)veket mot kvinnorna och hur högern stal feminismen.* Stockholm: Atlas förlag.

Utbildningsdepartementet (1994). *Vi är alla olika. En åtgärdsrapport om jämställdhet i skolan som en pedagogisk fråga och ett kunskapsområde.* Ds 1994:98. Stockholm: Utbildningsdepartementet.

Wahl. A (2003). *Könsstrukturer i organisationer.* Lund: Studentlitteratur.

Wajcman, J. (1991). *Feminism confronts technology.* Cambridge, UK: Polity Press.

Wernersson, I. (1985). *Makt och kön. Sociala relationer och individuella förhållningssätt bland skolelever.* Stockholm: Delegationen för jämställdhetsforskning.

Wernersson, I. (1991). *Könsskillnader i gymnasieskolan. En kunskapsöversikt*. Göteborg: Institutionen för pedagogik, Göteborgs universitet.

Weiner, G. (1994). *Feminism in education- an introduction*. Buckingham: Open University Press.

Weiner G., Berge B-M. (2001). *Kön och kunskap.* Lund: Studentlitteratur.

Wikberg-Nilsson, Å. (2006). *Kvinnor i civilinge*njörsprogram – hinder och förutsättningar för ökad rekrytering. Research report. Luleå: Luleå tekniska universitet. Retrieved August 1, 2012 from: http://epubl.ltu.se/1402–1528/2008/01/LTU-FR-0801-SE.pdf

Wistedt, I. (2001). Five gender-inclusive projects revisited. A follow-up study of the Swedish government's initiative to recruit more women to higher education in mathematics, science and technology. Stockholm: Högskoleverket.

SECTION III

ENGINEERING EDUCATION

HÅKAN AHLBOM

9. WHY CHOOSE A REGIONAL ENGINEERING EDUCATION PROGRAMME?

INTRODUCTION

In this chapter, factors important to students' decision to take on studies in engineering are explored and described. The question of to what extent studying at smaller, regional engineering universities is seen as an attractive alternative to studies at larger, more prestigious engineering education providers is also addressed.

Obviously, numerous factors contribute to the choice to become an engineer. This makes attracting and retaining engineering students a complex task. The need for an increasing number of engineering graduates has been regularly pointed out by both industry and policy makers during the last thirty years (e.g., SOU 2010:28**,** 2010; Jackson, 2002; NAE, 2004, 2005). To accomplish an increase in the number of applicants to higher engineering studies, we need to know more about why students choose engineering studies.

In a longitudinal study of engineering, students' engineering-related value beliefs were explored (Matusovich, Strevler, & Miller, 2010). According to this study, students' values are pointed out as a key factor in students' choices to become engineers. Engineering students and their values are focused also in my study. Before revealing the focus of my study, some brief words about the context from which it was conducted are needed.

In the late 1970s, there was a major higher education reform in Sweden (SFS 1977:263). To increase the availability of higher education, a number of smaller universities and university colleges were established around the country. The establishment of these regional institutions for higher education was an important initiative in decentralising higher education, which was promoted by both national and regional politicians. Today, twenty-two universities/university colleges around Sweden offer training in various technical university programmes. The educational profiles of these universities/university colleges however differ. Two categories of higher education in engineering in Sweden can be identified: there are universities that train both engineers (Master of Science in Engineering, MaSE) and engineering technicians (Bachelor of Engineering, BaE), and there are universities/university colleges that train only BaE students.

Since 2007, the various technical university programmes in Sweden have been ranked. The 2011 ranking (Urank, 2011) differs very little from previous rankings. Beside some minor adjustments regarding positions on the list, a recurring pattern is

I.-B. Skogh & M.J. de Vries (Eds.), Technology Teachers as Researchers, 173–198.

recognisable in the ranking. The major technical universities are ranked highest. They are often located in or near the major cities in Sweden and they offer large volumes of engineering programmes. The smaller, regional universities/university colleges with just a few tens of degrees in engineering education yearly are ranked lower.

Who the applicants to the major technical engineering programmes are and the various reasons for choosing to study at a major technical university have been highlighted in previous studies (Schriener, Henriksen, Sjaastad, Jensen & Løken, 2010.). In my research, I have chosen to also turn my gaze in the opposite direction. This study primarily aims at exploring and describing BaE students' motives for choosing studies in engineering. However, the reasons for the students' choice to study engineering at a smaller, regional university will also be addressed.

Why this interest in the students 'going the other direction' someone might ask. To me, the answer is obvious. The recruitment of engineering students outside the major cities needs to be secured and a lot of money and prestige has been put into the establishment of regional institutions of higher education. Knowledge and understanding about/of students' reasons for choosing or not choosing regional options is therefore of interest not only to regional and national decision makers, concerned educators and potential engineering students but indeed also to the public/tax payers.

AIM AND RESEARCH QUESTION

There is a mismatch between society's need for engineering competence and the interest among young people to choose an engineering career. There is also a mismatch between the industry's need to replace retiring engineers at the BaE level and the interest among students (those who in fact do apply for engineering studies) to choose BaE-level studies instead of MaSE-level studies. There is yet another mismatch between the application rate between the major and the regional technical universities/university colleges. To even out these mismatches, we need to explore the different factors influencing the balance between the needs of society and the needs of individuals.

In this study, I have chosen to focus on the engineering students. My study aims at exploring and describing BaE students studying at a regional technical university. What were their motives for entering engineering studies? The following research question is accordingly put:

What values do engineering students express regarding their choice to engage in (1) engineering studies and (2) engineering studies at a regional university?

BACKGROUND

The Recruiting Situation for BaE Engineers

The European commission emphasises the importance of giving more young people from all parts of society the opportunity to get a university education. The goal is to increase the number of inhabitants with a university degree from today's 26% to 35% by 2020 (EU, 2011). This study is limited to students completing the Bachelor of Engineering (BaE) programme In a prognosis from Sweden Statistics, the demand for BaE in engineering is, in 20 years' time, expected to be twice as large as the supply. The freshly graduated Bachelors of Engineering will, in the coming years, have to replace retiring personnel with degrees from an outdated (1960s-1980s) engineering education in upper secondary school (SCB, 2009).

Statistics regarding the number of students beginning an engineering education or leaving it with a degree show the same pattern. Between academic year 2004–2005 and 2008–2009, the number of beginners in Bachelor of Engineering programmes decreased by 14%. During the same period, the total number of students beginning a programme leading to any academic profession exam increased by 3.7% (Högskoleverket, 2010) and the total number 20-year-old people went up by 25% (Mjardevi Science Park, 2010) due to a temporary demographic trend. In the long run, most countries in the OECD[3] are facing a significant reduction in the population of young people. In the year 1980, 16.6% of the population was between 16 and 24 years, but declined to less than 12% in 2008.

Despite this reduction in population of young people, there has been an increase in numbers of students undertaking higher education. This expansion originates from the increasing opportunities for young people to take part in secondary and tertiary education in the OECD countries. Figures from, e.g., Denmark show a decrease of individuals in the age group 20–24 years from 1985 to 2001 by 20%. During the same period, the numbers of graduates increased by 40% (OECD, 2008). The number of female beginners in Swedish Bachelor of Engineering (BaE) education has always been outnumbered by male beginners. It should however be noted that almost the whole drop in the numbers of beginners mentioned above is found among men—17.4 % (see Figure 1).

The decreasing number of beginners will consequently lead to a decreasing number of degrees issued. Between the academic years 2004–2005 and 2008–2009, figures dropped by more than 30%. The drop rate among females was, during this period, larger than for males (female drop was 45%). This indicates that there are a larger number of female dropouts in on-going education today (see Figure 2).

TECHNOLOGY EDUCATION IN SCHOOL AND AT THE UNIVERSITY LEVEL

To understand why students choose engineering studies, we need to know the students' educational background. What technical training have they received during their school years? Technology education in Swedish compulsory school has been described by a number of researchers (e.g., Elgström & Riis, 1990; Skogh, 2001; Blomdahl, 2007). Technology education in upper secondary school—the level preceding engineering studies at universities or the 'history of engineering studies' in Sweden—is not equally described. In this section, both these areas will be briefly described.

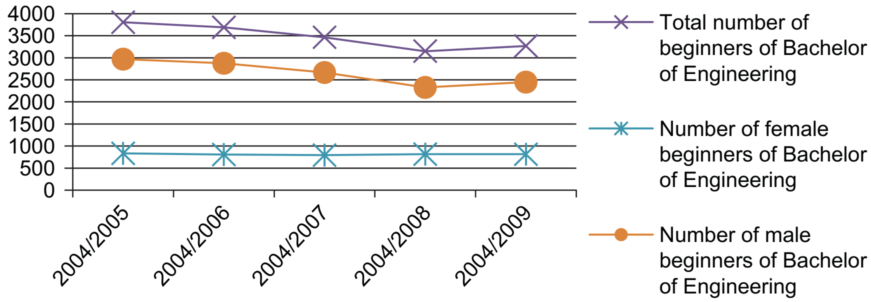

Figure 1. The number of beginners in Bachelor of Engineering education at Swedish universities between 2004–2005 and 2008–2009 (Högskoleverket, 2010)

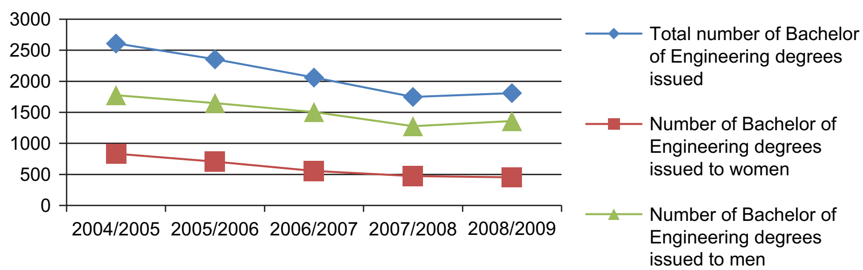

Figure 2. The number of issued Bachelor of Engineering degrees from Swedish universities between 2004–2005 and 2008–2009. (Högskoleverket, 2010).

Technology Education in Swedish Upper Secondary School

Technology education has been available in Swedish upper secondary school since the middle of the 19th century. During most of the 20th century (until the 1980s), technology was offered within a specific upper secondary school programme (*tekniskt gymnasium* in Swedish). It was a four-year programme ending with an engineering degree, a so-called '*Gymnasieingenjör*' hereby referring to the Swedish word for upper secondary school (gymnasium). These 'upper secondary school engineers' represented, for a long time, a major part of the technically educated workforce in Sweden (Högskoleverkets rapportserie, 2002).

During the 1990s, a new technology programme in upper secondary school was introduced. The duration of this new programme was three years. Instructions were, in accordance with the new curricula presented at the time, to be oriented primarily towards technological literacy, leaving the previous focus on engineering education for industry behind (Skolverket, 1994).

In the autumn of 2011, the newest, current upper secondary school curriculum was introduced. There are today two kinds of upper secondary school programmes. Certain programmes prepare students for higher education (university). The

Technology programme is one such example. Other programmes prepare students for a profession (e.g., electricity and vehicle engineering programme).

Regarding the Technology programme, the possibility of taking a fourth year of studies is now reintroduced (Skolverket, 2011). The aim of the fourth year is to (again) meet the demand from industry and other stakeholders. The introduction of this fourth year could be seen in the light of the earlier mentioned generational change. A lot of engineers with an upper secondary education will retire soon and there is a great need of replacing them (SOU 2010:28, 2010).

Technology Education at the University Level

In Sweden, the word 'engineer' usually is associated with technology in its broadest sense. Initially, an engineer was a person serving warfare. The origin of the word 'engineer' is the French word *ingéniur*, which means 'war machine'. According to the Normand chronicles, an engineer was a man servicing a catapult[4], named an engine. The tasks for military engineers changed with time and by the 17th century, they were involved in all kinds of construction matters from the building of defence and warfare facilities to canals. The Swedish king Gustaf II Adolf (1594–1632) engaged military engineers when building new cities. In Sweden, the status of the engineers followed France and was for a long time connected to military organisations. The education gave the engineers an advanced theoretical competence compared with the one given in England where practical knowledge was of higher importance. This is explained by the fact that English engineers, due to the more developed industry, often worked as mechanical constructors or technicians.

In 1844, the title of *civilingenjör* was introduced in Sweden. The title could be seen as an attempt to give engineering education validity for civilian purposes. Engineering education however still remained within the military organisation throughout the 19th century. To serve the needs of the Swedish industry and to provide theoretical technological education at the university level, *Teknologiska Institutet* (1826) in Stockholm and *Chalmerska Slöjdskolan* (1829) in Gothenburg were founded. The former was renamed to The Royal Institute of Technology (KTH) in 1876. From the year 1915, the title *civilingenjör* was corresponding to a person having a university exam in technology (Berner, 1981).

A great expansion in the number of graduated engineers was taking place during the 20th century. In Sweden, the number of engineers (all categories) went from 18000 in the 1930s to 237,000 in the1980s. The major increase was seen among the earlier mentioned upper secondary school engineers (*gymnasieingenjör)* without a university degree (Berner, 1981).

In 1993, the demand in society for people with education in science and technology in general, and for qualified engineers in particular, led to the development of a new university-level education programme in engineering at the Bachelor level (BaE). This BaE programme was to provide engineering education with higher demands on quality and at a theoretical level than was provided by the engineering education offered in upper secondary school. The intention was to successively replace engineers with a degree from upper secondary school with engineers having the new university based-education. The Swedish government thereby adapted to the structure recommended by the Federation of National Engineering Associations (FEANI) with three categories of technological education: (1) *Technicians* who were assumed to take care of daily work with proven, known technology in energy and production system. (2*) Bachelors of Engineering*, who were expected to apply and develop known technology in production and construction and (3) *Masters of Engineering* responsible for developing new technology (Högskoleverkets rapportserie, 2002).

In the mid-1980s, a Bachelor of Engineering degree demanded two years of studies. In order to adjust to the Bologna system, the time of studies in the new programme was extended to three years and the Bachelor of Engineering degree (BaE) was introduced.

THEORETICAL INFLUENCES

We humans are social creatures. Our lives and our decisions are highly dependent on the people that surround us. This well-known phenomenon is described by both philosophers (e.g., Bronfenbrenner, 1989; Mead, 1969; von Wright, 1983) and educational researchers (e.g., Bernstein, 1975; Säljö, 2010). In this study in particular, the thoughts presented within the so-called symbolic interactionism (Mead, 1969) has been a source of inspiration. A brief presentation of the main features of this theory follows below.

Symbolic Interactionism

According to Mead (1969), individuals are what they are through help from, and together with, the people around them. Identity and consciousness is built up as a consequence of social interaction. The awareness of others makes individuals dynamic and active human beings, who interpret the environment and then actively affect it. In social interaction, self-representation is important. The awareness of the self (and of other objects/subjects) arises in social interaction. "The self has the characteristic that it is an object to itself . . . This characteristic is represented in the word 'self', which is a reflexive, and indicates that which can be both subject and object." (Mead, 1969, p. 136–137)

The use of symbols enables us to develop the interaction process. Here, language is the most important symbol, but also gestures and attitudes are important tools in the interaction process (Ahlgren, 1994). It should be noted that although our perception and valuation of ourselves is shaped from our perception of how others perceive and value ourselves, the values of all individuals or groups are not equally important. Persons who have greater significance for the individual's self-evaluation are, within symbolic interactionism, called *'significant other'.* However, all 'significant others' are not equally significant to an individual in any given situation. People are significant to each other from different aspects and for different reasons. Who counts as significant is decided by each individual.

Other Influences

The influence from *'significant others'* raises questions about individuals' social class. According to Bourdieu (1987), social class could be defined from a number of aspects, such as economic, symbolic and cultural and social capital.

> . . . sets of agents who, by virtue of the fact that they occupy similar positions in social space (that is, in the distribution of powers), are subjected to similar conditions of existence and conditioning factors and, as a result, are endowed with similar dispositions which prompt them to develop similar practices (Bourdieu, 1987, p. 6).

Bourdieu introduces the concept of *habitus*, hereby meaning certain ways/set of acting shared by people joined together in the same structure of society. Those 'set of acting' are, according to Bourdieu, transferred from one generation to another within the structures of society (Bourdieu, 1994).

A concept similar to 'significant others' is used by Dick and Rallis (1991). They refer to the same kind of relationship by using the term *socializers*. Having the same focus as in this study—students' career choices—Dick and Rallis (1991) suggest that socializers' attitudes and expectations regarding career choice are influential. The socializers provide students with their own earlier experiences from the area/issue in question and also of their own (the socializers') ways of dealing with this area/issue. It is, according to Dick and Rallis (consistent with Mead), however, not a question of a one-way influence; students also through their attitudes and ways of receiving input from the socializers. The cultural milieu shapes not only the attitude and expectations of the socializers but also the students' perception of them and what they believe about the value of career.

RELATED RESEARCH

There are numerous studies focusing students' choices of career. In this study, a selection of studies of particular relevance to this study is briefly presented. The presentation aims at highlighting identified themes regarding reasons behind students' choices found in the literature.

Pedagogical Development

There are many researchers suggesting that pedagogical and programmatic changes are necessary to influence current and perspective students' choices to be engineers (e.g., Kaijser, 1998; Williams, 2003; NAE, 2008; Sheppard, Macatangay, Colby, & Sullivan 2009). Subject content, work methods and assessment methods as well as gender aspects of engineering education are examples of issues discussed in these studies. However, before we can effectively design these pedagogical and programmatic changes, we need knowledge about the students' perspectives on why they choose engineering.

The Matter of Expected Status

To understand the factors that lie behind students' choice of education and career, we have to understand the difference between choice-making in the pre-modern society vs. in the present modern society. According to Bauman (2001), pre-modern society social factors such as gender and parents' social status were important factors in developing the identity. In our modern, industrialised society of today, personal choices and values contribute in a more substantial way to the process of developing the personal identity. The choices you make are, according to Bauman, increasingly contributing to the image of the person you 'are' (or the person you want to be). Today, most young people in Sweden are given the opportunity to make choices themselves, education included. The trends among young people regarding what are high – and low-status careers or institutions will, at least to some extent, affect their choice of study path. An example of students' tendency to favour high-status education programmes/universities is illustrated in the results from a questionnaire issued to engineering beginners at the reputed Royal Institute of Technology (KTH). Findings show that the reputation of the university was, among these students, more than three times as important as the nearness to their domicile (KTH, 2008). To paraphrase Giddens (1991): "The question nowadays is not *what* you want to be but rather *who* you want to be."

Interest in Technology

There is a decreasing interest among young people in Sweden to enter a career in the technical/engineering area (SOU 2010:28, 2010). This problem is shared by most countries in the industrialized world. The question of why is interesting. According to Schreiner & Sjøberg (2010), there are possible links between a country's Human Development Index (HDI) and young people's attitude toward science and technology education. Findings in their worldwide ROSE study (Relevance Of Science Education) show that young people in countries with a high HDI express low interest in science and technology education and the reverse situation occurs in countries at the other end of the HDI scale.

The Royal Institute of Technology (KTH) regularly issues a questionnaire among beginners in their programmes for Bachelor of Engineering, about what factor the students consider as important for their choice of school. For six years (2003–2008), an interest in technology and science together with the good reputation of the education provided at KTH has been among the two factors that the students gave the highest score. Other factors of major importance for their choice of university were the opportunity to choose among many different occupations and the possibility to have a prosperous career after their exam. (KTH, 2008).

A Norwegian study (Schriener & Henriksen, et al., 2010) highlighting students' choice of study paths indicates that the combination of an interest in technology and engineering and the perceived possibility to get ‘interesting work’ plays a major role in students’ choice of an engineering career/education. An OECD study (OECD, 2008) came to the same conclusion: “Student’s decisions about study and career path are primarily based upon interest in a particular field, and on their perceptions of job prospect in the field” (OECD 2008). The same results were found also in the Womeng study (EU, 2006).

In a previous study (Ahlbom, 2011), 15-year-old pupils were interviewed about their interest in technology. The focus of this particular study was on the students’ views on the actual instructions given by teachers during technology classes in compulsory school. Finding reveals the importance of (1) teachers’ presentation of the subject and (2) in what environment the instructions were performed. When asked about his interest in technology, a boy in the study frankly states, *“*No!” His explanation for this fact was that he was not “interested in electronics”. All instruction in technology he had received so far had been in electronics. His conclusion was that technology equals electronics. The fact that this boy spent all his spare time repairing old cars and that he had made the choice to attend an education for becoming a car mechanic was, according to him, far from an expression of interest in technology. The importance of technology teachers’ choice of subject content is stressed also by Skogh (this volume):“Technology education in school both symbolizes and embodies the whole concept of technology. If technology activities in school are ‘fun and interesting’ technology as a whole becomes ‘fun and interesting’”.

University vs. Location

According to Holzer (2010), new groups of students have entered university in Sweden during the last 25 years. Many of them are coming from homes without experience with academic studies. Holzer suggests that one of the reasons for this is the new possibilities that have occurred when new smaller, regional universities have been established, often in smaller cities. The vicinity of a university is, according to Holzer, an important factor when new groups without academic background take on university studies (Holzer, 2010).

A quantitative study of young people’s hopes and dreams regarding their private and occupational future (19–25 years) was performed in the region of Gävleborg during 2011. The study showed that more than 50% of the interviewed were interested in getting some form of university education (Jansson & Koskela, 2011). Comparing two different questionnaires circulated among beginners at KTH in Stockholm and the regional university of Gävle (HIG) reveals some differences. The major part of the beginners at Gävle was in the age of 20–25, while the figure for KTH was 18–21. For students at HIG, proximity to the university was the factor that received the highest score, while for the students at KTH, other factors earlier mentioned were of greater importance. For both universities, the major part of the beginners comes from the region where the university is located—for HIG 55% (2009) and for KTH 65% (2008) (HIG, 2009; KTH 2008).

Engineering—a Man's World?

According to the previously presented figures (See Figures 1 and 2) gender seems to play a crucial role in recruiting for education. Despite a lot of effort to increase the number of females taking education in Sweden and in other countries, the figures are still low.

The proportion of women applying for and beginning MaSE and BaE studies between 2004–2005 and 2008–2009 was between 23% and 28% (Högskoleverket, 2009). The figures are mean values and vary depending on the branch of engineering. The exam figures are a bit higher. The number of, e.g., MaSE exams among women was between 28% and 32% in 2008–2009 in comparison to the figures ten years earlier when only 7% of the graduates in the technological area were women (ibid.).

The BaE programme in chemistry had the largest proportion of women—almost 60% of the graduating students were women in 2008–2009. Computer and Electronic Engineering show the lowest figures—between 15% and 18%, of the graduating students were female (Högskoleverket, 2010).

The reasons behind the fact that many women distance themselves from technology have been addressed in a number of studies. Ottermo (2008) points out that the reasons behind women deselecting technology studies are often simplified in wordings stating this "being their own fault". According to another study (EU, 2006, p. 61), female engineering students have to put up with discrimination "in the form of jokes, remarks and even different exam standards".

Many of the traditional engineering areas like mechanics, electronics and computer science are today dominated by men. Berner (2003) suggests that the reason for this could be found in the intimate connection to traditional *masculine areas* like mining, workshops and construction. Areas of engineering not equally connected to typical masculine areas (e.g., biochemistry) do not show the same pattern. On the contrary, these areas are almost dominated by women (Högskoleverket, 2010; Berner, 2003).

The differences in opportunities between men and women are often referred to as being a consequence of the existing 'order of gender'. The origin of these differences could be traced to the life stories of men and women. According to research (e.g. van Diemen, Kuiper, E. R., Mulder, B., Aurell, H., Davidsson, B., Skogh, I-B & Stjerndahl, I-L., 2005) women and men are "exposed to different experiences as a result of culture, which means that they have lived through different and segregated socialisation processes. Thus women and men have developed contrasting skills and interests and have carried out different tasks."

METHOD

The focus of this study is to explore and describe the values expressed by engineering students regarding their choices to engage in engineering studies at a regional university. I have approached this task by using a survey (pilot study) and a variant of an interview methodology specifically developed for this study by Professor Richard Kimbell of Goldsmiths College in London.

Pilot Survey

A pilot survey was performed with the aim to test questions and strategies of questioning engineering students regarding which factors they consider important when choosing a BaE engineering education. The survey was made through semi-structured interviews with four students—one woman and three men—in different engineering programmes (mechanical, electronics and economic engineering programmes) studying at a regional university. All four students were attending their second year of these programmes.

The choice to interview the students during their second year was due to the possibility of gaining a more 'mature view' of the different factors influencing their choice of education. At this point of time, they could be expected to have had time to reflect on their motives and the outcome of their decision.

The selection of respondents was made through the programme directors of the engineering programmes at the university. The programme directors made a selection among students willing to participate in the study. The following areas were addressed:

- Family background (including informants' thoughts about possible parental influence regarding study path and career choice)
- Place of residence before and after entering engineering studies
- Experiences of school in general and of technology education in particular (compulsory school, upper secondary school)
- Reasons for choosing engineering studies (including reflections regarding the importance of having an interest in technology to be successful in engineering studies)
- The origin of their interest in technology
- Expectations regarding future status, salary and job opportunities after completing engineering studies

The semi-structured interviews were audio recorded and transcribed directly after the interviews. Thereafter, the transcripts were read multiple times in search for possible patterns. The questions are linked to the findings of the studies previously presented (section on Related research, p. 8–11):

MAIN STUDY

The result from the pilot study constitutes the basis for the design of the main study, e.g., all question areas presented to the students in the main study (card games and group interviews) relate to the factors expressed by the students in the pilot study.

The Informants

To get access to groups of engineering students willing to be interviewed proved to be harder than I had expected. Teachers involved in on going courses for engineering students were contacted. I asked for permission to visit a lecture in which I could present the research project to the students and ask them to participate in an interview on a voluntary basis.

In total, 19 students (from five different student groups) agreed to be interviewed (17 men and two women). The size of the groups differed slightly; one of the groups had three informants, the rest of the groups, four informants each. The majority of the informants were men, four of the groups consisted entirely of men and one group consisted of two women and one man. The informants are between 20 and 29 years old. A majority of the informants (13) are between 20 and 22 years old. All except one informant lives in the same town as the regional university. This student lived in a town nearby.

Out of the 13 informants living in the same town as the university, three were born and raised there. In total, 11 of the students came from other places around Sweden and had moved to the town in question for their studies. The informants came from four different engineering programmes, i.e., mechanical, computer, electronics and building engineering (c.f. the pilot study).

The time and place for the interviews to be performed were decided during the 'recruitment visit' to the respective lectures visited. All interviews took place at the regional university and at a time chosen by the informants.

Card Game

In order to receive information about the factors that are of importance when choosing an engineering education, it was decided to do a further interview-survey. The method was given the name *Card game*, and hereafter this term is used when referring to the method.

The interview method is designed to give information on two levels—the individual level and the group level. The factors the students were supposed to rank in order of importance to their choice of engineering studies were based on the categories highlighted as important in the pilot study. A deck of cards with text and illustrations were made. The following 16 factors corresponding to the different categories were chosen and presented to the informants:

How the Card Game was Performed

The first part of the card game is a quantitative method to get information from each individual informant about which of the presented factors would get the highest scores. The second part is qualitative, where the informants discuss their results in small groups and give their explanations as to why they have chosen a particular set of factors.

The informants were gathered into groups of 3–5 students. The card-game method was described to the informants, and they were informed about the purpose of the interview and how the collected information would be used in the study. After this introductory phase, each informant got a set of cards according to the presentation in the previous subsection (Figure 3a and b).[5] The informants were seated separated from each other with a table in front of them.

Each deck of cards handed out to the informants consists of 20 cards. Out of these 20 cards, five contained the statement "OTHER FACTORS". This option was meant

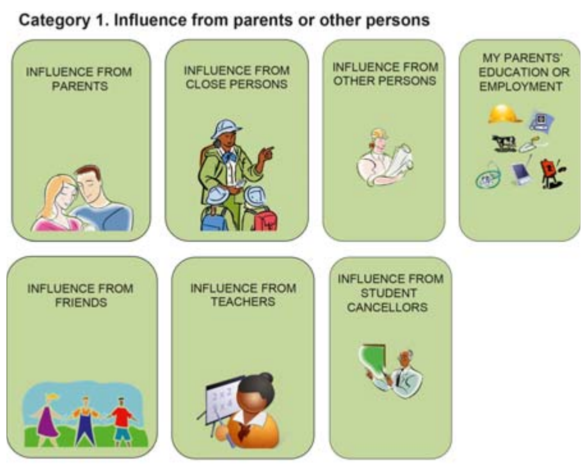

Figure 3a. Cards used in interviewing students.

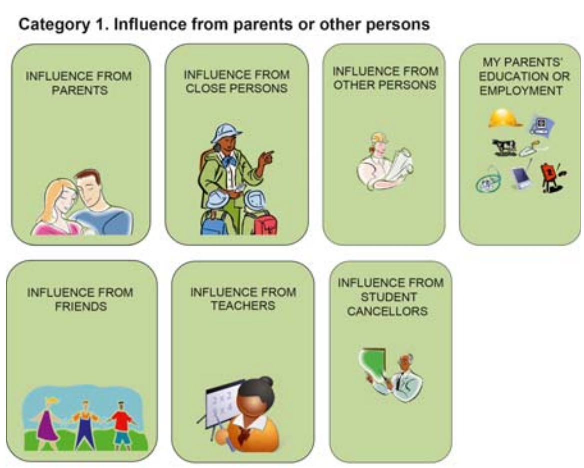

Figure 3b. Cards used in interviewing students

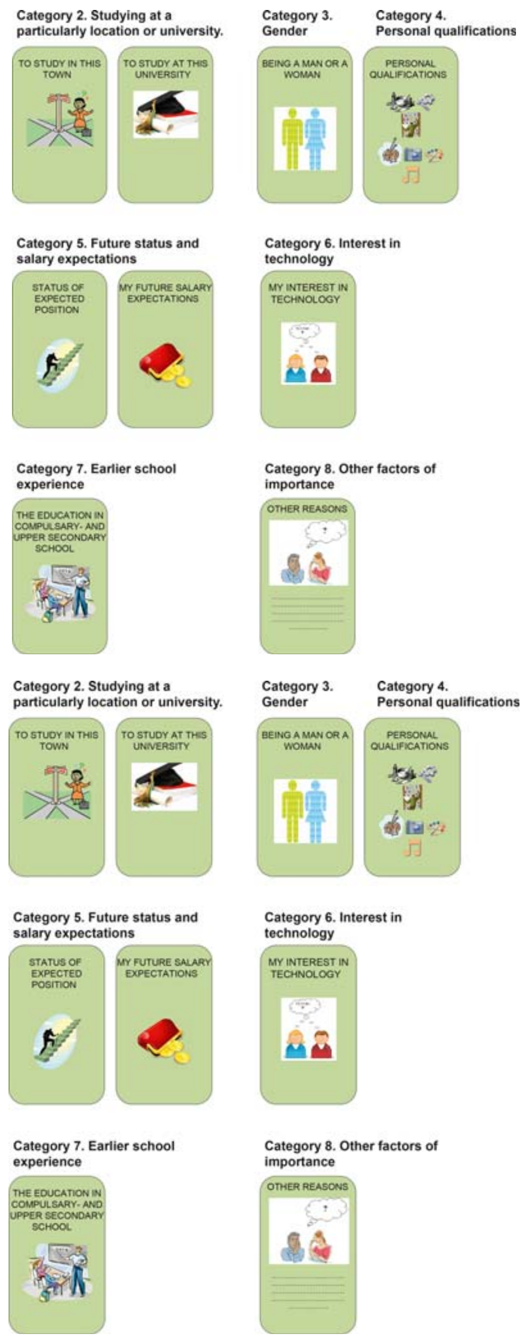

Figure 3b. Cards used in interviewing students (cont.)

to capture any factors that were not stated on the other cards. If this category of cards was used, the informants could state the factor on a sticky note. In the introductory phase of the session, the informants were informed that they freely could suggest any number of factors that they considered to be of importance to their choice of engineering studies. They were also invited to rank the card messages. Instructions given at this stage were: *Which factors do you consider of most importance for your choice of technology education?* The cards/factors the informants considered to be most important were to be put to the left of the desk in front of them. This part of the interview took 10 minutes, approximately. The various combinations of cards/statements were documented by photographing at the end of this first part of the card game interview.

Directly after the closure of the first part (individual arguments), the second part started. The informants were now gathered around one table with their choice of cards in front of them. Everybody had the opportunity to see the choice of cards of the other informants. A discussion around the individual choices of important factors followed. The interviewer led the group discussion with questions around the chosen sets of cards. The discussion was audio recorded and directly after the interview it was transcribed and printed. In the transcript, the statement of each informant was identified by the first letter of their first name. When more than one informant with the same first letter occurred in the data, the second letter in their first name was used to distinguish statements from each other. The transcripts from the different groups were assigned different colours for easier recognition during the analysis phase.

Analysis—Individual Choice of Card/Phrase

The analysis of the first qualitative part of the card game session—the photo of the chosen set of cards for each student—is based on the use of a scale designed for the purpose. The 'top score factor' is given 16 points on the scale, the next one gets 15 points and so on. The total sum of the results for all five group interviews was added and a diagram was made. The result is obviously not statistically significant due to the small number of participants. The result from this first phase of the card game (part 1) is instead intended to be used as a starting point for further discussion with the informants during the second phase of the card game.

Analysis—Group Discussions

The results from the second part (group discussion) during which the students discussed their individual arguments for their choice of factors were also analysed. The transcriptions were read multiple times in order to identify categories and patterns in the collected data. By the different colour of the text, and the capital letters in front of each statement, it was possible to identify to what interview and to which person the statement belonged. Suggested patterns and categories had been tested and re-tested numerous times.

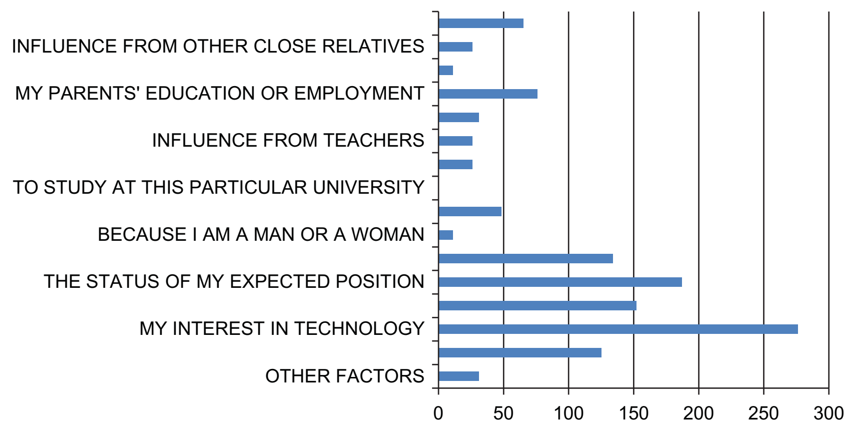

Figure 4. The score chart from the card game of 19 engineering students.

Ethical Considerations

The ethical rules (codex.vr.se) that apply in the context of the interview and the treatment of the material were given the informants in advance of participation. The informants were reminded that their participation was completely voluntary. They were, at any time, free to terminate the interview. The sessions were documented with an audio-recording device to be transcribed and categorised by me at a later stage. All collected data was depersonalised for discretion. To avoid identification of the two female informants, most of the statements presented in the result lack references to the gender of the informant. The statement/game card specifically highlighting gender is an exception from this principle.

RESULTS

The Pilot Study

The pilot study highlighted the importance of in what way questions should be asked in order to get as much valid information as possible. The necessity of avoiding leading questions was for example obvious. An alternative questioning method was therefore developed. However, the pilot study questions 'themselves' were found to be useful.

THE MAIN STUDY

Results—Card Game

In the first quantitative part of the *card game* inquiry, each informant was supposed to choose individually what factors they considered of most importance to their choice of education. They had the free choice of picking as many cards as they wanted.

There was a variation between two and eight cards that each student picked. It was seen that 15 of the informants picked between four and six cards, two informants picked out two cards, and seven to eight cards were picked by two informants, respectively.

The photos of the picked cards by each informant were coded with values on each card depending on order of appearance. The card first in order got the highest score. As there were 16 different cards, the highest scored card got the value of 16 and the next card got the value of 15, and so on. Figure 4 shows the total results from the whole group of informants.

The factor that proved to be highest in significance regarding the choice to enter engineering studies was the card/phrase '*my interest in technology'*. Of all 19 students, 18 had picked out this particular factor. Of all the students, 10 ranked it as the most important, four as the second and four as the third in order. The next factor of importance was the card with the phrase *'status of expected position'*, which was picked by 15 of the students. Two ranked it as number one, one as number two and eight students placed it in third or fourth place.

When all cards showing *socializers* (influence from parents, relatives, friends, teachers, counsellors and other persons close to the student) chosen by the informants are put together, they are third as factors of major importance to the choice of taking on engineering studies. Among the socializers, parents were considered of most importance by the students.

In fourth place came '*My future salary expectations'* picked by 12 of the students. Three of them placed it in second place and the rest at a lower rank. Almost with the same score were the two factors 'P*ersonal qualifications'* and '*The experience I got from primary and secondary school'*. '*My parents' education or employment'* came next in rank followed by '*Influence from parents'.*

For the students in the inquiry it seems that '*To study in this particular location'* is of greater importance than '*To study at this particular university'*. The latter factor was not chosen by any student.

Two students choose to use cards marked '*Other factors'*. One of them ranked "unemployment" as an important factor and ranked it second. The other student put as another factor "my will to increase my knowledge in the technology subject" and placed it as number one. Only one student used the card '*Because I am a man or a woman'* and ranked it as number six out of seven cards.

Results—Card Game Discussion

In the second part of the interviews, the informants gathered with their chosen cards in front of them. All informants in each group were able to see also the cards of the other informants. The informants were interviewed about their choices. In the following section, the most significant results from the interviews are presented. The order in which "factors" are discussed is the same as the score result from the quantitative part shown in Diagram 1.

My Interest in Technology

Most of the students explained their choice of the factor '*My interest in technology'* as being fundamental for their career choice. Having an interest in something is important for the motivation. One of the students said, "Without interest there is no motivation", and another said, "I think to be motivated and to develop you need an interest in what you are dealing with". Interest is not only seen as an interest in technology education by one informant but more as an interest in future occupations based on the chosen education. This informant stated, "My future work shall be so interesting that I can stay until I retire".

To the question where their interest in technology originates from, there was a consensus among the informants. It appears early in life. Two of the informants mentioned their early childhood and the do-it-yourself building kit Lego™ as a great inspiration and something that develops children's interest in technology. For some of the informants, inspiring persons have played crucial roles in developing their interest in technology. It could be a parent, but also somebody else. Most of the students did not consider the technology education they got in compulsory school as a developer of their interest in technology. It was also obvious that they had very different experiences of how the subject was presented in their specific schools. Their education in technology in compulsory school varied from almost nothing to practical work with turning and welding in the workshop.

The informants were more positive about the effect of technology studied in upper secondary school on their interest. A majority of the informants took a programme related to technology in upper secondary school.

In one of the groups, there was a discussion about what we mean when we say 'technology'. One of the informants who did not use the card '*My interest in technology'* said, *"I think I have another view of what technology is . . . I think of technology as only computers . . . I mean machines . . . that's what I think technology is, not math."*

Socializers

When the informants comment on why they chose to use any of the cards including the one on socializers' influence, parents seem to be of greatest importance. Not always by their direct influence, but more through the role of being supportive. One of the students put it like this, ". . . *they [parents] have always been supporting me in what I have been doing, for example, when I was hammering on the kitchen cupboard, they saw it as a future training for using tools."* From the answers, the conclusion could be made that the support from parents is about the importance of getting an education, but not necessarily an engineering education. One of the informants expresses himself like this, *". . . they [my parents] have always inspired me in doing something I am interested in and something I enjoy."* Another says, *". . . my parents' influence is not in a certain subject but more that I should have a good education and work."*

Among the informants, several of them have a parent, often the father, who is an engineer, but not necessarily in the same branch of engineering as their own choice of education. One of the informants doesn't consider his father, who is an engineer, as a role model, but as he says, *". . . he has probably in some way*, *without me being aware of it*, *inspired me."* Another student says, *". . . [My father] is the reason for my interest in technology and especially in construction. I myself have been working as a carpenter*, *and thanks to him*, *I have chosen construction*, *and it suits me."*

According to the students, parents' education and employment play a major role in the choice of taking an engineering education or even an academic education at all. In response to a direct question to the students—if the fact that parents have an academic education is of importance for the decision to enter a university education—most of the students saw it as a crucial factor. One of them, with parents without an academic education, expressed himself like this, *". . . It is not easy to be the first."* For one of the students, the initial reason for entering an engineering education was the fact that his mother, at the age of 40, had finished a three-year university education. He said, *". . . If she was able it is possible for me as well."*

Inspiring teachers both in compulsory school and upper secondary school are mentioned as important socializers by three of the students. One thinks that an inspiring teacher, *". . . sows seed . . . and it lays there. [It is important to] have a good teacher especially in upper secondary school when next step is an academic education or working life."*

Some of the informants describe how they were influenced by other persons regarding their choice of education. One of them describes how he met a friend of his father who asked if he was interested to work as a trainee in their consulting company. After working there for a year, he was offered a position if he educated himself to a construction engineer. Another informant describes his meeting with an education counsellor who totally changed his education plans. The student had decided to take a vocational education in upper secondary school. The counsellor persuaded him to visit an education fair and after that he changed his choice to the science programme in upper secondary school. By this change, the choice of becoming an engineer became easier.

Status of Expected Position and Salary Expectations

The interviewed students consider an engineer as a trustful person with a certain status. Having a degree as an engineer is high in status according to them. One of the informants made this reflection about the status, *". . . It is more the education . . . the fact that you have been studying for three years to get the degree feels much*, *much better. If the engineering degree is from upper secondary school or a bachelor of engineering is not that important. More the fact that you do have a degree."*

The idea that engineers are expected to take on great responsibility from the employer is mentioned by many students as being a factor increasing the status. One of them described the picture of the engineer as, *" . . . If you tell someone that you* *are a construction engineer*, *they probably think: This is an intelligent person who you can trust. That's the way I have felt anyway."* One of the interviewed women expressed herself like this, *". . . Especially if you are a girl and tell people that you are studying to become a construction engineer*, *they say*, *'Cool!'. So I think that other think of it as higher in status than you do yourself."*

An informant said, ". . . many [people] think of a smart person when they hear the word engineer" .and that, ". . . to become an engineer you have to study a lot and put less time on pleasure."

For one of the informants, status is when you get a higher position in society than your parents. He described it as, *". . . making a journey."* In Sweden, making so-called social "class journeys" is something worth bragging about in social life.

The informants consider salary an important factor for choosing to be an engineer, although very few of them knew what a normal salary of engineers could be. One of the reasons they gave for getting a high salary was spending three years in education. They meant that education should pay off. One of the students put it like this, *". . . perhaps you wouldn't educate yourself if it didn't give you a higher salary."* And another one in this way, *". . . For me it is a driving force to be educated in something where I can develop myself both in terms of salary and skill in work."*

Personal Qualifications

The ability to solve problems and curiosity are described by the informants as important personal qualifications when you attend an engineering education. One of the students described his curiosity by saying, *". . . Yes*, *you want to investigate more and more about different things and how they work*, *it's a bit like having an interest in research."* Another describes his ability and pleasure in reading technical manuals as an important personal qualification for him. In one group, they discussed if there is a difference between being curious and being interested. One student considers her interest as her personal qualification.

Gender

Comments regarding gender occur only in the group discussion where the two participating women were involved and the card '*Because I am a man or a woman'* was picked as a factor of relevance. The woman who used the card explained her choice by saying, *". . . when I thought about what education to choose I saw that there were a lot of educations to choose among . . . many people and especially girls who are engineers themselves gave me the advice to choose engineer*, *because you will be very much sought after especially as a female . . ."*

University vs. Location

None of the informants used the card '*To study at this **particular** university'*. However, the card '*To study at this particular **location**'* was picked by three students. During the discussions, however, the fact that the universities were close to the students' residence was highlighted as being an important factor to many of the students. Words like *nearness*, *not move*, *close to my family*, *the closer the better*, *hard to move from X*, were used frequently in the discussion.

In three of the groups, the informants compared the university they attend with other bigger and older universities (e.g., Chalmers Technical University in Gothenburg and KTH in Stockholm). As regards status and quality of education, some of the students meant that the older universities are higher in status, but that does not necessarily mean that the education is better. One of the informants expressed himself about what he had thought about the university he now studied at before he entered the education, *"it feels like if you aren't able to get in to other universities you could get in here." He had changed his opinion after entering his education and now he says*, *". . . it is a damn good education."*

DISCUSSION

Two research questions have been raised in this chapter. The first question (Q1) addressed the focus on engineering students' reasons regarding their choice to enter engineering studies. The second question (Q2) addresses the choice of a smaller, local university.

The results will be discussed in accordance with these questions.

Q1. What Values do Engineering Students Express as Important Factors in General When Choosing an Engineering Education?

According to the students in the study, the most important factor to stimulate recruitment for engineering studies is the individual's *interest in technology*. The informants emphasise the importance to acquire this interest early in life, probably already in pre-school. The question is where this interest in technology is picked up? The students in the study had very different experiences from instructions in technology in compulsory school. When the students talked about their experiences from technology education in compulsory school, they referred to a wide range of examples of how the teaching was performed. One informant expresses this in the following way: *"[Teachers] . . . sow seed . . . and it lays there. [It is important to] have a good teacher especially in upper secondary school when next step is an academic education or working life."* Teachers should be aware of the fact that the content they use in their teaching is defining the subject for the student, and also what he/she is supposed to be interested in. These findings are very much in line with previous research (e.g., Ahlbom, 2011; Skogh, this volume).

The importance of people showing passion for technology outside the school is also pointed out by the students. Inspiration may be awakened by a family member: *"[My father] is the reason for my interest in technology and especially in construction. I myself have been working as a carpenter*, *and thanks to him*, *I have* *chosen construction*, *and it suits me."* Others mention 'significant others' (Mead, 1969) outside the family circle. (e.g., the student who was offered a trainee position from a friend of his father and from this experience became interested in becoming an engineer).

The students consider personal qualification as an important factor when choosing an engineering education. In the discussion session, their definition of 'necessary personal qualifications' varies. One student means that curiosity is an important factor. In another group, the discussion focused on the distinction between curiosity and interest. Is it possible to develop and grow one's interest or curiosity in technology?

Status and salary expectations are also mentioned as being important factors. The students describe an engineer as a person with great responsibility. Being responsible and trustful is something that increases the status. One of the students describes it like this: as an engineer you will take on great responsibility from the employer. This is a fact that informants mention as a factor increasing the status. One of them described the picture of the engineer as, *". . . This is an intelligent person [an engineer] who you can trust."*

Even if some of the students did not know what salary they could expect after graduating, they consider a good salary as important. One of the reasons for that was the fact that they spent three years at the university, something that should pay off. For one of the students, the relation between education and expected salary was put like this, *"perhaps you wouldn't educate yourself if it didn't give you a higher salary."*

The importance of pedagogical development in engineering education pointed out by, e.g., Kaijser, 1998; Williams, 2003; NAE, 2008; Sheppard et al., 2009, is not reflected in the findings of this study. The students express few (if any) comments regarding the pedagogical strategies and methods used by the university teachers in the various engineering courses. However, these kinds of remarks regarding teaching methods are frequently expressed regarding the technology education the students in the study encountered in compulsory school.

Q2. What Values do Engineering Students Express as Being of Importance for Choosing a Technology Education at a Regional University?

The second research question focuses on the recruitment of engineering students outside the major cities. As mentioned previously, a lot of money and prestige has been put into the establishment of regional institutions of higher education in Sweden. Hopes of possible recruitment of new groups of students for engineering education as well as increased regional availability of engineering expertise have been expressed by those in favour of regional engineering universities. Findings show that the possibility of attending a university close to the students' home municipality is considered important. Several of the students in the study refer to this possibility as a major factor for their choice of starting academic studies. This is, according to the students, not something 'typical' for engineering education/studies but is valid for all kinds of academic educations.

The results fit well into the pattern pointed out by Holzer (2010) who argues that the new possibilities that have opened up when new smaller, regional universities have been established around the country are an important factor behind new groups without academic backgrounds taking on university studies. Accordingly, findings indicate that both society and potential engineering students will benefit from engineering universities being made available to students in the whole of Sweden.

CONCLUSIONS

There are obviously a lot of different factors that are of importance for students to make the choice of attending an engineering education. The students in this study highlight the following choices as being of particular importance to them:

- Interest in technology
- Personal qualifications
- Influence from different persons in or outside school
- Expected status and salary
- Attending an engineering education close to their home municipality

To provide society with engineering expertise, a number of things have to be done. If the most important factor for choosing engineering education is the students' interest in technology, measures need to be taken to make this interest develop and grow.

- Technology education in compulsory school must be developed into a subject providing a creative environment, both in terms of well-educated teachers and with modern equipment, suitable for stimulating an interest in technology.
- It is (according to findings) important that students with a special interest/ability in technology are given the opportunity to develop their skills and qualifications. To, for example, initiate meetings with inspiring 'role models' in or outside school will benefit both interested and 'not-yet' interested students.
- Society must signal that education is profitable, both in status and in earnings, engineering education not being an exception. When engineering students make the choice of attending three years of education, they must trust that their choice is one that pays off.
- It is important that society enables new groups of students entering university the closeness that is of certain value. Some of the students in this study have for example established a family. The possibility of combining engineering studies at a regional university with family life is a central factor to their choice.
- Regional universities are important 'as such' but there is also a quality aspect. Regional universities need to be competitive in education quality. It is therefore important to secure economic resources, staff competence and development opportunities at all regional engineering universities.

NOTES

[1] *Civilingenjör* in Swedish
[2] *Högskoleingenjör* in Swedish
[3] OECD: Organization of Economic Co-operation and Development. The 33 member countries of OECD are Australia, Austria, Belgium, Canada, Chile, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, Korea, Luxembourg, Mexico, the Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey, United Kingdom, United States.
[4] An antique gun used for throwing stones
[5] The text on the cards was written in Swedish.

REFERENCES

Ahlbom, H. (2011). Teknikintresserad? – Jag? In S. O. Hansson, E. Nordlander & I-B. Skogh,(Eds.), *Teknikutbildning för framtiden*(pp. 8–22). Stockholm: Liber.

Ahlgren, R-M. (1992). Jag en social varelse. In P. Björklid & S. Fischbein (Eds.), *Individens samspel med miljön* (pp. 29–42). Stockholm: HLS Förlag.

Bauman, Z. (2001). *Det individualiserade samhället. Göteborg:* Daidalos.

Berner, B. (1981). *Teknikens värld: teknisk förändring och ingenjörsarbete i svensk industri.* Lund: Arkiv för studier i arbetarrörelsens historia

Berner, B. (2003). *Vem tillhör tekniken?Kunskap och kön i teknikens värld.* Lund: Arkiv förlag

Bernstein, B. (1975). *Class, codes and control: Towards a theory of educational transmission* (Vol. 3). London: Routledge & Kegan.

Blomdahl, E. (2007). *Teknik i skolan: En studie av teknikundervisning för yngre skolbarn* (Studies in educational sciences, nr 99). Stockholm: Stockholms universitet.

Bourdieu, P. (1987). What makes a social class? *Berkley journal of sociology, 32*, 1–18.

Bourdieu, P. (1993). *Kultursociologiska texter*. 4. uppl. Stockholm: B. Östlings bokförlag. Symposion

Bourdieu, P. (1994). Structures, Habitus, Power: Basis for a Theory of Symbolic Power. In N. B Dirks, G. Eley & S. B. Orther (Eds.), *Culture/power/history-a reader in contemporary social theory* (pp. 155–199). New Jersey: Princeton University Press. Retrieved October 2, 2011 from: http://www.google.se/books? hl=sv& lr=&id=ZOOAMZu8mhIC &oi=fnd&pg=PA155&dq=bourdieu+habitus+1994&ots=4akyF0lVcy&sig=TxblFV_tGewbxYdO9nK

Bromfenbrenner, U. (1989). Ecological systems theory. In R. Vasta (Ed.), *Six theories of child development. Revised formulations and current issues* (pp. 187–250). London, Pennsylvania: Jessica Kingsley Publishers.

de Vries, M. J. (2009). The developing field of technology education: An introduction. In A T. Jones & M. J. de Vries (Eds.), *International handbook of research and development in technology education* (pp. 1–9). Rotterdam: Sense Publishers.

Dick, P. T., & Rallis, F. S. (1991). Factors and influences on high school students' career choice. *Journal for Research in Mathematics Education*, *22*(4), 281–292. Retrieved October 2, 2011 from: http://www.jstor.org/pss/749273

Elgström, O., & Riis, U. (1990). Läroplansprocesser och förhandlingsdynamik: Exemplet obligatorisk teknik i grundskolan (Linköping studies in arts and science, nr 52). Linköping: Linköpings universitet.

EU. (2011). *Reform program for higher education.* Information material. Retrieved October 12, 2011 from: http://ec.europa.eu/news/culture/110926_en.htm

EU. (2006). *Creating cultures of success for women engineers–Womeng.* European research on social sciences and humanities. Project HPSE — CT-2002–00109. Final report. Luxembourg: Office for Official Publications of the European Communities, Retrieved November 26, 2011 from: http://ec.europa.eu/education/lifelong-learning-policy/higher_en.htm

Giddens, A. (1991). *Modernitet och självidentitet.* Göteborg: Daidalos.

Holzer, S. (2010). *University choice, equality, and academic performance*. Växjö: Växjö University Press.

Högskolan i Gävle, (2009). *Startenkät 2009.*

Högskoleverket (2010). *Rapport 2010:10R*, *Universitet och högskolor*, *Högskoleverkets* årsrapport 2010. Retrieved December 16, 2011 from: http//:www.hsv.se/download/18.5549c4e7128dec8c628.000.2899-universitet-hogskolor-arsrapport-2010.pdf

Högskoleverkets rapportserie 2002:27 R (2002). *Tekniskt sett. Högskoleingenjörer – kartläggning och enkätstudie.* Stockholm: Högskoleverket.

Jackson, S. A. (2002). The quiet crisis: Falling short in producing American scientific and technical talent. In *Building engineering and science Talent* (pp. 1–12). Report. San Diego, CA: BEST

Jansson & Koskela. (2011). *Unga vuxna I Gävleborgs län – resultat av en enkätstudie och förslag på insatsområden.* Falun: Dalarnas forskningsråd

Kananoja, T. (2009). Technology education in general in Finland. In A. T. Jones & M. J. de Vries (Eds.), *International handbook of research and development in technology education* (pp. 41–50). Rotterdam: Sense Publishers.

Kaijser, A. (1998). Ingenjörer i takt med tiden. I: *Vad är en ingenjör*?. Linköping: Linköpings universitet.

KTH (2008). *Startenkät 2008. Jämförelse med tidigare år. Högskoleingenjörer.* Matusovich, H., Strevler, R., & Miller, R. (2010). Why do students choose engineering? A qualitative, longitudinal investigation of students' motivational values. *Journal of Engineering Education, 99*(4), 289–303.

Mead, G. (1969). *Mind*, *self and society.* Chicago: University of Chicago Press.

Middelton, H. (2006). Changing practice and changing lenses: The evolution of ways of researching technology education. In M. J. de Vries & I. Mottier (Eds.), *International handbook of technology education* (pp. 53–61). Rotterdam: Sense Publishers.

Mjardevi Science Park, (2010). *Vem vill bli ingenjör?* Information material. Retrieved January 12, 2012 from: http://www.mjardevi.se/sv/om-mjardevi/nyhetsarkiv/299-vem-vill-bli-ingenjoer

National Academy of Engineering (NAE). (2004). *The engineer of 2020: Visions of engineering in the new century.* Washington, DC: National Academies Press.

National Academy of Engineering (NAE). 2005. *Educating the engineer of 2020: Adapting engineering education to the new century.* Washington, DC: National Academies Press.

OECD (2008). *Encouraging students' interest in science and technology studies*. Report. OECD: Global Science Forum.

Ottemo, A. (2008). *Rekryteringssarbete och genusmönster i rekryteringen till Chalmers utbildningar på EDITZ-området*, Göteborg: Chalmers tekniska högskola.

SCB (2009). *Trender och prognoser 2008.* Retrieved October 16, 2011 from: http://www.scb.se / statistik/_publikationer/UF0515_2006I30_BR_00_AM85BR0901.pdf

Schreiner, C.;Henriksen, E.; Sjaastad, J; Jensen, F.; Løken,M. (2010). *Vilje-con-valg: Valg og bortvalg av realfag i* høyere *utdanning.* KIMEN Skriftserie, Nr 2. Oslo: Naturfagssentret. Retrieved November 20, 2011 from: http://www.naturfagsenteret.no/aim/naturfag3/files/8/d/8/795896e8913c808fbb3ab5eebfac25046578e49e9f/8d8795896e8913c808fbb3ab5eebfac25046578e49e9f.pdf

SFS, *Högskoleförordningen* (1977:26). Retrieved May 29, 2012 from: http://www.notisum.se/rnp/sls/lag/19770263.htm

Sheppard, S., K., Macatangay, A., Colby & Sullivan W. (2009). *Educating engineers: Designing for the future of the field*. San Francisco, CA: Jossey-Bass.

Schreiner, C., & Sjøberg, S. (2010). *The ROSE project. An overview and key findings.* Retrieved November 20, 2011, from: http//:www.uv.uio.no/ils/english/research/projects/rose/publications/the-rose-project.pdf

Skogh, I-B. (2001). *Teknikens värld-flickors värld: En studie av yngre flickors möte med teknik i hem och skola* (Studies in educational sciences, nr 44). Stockholm: HLS Förlag.

Skolverket. (1994). *Läroplan för de frivilliga skolformerna*, *Lpf 94*. Retrieved November 11, 2011 from: http://www.skolverket.se/2.3894/publicerat/2.5006?_xurl_=http%3A%2F%2Fwww4.skolverket.se%3A8080%2Fwtpub%2Fws%2Fskolbok%2Fwpubext%2Ftrycksak%2FRecord%3Fk%3D1071

Skolverket (2005). Slöjd. Ämnesrapport 253. Nationella utvärderingen av grundskolan 2003. Stockholm. Frizes.

Skolverket (2011). Läroplan, examensmål och gymnasiegemensamma ämnen för gymnasieskola 2011. Retrieved November 11, 2011 from: http://www.skolverket.se/2.3894/publicerat/2.5006?_xurl_=http%3A%2F%2Fwww4.skolverket.se%3A8080%2Fwtpub%2Fws%2Fskolbok%2Fwpubext%2Ftrycksak%2FRecord%3Fk%3D2705

Skolverket (2011). *Läroplan för grundskolan*, *förskoleklass och fritidshem*, *Lgr 11*. Stockholm: Skolverket
SOU 2010:28. (2010). *Vändpunkt Sverige– ett ökat intresse för matematik*, *naturvetenskap*, *teknik och IKT.* Teknikdelegationens betänkande. Stockholm: Fritzes.
Säljö, R. (2010). *Lärande i praktiken. Ett sociokulturellt perspektiv.* Stockholm: Norstedts.
Urank (2011). Report. Sveriges universitesranking. Retrieved May 15, 2012 from: http://www.urank.se
Williams, R. (2003). Education for the profession formerly known as engineering. In *Chronicle of Higher Education* (Vol. 49), January 24, 2003. University of New South New Wales, AUS.
van Diemen, Kuiper, E. R., Mulder, B. Aurell, H., Davidsson, B., Skogh, I-B, & Stjerndahl, I-L (2005). *Kvinnor som skapar teknik.* Nutek förlag.
von Wright, G. H. (1983). Determinism and the study of man. In *Philosophical papers of Georg Henrik von Wright. Practical reason* (Vol. 2, pp. 35–52). New York: Cornell University Press.

PATRICIA KINGDON

10. THE SUCCESSFUL STUDENT

A Study Examining How Young Swedish People Represent Engineering Students Discursively

INTRODUCTION

During the past two decades, Sweden – just like many other OECD – countries – has experienced a decline in the number of students who begin studies at technical university. This development has troubled several Swedish governments. The current government[1] perceives the declining interest to study at technical university as a threat to the nation's economic growth and wealth (Sveriges Regering Utbildnigsdepartmentet: Globaliseringsrådet, 2008, pp. 4–5). This way of reasoning derives from the notion that a nation's ability to do well in the future depends on its ability to foster knowledge among its citizens. In Sweden, this notion has frequently been linked to the country's ability to produce engineers. This has resulted in a discourse that brings engineering forward as an area of knowledge that is particularly important to Sweden's economic growth and wealth. It is therefore not surprising that several Swedish governments over the years have initiated investigations and campaigns with the aim to direct young people towards technical university. In addition other parties such as trade organisations, technical universities and unions have made their own surveys and campaigns.

Even in times when the number of applications to engineering programs has been high, Swedish governments have been involved in calling for more engineers. The Swedish National Agency for Higher Education means that the need for engineers has been emphasized since the 1960s (Högskoleverket, 2002, p. 9). The demand for engineers and engineering students has fluctuated with the ups and downs of the Swedish economy. In the 80s, the call for engineers peaked due to a perceived shortfall of technically trained people in the industry (Berner, 1981). In the early 90s, the call for engineers was less urgent. This was most likely an effect of the economical regression that Sweden and many other nations were experiencing at the time. In the late 90s there was a pronounced decline in the number of applicants to technical universities. Some technical colleges and universities had problems filling their spaces. This declining interest for studying at technical university in the 90s coincided with better times for the Swedish economy.

Statistics from the Swedish National Agency for Higher Education show that the number of applicants to technical university started to drop in 1999/2000, and

I.-B. Skogh & M.J. de Vries (Eds.), Technology Teachers as Researchers, 199–221.

continued to do so until 2007 (Högskoleverekt, 2011a). Since then there has been an increase in applications to university in general. In 2011, the Swedish master of engineering programs had recovered from the 'bad years'. In the autumn of 2011, these programs had approximately 200 more applicants than they had in the autumn of 2001(ibid). The number of applicants to the middle engineering programs has increased since the 'bad years'. But the recovery has been less prominent than on the master of engineering programs. In the autumn of 2011, the number of recruits to the middle engineering programs was still 2000 fewer than in the autumn of 2001.

The latest initiative that a Swedish government has taken to encourage young people to take an interest in science and technology was launched in 2008. It started with the forming of a temporary delegation: *The Technology Delegation*. Their task was to investigate how young Swede's interest in science and technology could be increased and how the number of recruits to technical university could be increased. In addition to investigating the matter and making suggestions the Technology Delegation was commissioned to actively encourage young people to study technology and science. To do this the Technology Delegation organised a recruiting campaign with the aim to direct 15 year olds towards the science program in upper secondary education. This route was chosen because the science program is an educational program that is known to have a particularly high percentage of students going on to university studies (Högskoleverket, 2011b p. 14). The interest in studying science and technology is also high among students from this program (Statistiska Centralbyrån, 2010b). The Technology Delegation also arranged seminars with influential individuals from the fields of science, technology and education. The doctoral students from the research school TUFF were also invited to these seminars. At the seminars, focus was on coming up with new ideas for how young people's interest in science and technology could be increased. The Swedish astronaut Christer Fugelsang and other influential people were taken on board to give the cause publicity.

In the Technology Delegation's final report SOU 2010:28 the difficulties in increasing the interest for studying at technical university among young people is presented as a problem that can be fixed by making changes to the current educational system. The Technology Delegation's opinion was that the years of compulsory education are the most crucial years when it comes to influencing young people to take an interest in science and technology (2010, p. 94 ff.). In the report they point out that that compulsory education has failed to awaken the Swedish youth's interest in science and technology. This, they argue, is a consequence of very few teachers in compulsory school having any, or enough technical training. The Technology Delegation suggested that municipalities and principals should be made responsible for making sure that teachers receive technical training (2010, p. 105).

The commission in itself and many of the suggestions that the Technology Delegation proposed are in many ways a repetition of what had been said in an earlier governmental initiative: The NOT – project, which was a project initiated in 1993 and extended in 1999 until 2003 (The Swedish National Agency of Higher Education, 2002, p. 9). The aim of the NOT-project was to stimulate young people's interest in science and technology, especially among girls (Rang, 2005). Both the NOT-project and the Technology delegation are examples of governmental initiatives where the objective to investigate is mixed with an instrumental aim to fix what is experienced as a problem. Mixing instrumental aims with the objective to investigate a subject matter is not an approach that is recommended by researchers. For this reason I support the idea that a critical approach should be used when investigating this subject matter further. This does not mean that I do not support research about what is good technical school practice, e.g., what pedagogical methods can encourage young people to take an interest in science and technology, and thus make them interested in studying engineering. It simply means that I believe that there is a need for research that problematizes the subject matter before any more attempts are made to fix what is experienced as a problem. Often when the difficulties in increasing the number of recruits to technical university are discussed, it is said that there is a mismatch of attitudes between on one hand young people's views and priorities of occupational choices and on the other hand their attitudes towards science and technology education. A common explanation of why this is the case is that young people's image of the engineering student and engineering studies is negative. My view is that very little attention has been given to a critical examination of this notion. For this reason, I have made it the objective of my licentiate thesis to perform a critical examination of this subject matter. Note, that the aim with this project is not to solve the problem how to increase the recruitment to technical universities. It is to problematize assumptions that governing strategies of young people's educational and occupational choices are based on.

The approach that has been chosen to examine the subject matter is to perform two separate studies of two different discursive contexts: one that represents Swedish youth (this text) and another that represents a Swedish technical university (KTH). In both of these studies the ways that engineering students are represented discursively are examined. The aim is to approach an understanding of what the normative view is on who is considered suitable for engineering studies, thus who is excluded from this area of knowledge.

AIMS AND OBJECTIVES

The objective of this study is to examine how young people in Sweden represent engineering students discursively, thus how they construct a notion of the subject who is suitable for studies at a technical university. Knowing what young people think is important because in today's society one's choice of occupation is a matter of self – actualization and not an obligation imposed upon us. The sociologist Rose phrases this as follows:

> Work is no longer an obligation imposed upon individuals, nor an activity only undertaken for instrumental reason. Work itself is a means of self – fulfilment, and the pathway to company profits is also the pathway to individual self-actualization. (Rose, 1999, preface to the first edition, p. xxix)

BACKGROUND

Attitudes Towards Science and Technology

The Rose Project – the relevance of science education is a recent example of a study that points towards a mismatch existing between young people's attitudes towards technology and science, and science and technology education. The Rose project is a comprehensive international study about attitudes towards technology, and how they differ from nation to nation. In one of the project's reports, Schreiner & Sjøberg suggest that most people, young and old, have a positive attitude towards science and technology (2010, p. 7). Most positive are the populations of the developing world (Schreiner & Sjøberg, 2010, p. 15). Schreiner & Sjøberg find that young people, mostly in the richer countries are more sceptical towards technology and science than the adult population, and girls are more sceptical than boys (2010, p. 7). The suggested mismatch between young people's attitudes toward technology and science, and science and technology education appears in the Rose study when young people are asked about their attitude towards science and technology education. This proves to be much less positive than their attitude towards science and technology in general (Schreiner & Sjøberg, 2010). These findings, added to the declining number of applicants to technical university have led to technical universities perceiving, or fearing that they are associated with a negative image. To come to terms with this, many technical universities have conducted studies of their own. Two Swedish examples of such studies are briefly mentioned in this text. One is a smaller survey conducted by The Royal Institute of Technology (KTH), in Stockholm, the other is a critical study commissioned by Chalmers Technical University in Gothenburg. In both of these studies it is suggested that engineering students are associated with geeks, especially maths geeks (KTH 2006, Ottemo 2008). In KTH's survey from 2006 it is proposed that the general public in Stockholm associate the engineering student with a person who prefers numbers to people, in other words a maths geek. The objective of Chalmers' study that was conducted by Ottemo was to investigate what effect gender patterns in the EDITS – area (electrical engineering, computer science, IT and automation and mechatronics) at Chalmers Technical University have on the recruitment of students. Ottemo, who was commissioned by Chalmers to perform the study, found that engineering students within the EDITS – area perform student rituals that honour the mind as superior to the body. These rituals strengthen the identity of an intellectual masculinity, which consequently excludes women (Ottemo, 2008, p. 22 ff). Ottemo concludes: "technology is not neutral, it is soaked in conceptions of gender" (2008, p. 17).

In Sweden, the dominating approach to studying young people's attitudes towards technology and science has been to apply a gender perspective. Two perspectives have been dominant among these studies. One is the search for a school practice that can appeal to both girls and boys. A Swedish example of a study where this approach is used is Skogh's doctoral thesis in which Skogh has examined how girls' attitudes towards technology are affected by early experiences of technical education (2001).

The other perspective is a historical one, not necessarily limited to a school context. Berner and Mellström are two Swedish researchers who have applied this approach in their research (Berner 2003; Mellström 2009). Both Berner and Melmström support the notion that through history, technical knowledge has been a masculine domain, and that this is a problem for any attempt made to recruit more women to technical education. In a recent doctoral study by Fröberg, the pedagogical and the historical perspectives have been combined to study how gender representations have been linked to the forming of the technology-oriented program, within Swedish Upper Secondary School during the late 90s. Fröberg's study confirms that it is difficult to change attitudes about gender, and that what is suggested in policy documents is not always what happens on the floor (2010).

CONCEPTUAL TOOLS

My interest in studying how the engineering student is discursively represented, and thus how a notion of who is considered to be suitable for studies at a technical university and who is not, has its roots in Foucault's way of thinking. The theoretical perspective that is used in this study is also inspired by the post-Foucaultian researchers Rose and Popkewitz. Here, I will give a brief description of what in these researcher's ways of reasoning is applicable for this study. This will be followed by a detailed description of the methodological approach.

There is no fixed way to use the notions that Foucault developed. Foucault himself suggested in an interview, that his notions should be used as a toolbox, and that it is up to each researcher to find out for him or herself what notions are suitable for the objective in mind (Foucault as cited in Olsson, 1997, p. 33).

Foucault's view on 'truth' is central to my understanding of the same. Foucault argued that what is considered as a 'truth' is an effect of what has been established as 'truth' in a specific social and cultural context, in a specific time (Foucault, 1977, pp. 142–144). In this context, this means that how engineering students are discursively represented has an effect on who is considered to be suitable for studies at a technical university, and who is not. An individual who chooses to study engineering cannot avoid being associated with the normative view that is brought forward by the discourse that is dominating at the time. This is why how educational choices and occupational choices are represented matter. Foucault believed that by studying how 'truths' are formed, one can come to an understanding of how the power balance shapes what is possible to say or think about a phenomena or an object during a specific time and in a specific social and cultural context. A common criticism against Foucault's way of thinking about 'truth' is that if we cannot reach beyond what is experienced as truth, what is real? Sjöberg addresses this criticism by saying that this approach does not mean that constructed 'truth' cannot, in practice, be experienced as extremely real (2011, p. 25). For example, if the majority of a population believes that engineering knowledge is difficult and demanding, those who study engineering are experienced as smart. As this discourse is established it is experienced as extremely real, and people will act as if this is a 'truth'.

According to Foucault we cannot stand outside the discourse. What we can do however, is to study the processes in play when so called ‘truths’ come into being. In an interview Foucault said that his role was

> to show people that they are much freer than they feel, that people accept as truth, as evidence, some themes which have been built up at a certain moment during history and this so called evidence can be criticized and destroyed. (Foucault as cited in Martin, 1982, p. 10)

Consequently discourse analysis can be used to expose how power relations influence how a discourse is established. The most common way to describe what a discourse is, is to describe it as a more or less uniform written or spoken statement about a phenomenon or an object. Foucault’s view on discourse was more complicated. He argued that it is both a result of a practice and the actual practice itself– the institution. According to Foucault, “the term ‘institution’ is generally applied to every kind of more or less constrained, learned behaviour. Everything that function in society is a system of constraint” (Foucault, 1980 p. 197–198). Consequently, there is no clear boundary between a discourse and what is institutional. The following quote may clarify what he meant:

> …If you take Gabriel’s architectural plan for the Military School together with the actual construction of the School, how is one to say what is discursive and what is institutional. (Foucault, 1980. p. 198)

I will now leave Foucault and bring Rose and Popkewitz into this context. Rose’s research is of relevance to this study because it provides a way of reasoning about how individuals are active in shaping themselves, including the choices we make in life, such as occupational choices. According to Rose, governing in an advanced liberal society is based on individuals continuously shaping themselves as autonomous self – responsible subjects who take responsibility for their individual life path by making choices on the basis of their own ideals, abilities and aspirations (Rose 1995, Dahlstedt and Hertzberg, 2011). This way of reasoning supports Schreiner & Sjøberg’s findings, which showed that a positive attitude towards technology and science is not enough to make young people interested in the engineering occupation. The educational or occupational choice has to match the individual’s ideals, aptitude and ambition (Schreiner & Sjøberg 2010, see also Oshborne 2009).

Popkewitz’s research is of relevance for several reasons. For one, it has been a source of inspiration for understanding how subjects are shaped within the educational practice. Furthermore, Popkewitz’s understanding of the notion of the cosmopolitan has proved most helpful when analysing the jargon used in this study. The cosmopolitan notion derives from the turn of the twentieth century. At this time the cosmopolitan was “a socialized individual who embodied the national exceptional” (Popkewitz 2003, p. 47). Those who did not live up to these demands were the barbarians of the time (ibid). Popkewitz’s notion of the cosmopolitan of today is slightly different than the cosmopolitan of the turn of the twentieth century.

His notion of the *cosmopolitan* is an active, problem-solving, self – managing, lifelong learner, at school and outside school (ibid). Popkewitz argues that those who do not live up to these demands are the barbarians of our time (ibid). These individuals are excluded as ‘other’; they are the ones at risk and those who are in need of help (Popkewitz 2003, 2008). The practice that is generally tasked with saving children at risk is the educational practice and the pedagogical expertise (ibid). In this study, the participants code certain skills, traits, aptitudes, attitudes and values to the subject who they perceive as suitable for studies at a technical university. As they do this they list demands and use systems of exclusion to include or exclude individuals from the discourse.

GENERAL DESCRIPTION OF THE METHODOLOGICAL APPROACH

To be able to analyse the jargon that is used when young Swedish people construct a notion of whom the engineering student is, I needed a discursive context to analyse. Because there are no official documents where young people in Sweden discursively represent engineering students, such a context had to be constructed. To do this, I designed an empirical study. The method which is used is inspired by an approach that I, in the spring of 2010 the lobby group *Teknikföretagen* saw in use when representatives from Teknikföretagen visited schools, to inform and talk to Upper Secondary School students about what the engineering profession and engineering studies at a technical university in Sweden are like. During these visits, Teknikföretagen used post-it notes, in a structured manner to encourage the Upper Secondary School students to have a conversation about their perceptions of the engineer and engineering education. I found this approach very successful and therefore I used their method as a source of inspiration when designing the methodological approach that is applied in the empirical study. A detailed description of the method is given after the description of how the participants were chosen.

The Participants

The participants were chosen because they were likely to be considering their possible future careers at the time of the study. Subsequently, I was lead to Upper Secondary School Students (17–18 years) who at the time of the study were enrolled in the last year of their three-year education[2].

Although Upper Secondary Education is a voluntary school form in Sweden, as many as 95 % of the 17 year olds, and 91 % of the 18 year olds were enrolled in Upper Secondary Education in 2009 (Statistiska centralbyrån, 2010a). According to Statistiska centralbyrån, 58 % of the enrolled students in the third year of Upper Secondary Education, in the 2009/2010-year, were planning to study at university/college within three years of their graduation from Upper Secondary Education (ibid p. 6).[3] How many of the students actually do this is too early to say. When Statistiska Centralbyrån followed up how many of the students who graduated in 2006 went on to study at university/college within three years they found that the percentage was 41% (2010a, p. 15).

In this study I have chosen to include only those who study at educational programs, which prepare students for higher education. The reason for limiting the number of participants, in this manner is that the vast majority of these students have the intention to study at university. This way, the participants match the target group of the recruiting campaign, which is analysed in the other study. The students who were chosen to participate in this study were at the time of the study enrolled at three different educational programs. According to Statistiska Centralbyrån the student's interest in studying at University within three years of graduation from Upper Secondary Education is as follows, at these programs:

- The Science program 99%
- The Social Science program 78%
- The Technology program 77%
  (Statistiska Centralbyrån, 2010a, 2010b)

Other than the high interest for studying at university these three programs were chosen on the basis of how their interest for studying technology differs from one another. According to Statistiska Centralbyrån the percentage of students who are considering studying technology is as follows at these programs:

- The Social Science program 3%
- The Science program 12%
- The Technology program 46%
  (Statistiska Centralbyrån, 2010b)

The intention of choosing students with a varying interest in higher technical education is that it is more likely to acquire spread views. Two classes from each of the above programs were chosen to participate in the investigation. A total of 114 school students participated in the study. Each of the educational programs is located at a different school. The municipality and the town are the same. The town where these schools are located is a medium sized town by Swedish standards. The interest in studying at University is 13 % lower in this region than the national average (Statistiska Centralbyrån, 2010a). In the town, there is a University (College) that offers educational programs in some of the engineering fields.

DETAILED DESCRIPTION OF THE EMPIRICAL METHOD

Introducing the Study to the Participants

After all the initial contacts and ethical considerations had been dealt with, I meet the students, class by class. The time that was set aside for performing the empirical study was about an hour for each class.

As soon as the students walked into the classroom they were put into groups of three to four students. To make it possible to study whether or not gender had an impact on the result, some groups were kept all female or all male. The gender perspective is however, not explored in this text. The reason for this is that I have focused on finding out what the normative view of the subject who studies engineering is among the participants. Of the 114 participants 66 were male and 48 were female. The study is to the larger part a group activity, so the space had to be organized to facilitate interaction. This was achieved by organizing desks and chairs so that a group of four students could sit together. This was done before the participants came into the classroom. During the first ten minutes the participants did individual work. It was therefore important that each student had a space of his/her own within the group space. This was achieved by giving each participant a desk of his/her own within the group space. After I had introduced myself, the objective of the study was explained. I also made sure that the students knew that participation in the study was voluntary. All students were informed that they were free to leave if they did not want to participate. None of the students chose to leave.

The Post-it Notes are Used

During the first ten minutes, the participants were asked to write remarks on post-it notes individually. Four different coloured post-it notes and four different categories were used when doing this. The categories were:

1. Pink – Traits associated with engineering students' personalities.
2. Yellow – Knowledge and skills associated with engineering students.
3. Green – Views about the engineering education.
4. Orange – Views about the engineering occupation.

The pre-specified categories were chosen for the reason that I believed it would help the students to get started on the task. It could probably have been done without the pre-chosen categories, but from my experience as a teacher, I know that students generally find it easier when an assignment has a clear framework or structure. The categories were formulated to match the objective. When the ten minutes of individual work were up, the students were asked to stick their individually written post-it notes on a large piece of paper (poster-size), which was placed in front of them on the four desks that formed the group space. During the following 15 minutes, the group members were asked to engage in a discussion about what remarks they agreed and disagreed with. To encourage the students to be open about what they disagreed with they were asked to stick red stickers on the post-it notes that had remarks they disagreed with. The students were asked not to take away any of the post-it notes. In each class three of the group discussions were recorded. The purpose of the recordings was to make it possible to follow some of the discussions more closely. Later, when organising the remarks, the recordings proved helpful to clarify what was meant by some remarks that at first seemed unclear. For example, another group member asked a student about the meaning of a remark. The remark in question said "big brain". As the student who was responsible for the remark explained what she had in mind to the other members of the group, it became clear that what she really meant was "smart". When the 15 minutes of discussion time were up, each group was asked to share their results with the class. Each of the groups gave a brief summary of what remarks they agreed and disagreed with. After summing up what they had said, I closed the study by giving a brief presentation of some early results from the study where the recruiting campaign for KTH was analysed. This was done to give the students an idea of the context their participation would be related to.

Organising the Post-it Notes

The empirical material consists of 1200 remarks that were made on post-it notes, 123 red stickers that were used to show disagreement, and 18 recordings of group discussions. The original plan was take photographs of the posters, and code each of the post-it notes with a feature, which is called *image coding*, which is possible to do in the software Nvivio 8. With this feature, parts of an image can be coded, and after the coding has been made, the codes can be rearranged to generate statistics. Even though I had made a test before I started to code the actual material, the image coding process failed as I started to do the actual coding of the material. It is likely that the software could not handle the large amount of image coding that was required. Consequently, a second approach had to be used to organise the 1200 remarks. The software Excel was chosen for this purpose. This was not ideal, but as it proved to be good enough for the objective of examining what the normative view of the engineering student was in the study, I stuck to it.

When analyzing the empirical material, focus has been on identifying themes and patterns in the data. I started out making four tables, one for each of the pre-chosen categories, which were used to collect the material. When the remarks were listed in this manner, themes in the material were exposed. The identified themes were put into new categories, which I have chosen to call *categories*, *sub-categories* and *themes*. To make the analysis meaningful, remarks that were used less than five times were excluded. I have made some exceptions to this rule. When this happens there is an explanation. For example, synonyms of a remark that had five or more remarks when the synonyms were merged were not excluded.

The empirical results are accounted for in writing and not in tables. The reason is that the tables are far too extensive to be reproduced here. Each remark is accounted for with a number in brackets. The number signifies how many remarks there were of this kind. Each remark is also accounted for in percentages. This signifies how many of the 114 participants used this specific remark. As the remarks varied from group to group, using percentages can be slightly misleading. The reason for this is that it is more than likely that the support for a specific remark would change if all the remarks that were made had been listed and sent out to the participants for a rerun. I base this view on what I noticed as I listened to the recordings and saw the results of the group discussions. What I noticed was that the group members rarely

Figure 1. Image of Post-it notes from one of the groups.

disagreed. Only 123 red stickers were used to show disagreement with the 1200 remarks. Consequently, the number of participants who supported a remark could in fact be much higher than the actual number of remarks that were initially made. The percentage should therefore be read as an indicator of the weakness or strength of the discourse brought forward by the participants.

Each category is summarised in a mind-map, which gives a visual representation of the result. The main result is not discussed until the conclusion. This is also when the conceptual tools are used.

RESULTS

Personality

In this category remarks that link specific interests, personal traits and attitudes to the subject who is perceived as suitable for engineering studies are accounted for. The sub-categories that organize the remarks are: *interests* and *traits & attitudes*. Three themes were found in the sub-category: *traits and attitudes*, the themes are *smart and knowledgeable*, *self-managing* and *geeky.* Most of the remarks in the personality category originate from the pink post-it notes, which the participants were told to use to name personal traits that they associated with the engineering student.

Interests

The only interest that was singled out among all possible interests that one can have was *an interest in technology*. This was acknowledged by 7 % of the participants (8). Considering that technology is one of the main subjects (areas of knowledge) in engineering studies, the support for this remark was surprisingly low. However, no participants in the groups where these remarks occurred disagreed.

Traits and Attitudes

When re-organising the remarks, it became clear that traits are used as expressions of attitude. I believe this is an effect of the tendency to say, “he is ambitious” rather than “he has an ambitious attitude”. For this reason, I have chosen to call this sub-category *traits and attitudes.* Three themes are noticeable among these remarks. The themes are *smart and knowledgeable*, *self-managing* and *geeky*. The theme *self-managing* account for a wide range of remarks, which construct that the subject is an autonomous and self-managing student.

Smart and Knowledgeable

When merged, the remarks that said *smart* (37) and *intelligent* (5) totalled 42. Five participants in the groups where these remarks occurred disagreed. This means that 37 % of the participants perceive the subject who studies engineering, as an individual who is more intelligent than the average individual. The support for the remark *knowledgeable* was considerably smaller, only 11% of the participants remarked that the subject who studied engineering would be knowledgeable. The remarks that support this were: *has general knowledge* (7), *knowledgeable* (3) or *well educated* (2). I have interpreted this to mean that being smart, in this context, is seen as a trait rather than an outcome of being knowledgeable. In other words, the discourse that is upheld by the participants construct a notion of the engineering student’s “smartness” as a matter of potential rather than a result of learning or studying.

Self – Managing

82 % of the participants construct a notion of a subject who is self – managing (94). Consequently, the support for this notion is very strong. 43 of the 94 remarks express that the subject who studies engineering is active and hard working. The remarks were: *industrious* and *active* (12), *organised* (6), *focused* (2) *accurate* (3), *disciplined* (7) *autonomous* (5) and *serious* (8). In contemporary Swedish the word *serious* is often used to express that one takes one’s occupation or interest seriously. This expression is mostly used by the younger generation. When an individual is self-managing, this is usually associated with being ambitious. Ten of the 94 remarks expressed this. The remarks were: *ambitious* (8) and *has high ambitions* (2). Nine of the 94 remarks code the engineering student as a subject who is committed. The remarks were: *committed* (3), *motivated* (2) and *has a drive* (4). Being committed is often associated with a having a goal. In this context, 22 of the 94 remarks upheld this notion. The remarks were *goal-oriented* (18), *future-oriented* (2) and *wants success* (2). 22 of the 94 remarks link the subject who studies engineering with an aptitude for studying. The remarks were: *has stamina to study a lot* (6), *swot* (5), and *likes to study* (10). Only one of the participants in the groups where these remarks occurred disagreed. In many ways I find that the remarks in this category code the

subject who studies engineering as a successful lifelong learner. In other words the subject who study engineering is perceived as someone who lives up to the demands knowledge society has on its citizens.

Geeky

5 % of the participants code the subject who studies engineering as a *geek* (6). One of the participants in the groups where these remarks occurred disagreed. The common denominator for 'a geek' is that he/she is particularly good at something. In this study, a lot of remarks were used to link the engineering student to mathematics (these remarks are accounted for in the knowledge category). The low support for the view that engineering student is geeky is a rather controversial result because the image of the geeky engineering student is often used as an explanation of why engineering studies are "unattractive" to many young people.

The remark *glasses* (5) (eyewear) are used by 4 % of the participants to describe the engineering student. I this remark rather difficult to categorize. But as glasses is an attribute that is often used to sketch an image, or to describe a subject who is intellectual rather than physical I link this remark to the theme of the geek. But even after this connection has been made, the support for the geeky engineering student is still rather weak.

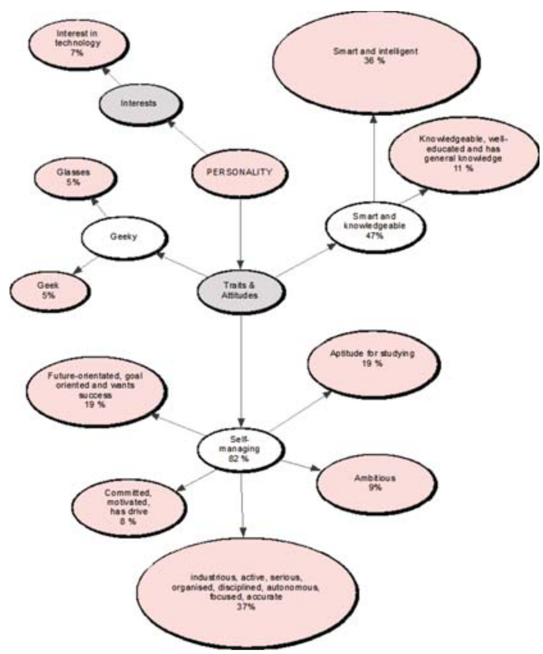

Figure 2. Personality.

Knowledge

The remarks in this category account for statements regarding competencies and skills that individuals who studies engineering are expected to know. The two sub-categories: *competencies and skills* organise the remarks in this category. The sub-category *competencies* organises the remarks that are associated with learning. The sub-category *skills* organise the remarks that link skills to the engineering student. Most of the remarks in the knowledge category originate from the yellow post-it notes, which the participants were told to use to comment on what areas of knowledge and skills they associate with the engineering student.

Competencies

The themes in this sub-category are *learns easily* and *creativity*. 5 % of the participants code the engineering student as a subject who *learns easily* (6). Another 11 % of the participants link the ability to be *creative* (13) to the individual who studies engineering. These two competencies are often emphasized in policies and reports' high lightening what is important to know to do well in a global economy. In policy documents these competencies are often linked to the term lifelong learning. None of the participants use this term. This is not surprising, as policy makers and young people do not always use the same terms. I find that the ability to learn and be creative is very much part of the term lifelong learning. Therefore one can say that the participants support the discourse of the lifelong learner. I say this despite the support for these remarks not being very strong. My view is that this connection can be made because the abilities to *learn easil*y and to be creative are in the same group of thought as the theme of the self-managed student in the personality category.

Skills

Three areas of knowledge (themes) were particularly linked to the subject who studies engineering. These were *technology*, *mathematics* and *physics*. 38 % of the participants code the individual who studies engineering as a subject who knows mathematics well (or does a lot of mathematics). The 43 post-it notes said either *maths* or *good at maths*. 40 % of the participants acknowledged that the individual who studies engineering knows technology (or does a lot of technology). The 46 post-it notes said *technology or technically skilled*. Two participants in the groups where these remarks occurred disagreed*.* 26 % of the participants link *physics* (30) to the subject who studies engineering. Science (3) was singled – out by 3 % of the participants. The same goes for *chemistry*, (3) singled-out by 3 % of the participants. In one of the groups where this remark was used one participant disagreed. The reason for mentioning science and chemistry even though these remarks were used less than five times is to illustrate how much stronger the support for the physics subject was than for other science subjects. Biology, which is one area of knowledge that is very much part of biochemistry did not even get a single remark.

Technology is an area of knowledge that has lot of branches. The participants of the study acknowledged the following areas of knowledge, which can be seen as branches of technology. The knowledge areas were architecture, building (construction), design, computer science, and electronics. 4% of the participants used a remark to link *architecture and building* (5) to the engineering student. 2 % of the participants used a remark that said *electronics* (2). 6 % of the participants used a remark that said *computer science* (7). 5 % of the participants used a remark that said *design* (6). One of the participants in the group where the design remark occurred disagreed. The reason for mentioning electronics and computer science even though these subjects were acknowledged less than five times is that I find that these areas of knowledge are branches of technology, which 40% of the participants wrote on one of their post-it notes. The discourse that is brought forward is that the main subjects that are linked to engineering are physics, mathematics and technology. It is most likely that physics and mathematics get strong support because many of the participants may know that to get accepted to a Masters of Engineering in Science program one needs a lot of credits in mathematics and physics from Upper Secondary education.

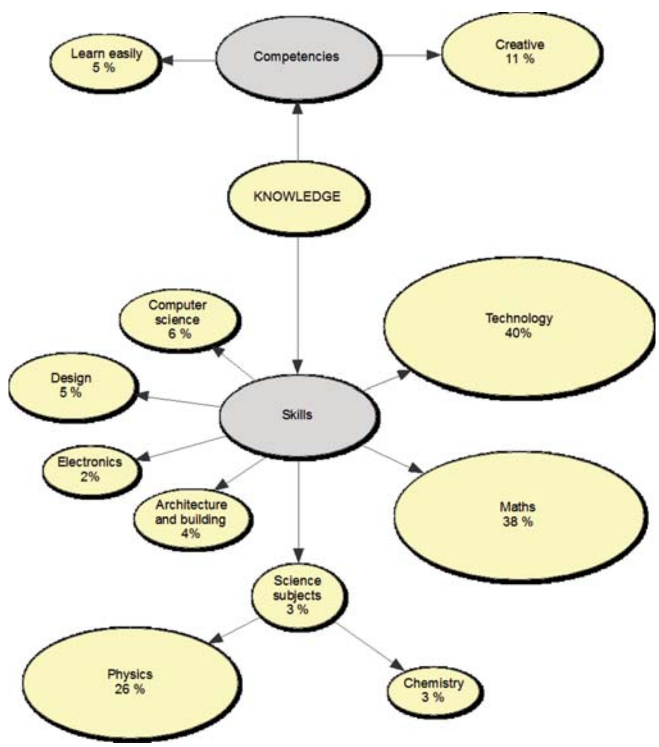

Figure 3. Knowledge

Engineering Studies

The remarks in this category account for the participants' expectations on what engineering studies are like. The sub-categories that organize the remarks are *fun or boring* and *effort*. The last sub-category organizes remarks that in different ways express that studying engineering is an effort. As the participants describe how they perceive engineering education they also construct a notion of what is expected from the subject who studies engineering.

Fun or Boring

10 % of the participants use a remark that suggests that engineering studies are *boring* (11). In the groups where these remarks occurred, five participants disagreed with the remark. 2 % of the participants remarked that engineering studies are *uninteresting* (2). In the groups where these remarks occurred, two participants disagreed with the remark. When the remarks *boring* and *uninteresting* were merged, 13 % of the participants supported this notion.

18 % of the participants used a remark to say that studying engineering is *fun* (21). In the groups where these remarks occurred, 11 participants disagreed. 10 % of the participants used a remark to say that engineering studies are *interesting* (11). In the groups where this remark occurred, one of the participants disagreed with it. Although there was a lot of disagreement about whether or not studying engineering is fun and interesting, or boring and uninteresting, the support for a positive attitude towards engineering studies was stronger than for a negative attitude. It is most likely that this is an effect of the students from the science program and the technical program being in majority; 75 of the 114 participants study at the science program or the technical program, which are educational programs where the students have a higher interest in studying at a technical university than at many other educational programs (Statistiska Centralbyrån, 2010b). Considering that the majority of participants study at a Science program, or a Technical program the support for the opinion that engineering studies is fun and interesting is rather low (cf Statistiska Centralbyrån, 2010b).

Effort

44 % of the participants confirm that studying engineering involves a lot of work. The remarks that support this notion say *a lot to study* or *a lot of work* (50). Only in one of the groups where these remarks were used did a participant disagree. 84 remarks or 74 % of the participants used some sort of remark to express that that studying engineering takes a lot out of you. The remarks that were used to say this said *demanding* (18), *tough* (38), *hard* or *difficult* (28). Only one of the participants in the groups where these remarks occurred disagreed. A theme that occurred a lot in this sub-category was stress. This is not that surprising considering the strong support for the notion that studying engineering is demanding. As many as 24 %

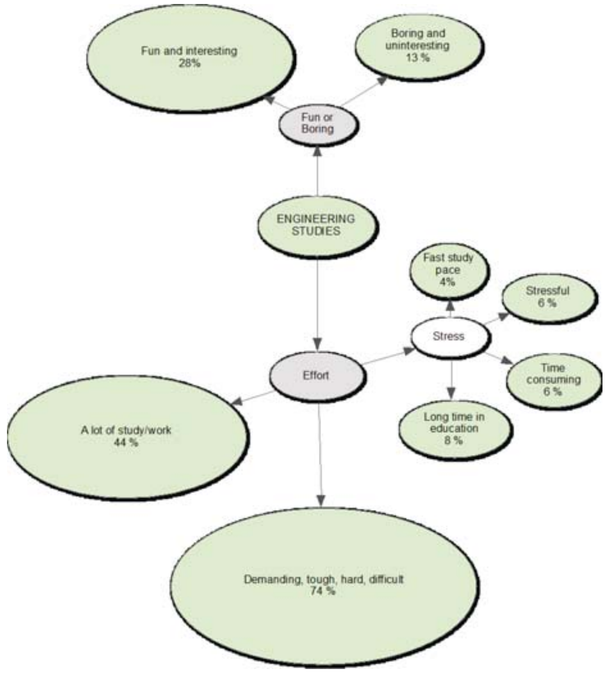

Figure 4. Engineering studies.

of the participants used remarks of some sort to express that studying engineering involves a lot of stress. The remarks were *stressful* (7), *high study pace* (5), *long* time in *education* (9) and *time consuming* (7). In the groups where the remarks *stressful*, *high study pace* and *long time in education* were used, one participant in each of the groups disagreed with the remarks. That something is an effort may at first appear as something that is only negative, but this is not completely true. However, that something is an effort can also communicate that one has the capacity to do something that is difficult and demanding. In other words it can communicate that the subject who studies engineering is competent and capable.

The Engineering Profession

The remarks in this category have been treated differently from the remarks in the other categories. The difference is that the remarks in this category have not been moved to other categories when analysing and sorting the data. This is because the remarks accounted for here originate from the orange post-it notes that were used for remarks that were linked to the engineering profession. The reason for including the participants' "speech" about the engineering profession in this study was that I thought that the participants would link motives and goals to the subject who is considered to be suitable for studies at technical university when sharing their views of the engineering profession. The sub-categories below are a result of the themes that were exposed among these remarks as they were listed in the table. The sub-categories are *status*, *engineering work* and *personality.*

Status

The remarks in this sub-category bring forward a discourse that constructs a notion that Swedish engineers have a high societal status. The participants are very much in agreement that the hard work during the years of education pays off in the long run, particularly when it comes to money. 75 % of the participants remarked that engineers are *well paid* (85). Only two participants in the groups where this remark occurred disagreed. Furthermore, 4 % of the participants remarked that the engineer's *starting wage is good* (5). Being well paid is usually associated with social benefits. This was confirmed in a wide range of remarks. Other than the obvious status markers: *high status*, *successful* and *upper class* the participants used metaphors to communicate high societal status. These remarks e.g. said *nice car*, *big house*, and *good-looking wife*. When merged, these remarks totalled 18, which means that 16 % of the participants remarked that the engineering profession is associated with societal benefits. The participants were however very much in disagreement about some of the remarks, especially remarks such as "good-looking wife".

Engineering Work

The remarks in this sub-category link engineering work to a wide range of engineering fields or describe what engineers do. 19 % of the participants used remarks that describe engineering work as *varied* (22). 8 % of the participants used the broad term *work with technology* (9) to describe what engineers do. Only one participant in the groups where this remark was used disagreed. Of all the engineering fields that exist only one received more than five remarks. This was *construction and building*, which 12 % of the participants acknowledged with a remark that said either *construction* or *building* (14).

The following remarks construct a notion of what the subject who works as an engineer does. 7 % of the participants find that *problem solving* (8) is something that engineers do. 9 % find that engineers *develop technology* (10). 5 % say that engineers do *calculations* (6). 7 % say that engineers have a function as *leaders* (lead or control) (8). Two participants disagreed with the last remark. 10 % of the participants construct a notion of engineers *working a lot* (11). Four participants disagreed with this remark. I interpret the remarks in this category to mean that the participants have a vague notion of what engineers actually do in their profession. Constructing and building is the only field that stands out in the material. My interpretation is that the tasks that were singled out by the participants were tasks that are usually associated with advanced engineering work i.e., develop technology

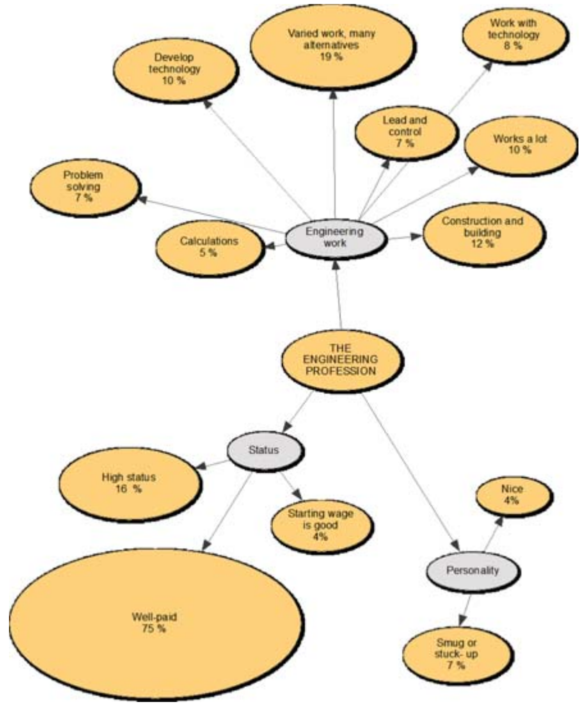

Figure 5. The engineering profession.

which is a task that is associated with engineers who have a degree in Master of Science of engineering (KTH official website).

Personality

The remarks that describe the personality of the subject who works as an engineer were largely contradictory. 4 % of the participants code the subjects who work as engineers as *nice* (5). One participant in the groups where these remarks occurred disagreed with the remark. 7 % of the participants code the subjects who work as engineers as *stuck-up or smug* (8). The support for the stuck-up could be an effect of the high societal status that is linked to the engineering subject.

CONCLUSION

The Successful Engineering Student

In conclusion, the discourse that is brought forward by the participants is one of a subject who wants success, and has what it takes to become successful. The notion of success is upheld in a wide range of remarks that are linked to the engineering student, i.e., the subject who studies engineering is represented as a *committed* and *future oriented* subject. The notion of success is reinforced by remarks such as *wants success*, *goal oriented*, *motivated*, *has drive*, *industrious*, *ambitious*, *active*, *autonomous*, *serious*, *disciplined*, *focused*, *organised*, *enjoys studying*, *aptitude for studying*, *learns easily*, *smart*, *knowledgeable*. This is a description of a subject who fits with Popkewitz's definition of a cosmopolitan which is an individual who is an active, flexible, self-managing, lifelong learner who is skilled in problem solving (Popkewitz, 2003, p. 47). I find that the engineering student that is constructed in the study meets all of Popkewitz's demands of a cosmopolitan. Other than the previously mentioned remarks that code the engineering student as a self-managing and active lifelong learner, the engineering student is also linked to skills in *problem solving* and *creativity*, which in this context is similar to flexibility.

Popkewitz argues that the individual who meets these demands lives up to today's standards of being well prepared for the future in a global knowledge society (2003, see also Andersson and Fejes, 2005, Fejes, 2005). Being prepared for the future is not just a matter of the individual's personal future. It can also mean that one has the knowledge that is considered important at a specific time in history. Individuals who meet these demands lives up to what nations in today's global economically order require of a successful citizen. At different historical times, different areas of knowledge have been brought forward as more important than others. In the political reports that were mentioned in the introduction, science and technology are singled out as areas of knowledge in which Sweden as a nation needs to be able to compete. I find that the notion of success and cosmopolitanism that is brought forward by the participants supports the discourse that the Swedish government brings forward in these reports. For this reason, I argue that the participating Upper Secondary School students produce a discourse of a successful cosmopolitan who meets the demands of the nation.

The participants also back up the notion of success as they describe what engineering studies are like. The remarks *difficult*, *hard*, *tough*, *stressful*, *time consuming* and *demanding*, *fast study pace*, *long time in education* and *a lot of work* code engineering studies as a path, which is only suitable for young people who are industrious and capable, in other words for those who are *smart* (smarter than the average). When taking into account the areas of knowledge that the participants associate with engineering studies, which are *mathematics*, *physics* and *technology* the effect is that these areas of knowledge are seen as hard and demanding. Consequently, to even consider to study at technical university the individual's self-image has to be that he/she is a smart and industrious student..

The notion of success is also upheld when the engineering occupation is the topic of study. The participants describe engineering as a *well-paid* job, which is associated with a *high societal status*. This again stresses that the engineering student is well prepared for a future in a knowledge society. The discourse that is upheld is that the individual who chooses to study engineering makes a low-risk choice. The only risk the he/she runs is the risk of failing, which is possible to do if one does not live up to the list of demands that are linked to the engineering student. As the list of demands that are linked to subject who studies engineering is rather long, this risk is, however, quite high. Basically, the individual has to be a confident lifelong learner to take on such a challenge. The questions hereafter sum up the demands that the subject who considers engineering studies has to live up to.

– Are you good at maths, technology, and physics?
– Are you smart enough?
– Are you self-managing and autonomous?
– Are you ambitious, industrious and motivated?
– Do you have the desire to be successful?

Those who say no, or those who are unsure whether or not they can live up to these demands are excluded from the discourse that is brought forward in this study. I interpret this to mean that the subjects suitable for studying engineering belong to an exclusive group of students. Ultimately, what it communicated is that only the best are suitable for engineering studies. This leaves out a lot of people. It is likely that a lot of young people feel that they cannot live up to the demands that are placed on the subject who is considered to be suitable for engineering studies. In order to increase the number of recruits to technical university the engineering discourse has to be changed. To continue to strengthen a discourse that supports the notion that engineering is a suitable educational choice for the exclusive elite is not a successful approach to increase the number of recruits to technical university. Therefore I suggest that technical universities, governments, etc. who want to increase the number of recruits should choose an inviting and supportive approach. What approach is actually used is something that I will examine further, as I analyse how engineering students are discursively represented in the Royal Institute of Technology's recruiting campaign 'KTH from the inside'.

NOTES

1 Sweden has since 2006 been ruled by a centre – right wing government.
2 Upper Secondary Education, in Sweden is either vocational or preparatory for higher education. Both are three years long.
3 The percentage of women was 65 %, and 51 % for men (Statistiska Centralbyrån, 2010a, p. 6).

REFERENCES/BIBLIOGRAPHY

Andersson, P., & Fejes, A. (2005). Recognition of prior learning as a technique for fabricating the adult learner: A genealogical analysis on Swedish adult education policy. *Journal of Education Policy*, *20*(5), 595–613.

Berner, B. (2003). *Vem tillhör tekniken? kunskap och kön i teknikens värld* [Who does technology belong to: knowledge and gender in a technical world]. Lund: Arkiv.

Berner, B. (1981). *Teknikens värld: teknisk förändring och ingenjörsarbete i svensk industri* [The world of technique: technical change and technical labour in Swedish industry]. Lund: Arkiv för studier i arbetrörelsen historia.

Dahlstedt, M., & Hertzberg, F. (2011). Den entrprenörskapande skolan, styrning, subjektskapande och entrprenörskapspedagogik [Schooling Entrepreneurs: Entrepreneurship, Governmentality and Education Policy in Sweden at the Turn of the Millennium] *Pedagogisk Forskning i Sverige*, *2011*(3), 179–198. Accepted for publication in the *Journal of Education* (2012).

Fejes, A. (2005) New wine in old skins: changing patterns in the governing of the adult learning in Sweden. *International Journal of Education*, *24*(1), 71–96.

Foucault, M. (1980). The Confession of the Flesh. In Gordin C. (Ed.), *Power and knowledge. Selected Interview and other writings 1972–1977 by Michel Foucault* (pp. 109–133). The Harvester Press Limited,

Foucault, M. (1977). Nietzsche, genealogy, history. In F. F. Bouchard (Ed.), *Michael Foucault: Language*, *counter memory*, *practice: Selected essays and interviews* (pp. 139–164). New York: Cornell University Press,

Fröberg, M. (2010). *Teknik och genus i skapandet av gymnasieskolans teknikprogram: översättnignar och gränsarbete på tre nivåer* [Technology and gender in the framing of the Technology programme in the Swedish upper secondary School: Translations and boundary work at three levels]. Retrieved November 27, 2011, from Linköping: Linköping University Electronic Press University: http://liu.diva-portal.org/smash/record.jsf?pid=diva2:304728.

Högskoleverket (2011a) Statistics retrieved from http://www.hsv.se, Nov 21, 2011.

Högskoleverket (n.d). (2011b) Universitet och högskolor. Högskoleverkets årsrapport 2011 [The Swedish National Agency for Higher Education. Annual Report 2011]. Rapport serie 2011: 8R. Retrieved from http://www.hsv.se/publikationer/varasenasterapporter/2011/universitetochhogskolorhogskoleverketsarsrapport2011/universitetochhogskolorhogskoleverketsarsrapport2011.5.27d863.681.30216405a680002388.html, July 22, 2011.

Högskoleverket (n.d). (2002), Tekniskt sett, Högskoleingenjör –kartläggning och enkätstudie [The Swedish National Agency for Higher Education. Technical seen, Middle engineergs – inquiry and survey]. Rapport serie 2002: 27R. Retrieved27 Nov, 2011 from www.hsv.se/download/18.../0227R.pdf

Mellström, U. (1999). *Män och deras maskiner* [Men and their machines]. Nora: Nya Doxa.

Martin, R. (1982). Truth, Power, Self: An Interview with Michael Foucault. In Gutman, M., & Hutton, P. H. (Eds.), (1988). *Technologies of the Self. A Seminar with Michael Foucault* (pp. 9–15). Amherst, U. S.: The University of Massachusetts Press.

Kungliga Tekniska Högskolan, Stockholm (2006) *Kommunikationsplattform* [Communication plattform]. Retrieved 2009 from KTH, Stockholm.

Olsson, U.(1997) Folkhälsa som pedagogiskt projekt. Bilden av hälsoupplysning i statens offentliga utredningar [Public Health as an Educational Project. The conception of health education in governmental committees]. Diss. Uppsala: Uppsala Studies in Education 72.

Osborne, J., Simon, S., & Tytler, R. (2009). Attitudes towards science: An update. Paper presented at the Annual Meeting of the American Education Research Association, San Diego, California, April 13–17.

Ottemo, A. (2008). Rekryteringsarbete och genusmönster i rekryteringen till Chalmers utbildningar på EDITZ-området. [Recruiting-work and gender patterns in recruiting education within the EDITS – area at Chalmers]. Genusdelprojektet inom EDITZ – översynen. Göteborg: Chalmers tekniska högskola.

Popkewitz, T. S. (2008) *Cosmopolitanism and the age of school reform*, *science*, *education*, *and making society by making the child*. Routledge: N. Y & London.

Popkewitz, T. S. (2003). Govering the child and pedagogicalization of the parent: A historical excursus into the present, In M. Bloch, K. Holmlund Moqvist & T. S., Popkewitz (Eds.), *Govering children*, *families and education*, *reconstructing the welfare state* (pp. 34–61). New York: Palgrave Macmillian.

Rang, B. (2005). *Not-projektet – tankegångar i Agenda 21s anda? en studie av texter ur ett feministiskt könsperpektiv*. [Note project – ideas of Agenda 21's spirit? A study of texts from a feminist könsperpektiv]. Göteborg: Institutionen för pedagogik och didaktik, Göteborg Universitet.

Rose, N. (1999). *Govering the soul*, *the shaping of the private self*. London & N. Y: Free Association Books.

Rose, N. (1995). Politisk styrning, autkoriet och experits i den avancerade liberalismen [Govering, authority and expertise in the advanced liberal society]. In I. K. Hultqvist & K. Peterson (Eds.), *Foucault – namnet på en modern vetenkaplig och filosofisk problematik* [Foucault, the name of a modern scientific and philosophical problems]. (2nd ed.). Stockholm: HLS Förlag, pp. 41–58.

Schreiner, C., & Sjøberg, S. (2010) *The ROSE project-An overview and key findings*, University of Oslo, Retrieved, November, 28, 2011. Retrieved from http://roseproject.no/publications/english-pub.html.

Skoogh, I. (2001). *Teknikens värld – Flickors värld: En studie av yngre flickors möte med teknik i hem och skol*a [The world of technology – the world of girls. A study of young girls' encounter with technology at home and in school]. Stockholm: HLS Förlag.

Sjöberg, L. (2011). *Bäst i klassen? lärare och elever i svenska och europeiska policytexter*. [Top of the Class? Teachers and pupils in Swedish and European policy texts]. Diss. Göteborg: Göteborgs universitet.

Sveriges Regering Utbildningsdepartementet: Globaliseringsrådet (2008) Insatser för att öka intresset för ingenjörsyrket [Efforts to increase the interest for the engineering occupation] Sveriges Regering Utbildningsdepartementet: Globaliseringsrådet [Government Offices, Swedish Ministry of Education: the Globalisation council]. Rapport serie: Ds 2008:10. Retrieved November 28, 2011 from http://www.regeringen.se/sb/d/108/a/96638

Statistiska centralbyrån (2010a) Gymnasieungdomars studieintresse läsåret 2009/2010 [The transition from upper secondary school to higher education 2009/10]. Statistiska centralbyrån [Official Statistics of Sweden Statistics]. *Tema rapport* 2010:2 Retrieved from www.scb.se, October 23, 2011.

Statistiska centralbyrån (2010b). Tabeller om gymnasieungdomars studieintresse på specifika gymneasieprogram läsåret 2009/2010. [Tables of the transition from specific programs at upper secondary school to higher education during the 2009/10 school year]. Retrieved from Official Statistics of Sweden Statistics on request, 5 October 2010.

Teknikdelegationen (2010) Vändpunkt Sverige ett ökat intresse för matematik, naturvetenskap, teknik och IKT. [Turnover for Sweden an increased interest in math's, science, technology and ICT]. Teknikdelegationen [The Technology Delegation]. Stockholm: Statens offentliga utredningar. SOU 2010:28. Retrieved November 28, 2011 from http://www.regeringen.se/sb/d/108/a/144868.

HELENA ISAKSSON PERSSON

11. WHAT YOU NEED TO LEARN

Engineers' and Industrial Designers' Views on Knowledge and Skills in Product Development

INTRODUCTION

Are there common knowledge and skills that professional engineers and industrial designers consider important in their work with product development? If so, to what extend does technology education in upper secondary school reflect and prepare students for the demands of working life?

The starting point for this study is questions raised in my practice as a design teacher in the upper secondary school Technology Programme. This particular educational programme focuses on design and product development. After three years of studies the students, depending on their interest, can apply to higher education in industrial design or engineering.

In contrast to education in upper secondary schools, higher education in industrial design and engineering (in Sweden) is separated into two disciplines. Professional industrial designers usually have a degree in art or design and professional engineers usually require a degree in engineering or science. Bridging the gap between these two disciplines and providing relevant technology education to students regardless of their chosen orientation (design or engineering) is indeed a challenge to teachers. What areas of knowledge and skills should be addressed in upper secondary technology education to make this possible?

In search of the answer to this question, professional engineers and industrial designers, all working with product development, have been interviewed. The findings presented in this article are based on the answers from these interviews. The study is part of a larger research project carried out within a graduate school programme (Technology Education for the Future, TUFF), which focuses on technology education (Skogh, 2010).

Research Question

Both engineers and industrial designers have important roles in product development. The interviewees in the study have different specialisations but contribute to the

I.-B. Skogh & M.J. de Vries (Eds.), Technology Teachers as Researchers, 223–251.

same technological knowledge area; product development. The research question explored in this article is:

- What skills and knowledge do professional industrial designers and engineers think are important to their work with product development?

The chapter is organized as follows. First, an overview is presented of engineering and industrial design education in secondary schools and higher education. The next section is devoted to the theoretical framework for this. The methodological approach, including the procedures for analysis, is then accounted for. The results are thereafter presented and discussed. The chapter ends with suggestions regarding how the findings could be beneficial to upper secondary school product development education.

TECHNOLOGY EDUCATION IN SWEDEN IN UPPER SECONDARY SCHOOLS AND IN UNIVERSITIES

In Sweden, a majority (92%) of 16 year-olds attend upper secondary school, even though it is a non-compulsory form of schooling (SCB, 2010). For most students (and parents) this is their first active educational choice. There are 18 national educational programmes to choose from; each designed to be a trajectory to a specific vocational branch or to higher studies within specific knowledge disciplines.

The Technology Programme

The structure of upper secondary school in Sweden was set in the mid-sixties. From then until the mid-nineties, the Technology Programme primarily prepared students for higher education in engineering. The programme was considered to be 'out of date' because of rapid developments in technology, a labour market in transition, and the fact that the programme attracted very few girls. It was removed as a separate educational programme from the school year 1992/93 (Sweden, 1989, 1992).

Demands for a 'pure' Technology Programme in upper secondary schools were raised by stakeholders from both industry and the research community (Sweden, 1994). In 2000, a new Technology Programme was launched with new interdisciplinary subjects, designed to be preparatory to higher education or working life. The focus was placed upon humans' relationship with artefacts combined with a holistic approach towards technology. The education was no longer oriented towards specific technology skills or occupations (Sweden, 1998). This gave schools and teachers the freedom to locally define the character of the programme.

A major reformation of upper secondary schools was conducted in 2011 (Sweden, 2008a). The Technology Programme was transformed again and since 2011 it has had five national branches, all exclusively preparatory to higher education; *Design and Product Development*, *Information and Media Technology*, *Production Technology*, *Community Planning and Architecture* and *Technology Sciences.* The reason for this delineation was, according to authorities, the need to clarify the nature of the programme and to attract more students to higher education in technology (Sweden, 2008b).

Higher Education

There are five national programmes in upper secondary school leading to higher education. To gain access to higher education studies, students are expected to have completed certain qualification courses. It is therefore important to make 'the correct' choice of programme and courses in upper secondary school if a student aims at studying at a university of some kind. Students who, for example, attend one of the twelve vocational programmes in upper secondary school need to choose a number of additional courses to meet the entrance requirements for higher education studies.[1]

Higher education in Sweden is organized in three levels or stages. The first level of educational studies aims at a bachelor's degree. Studies at the second educational level provide an education at the masters' level. At the third level, the students study towards a licentiate or doctoral degree (Swedish National Agency for Higher Education, 2012b).

In autumn 2011, a handful universities and university colleges (studera.nu, 2011) offered an education that is oriented towards industrial design. These educational programmes are characterised by a high artistic level. In addition to general or specific entry requirements, the students must present portfolios with materials that show their knowledge and skills in the field of design.

There are a variety of higher education programmes for those who want to become engineers. Some of these programmes focus on product development with a greater or lesser orientation towards the design field. The students' artistic qualifications are not considered in the sense of portfolios with work samples being required for admission.

THEORETICAL FRAMEWORK

Hermeneutics

This study is based on interviews with engineers and industrial designers. The approach taken in the analysis of these interviews is inspired by hermeneutical theory.

Hartman (2004) defines three important concepts in the hermeneutic examination process, *life world*, *comprehension* and *interpretation*. According to Hartman, the life world concept is defined as the ideas of humans or groups about themselves and their situation. Månsson (2003) traces the concept back to Husserl and his thinking about knowledge and how we experience our reality. Since we create our own reality, the life world is the source of all our knowledge and it is the basis for our experiences of reality (ibid). Alvesson and Sköldberg (1994) argue that *empathy* is a significant aspect in hermeneutic analysis. The interpretation of another person's life world will inevitably be influenced by our own understandings. Hartman (2004) argues that it is through our own pre-understanding that we interpret other people's life worlds. The fact that we cannot completely ignore our own life world makes it hard to entirely understand others. However, an interpretation of someone's life world leads to a new understanding and, accordingly, a new basis for coming interpretations. This is called the hermeneutic circle.

Ödman (2004) describes the hermeneutic process as consisting of four main elements: *interpretation*, *comprehension*, *pre-understanding* and *explanation*. The basis of interpretation is our previous experience, our pre-understanding. Since we cannot ignore our pre-understanding, it is both an asset and an obstacle in the interpretation. In the interpretation of an empirical material, we gain a new pre-understanding. According to Ödman (ibid), the interpretation is a synthesis between pre-understanding and explanation. Ödman (ibid) argues that explanation and comprehension are related and that we need to understand in order to explain and that explanations are based on understanding. When we interpret our empirical material, we need to alternate between the material as a whole and its parts. We gain new understandings and need to return to the material as a whole in order to bring to this our new understanding of the parts. As Alvesson and Sköldberg (1994) argue, the hermeneutic process can always continue; there is no final interpretation.

Ödman (2004) stresses the importance of this dynamics and emphasizes the importance of the *context* for the validity of the interpretation. We need knowledge about the context in which the object of our interpretation is situated, and the interpretation itself needs to be founded in a context.

Knowledge in Working Life

This study examines two occupational groups within the same context, product development. Since the respondents are professionals, we need to understand the nature of knowledge used in working life. The concept of vocational knowledge defines the knowledge used in working life without being directed towards a specific occupation.

Vocational knowledge. Höghielm (1998, 2005) defines vocational knowledge as closely related to the concepts of vocational culture, vocational practice and vocational competence. The vocational culture is based on the traditions in a particular vocation and it is based on mediated collective experiences. The vocational culture is normative, it shapes vocational practice and it defines to some extent what counts as vocational knowledge. Vocational practice is the rules and procedures that are used in a certain vocation. Höghielm (ibid) points out that these rules and procedures need not be the only right way to solve a specific work related problem, but they have developed and are taught in practice and are part of the vocation's "spirit".

To have vocational knowledge is to have the knowledge to solve problems related to a certain vocation; this includes having theoretical knowledge and the ability to intentionally and after reflection perform the right actions. Vocational competence is linked to how well a professional can use her or his vocational knowledge in relation to the expectations and demands within a given vocational context (ibid).

The interviewees in this study are regarded as practitioners with vocational knowledge in engineering or industrial design of a quality that is useful and necessary in product development.

The skilled professional practitioner. To have vocational knowledge is also to have vocational skills. The practitioner makes decisions based on previous experiences; Schön uses the term reflective practitioner (Schön, 1987, 2003 [1995]). This kind of knowing can according to Höghielm (1998, 2005) become tacit knowledge. Ryle (1949) argues that it is not possible to separate mental and bodily processes. He states that when we know all the rules and procedures for a given activity really well, we can find it difficult to remember them in detail and to explain our skills verbally to others. Ryle calls this knowing how, ('know-how'). Dreyfus and Dreyfus (2000) use knowing how and intuition as synonymous. They argue that intuition is based on tacit knowledge. Intuition is neither '[…] wild guessing nor supernatural inspiration, but the sort of ability we all use all the time as we go about our everyday tasks […]' (ibid, p.29). When experts act intuitionally their actions may appear unreflective. However, they are actually using a repertoire of decisions and actions that have been successful in similar situations. According to Dreyfus and Dreyfus '[…] experts don't *solve problems and don't make decisions; they do what normally works*.' (p.31).

Regardless of previous education, the interviewees' in this study possess vocational knowledge that makes them qualified to work within their position in working life. They are, in this context, regarded as having the knowledge and skills needed to be professional practitioners. However, more than just the 'right' vocational knowledge is needed to be a skilled practitioner in working life.

Key qualifications. In addition to the above-mentioned vocational competences, skills and knowledge of a more general and interdisciplinary nature are also important in working life. Definitions differ between countries and contexts. Examples of concepts commonly used to describe this additional knowledge are 'key skills', 'key qualifications', 'key competences' and 'new basic skills' (Kämäräinen, 2002). These concepts are associated with a person's capacity to work with others, to deal with new situations, to take initiatives, to be socially competent, to be flexible, communicative and analytical, and to solve problems, as well as a person's knowledge of languages and computing (Höghielm, 2005; Höjlund, Göhl, & Hultqvist, 2005; Kämäräinen, 2002). Nyhan (2002) argues that key qualifications are based on "[…] 'practical knowledge' […]" (p. 243) linked to contexts and situations. In this study, the term 'key qualification' is used to describe these abilities.

METHOD

Starting Point for Data Collection

Interviews have been conducted with industrial designers and engineers with the purpose of examining what skills and knowledge the interviewees consider to be important in their professional work. The interviews are based on questions from a questionnaire (Appendix). The questionnaire is intended to determine the interviewees' educational backgrounds, their views on what they do in their daily work and what they consider to be important knowledge and skills.

In the early stage of the research process, the intention was to send the questionnaire to a large number of engineers and industrial designers. The sample was however limited because of difficulties in finding work active informants who had the time to participate in the study. The research design was reconsidered and changed from an analysis of written answers from the questionnaire to an analysis of in-depth interviews based on the questionnaire's questions. The new design provided fewer answers, but gave the opportunity for obtaining a deeper understanding of the informants' responses.

The Interviewees

Twelve (12) career-active industrial designers and engineers from two different cities and of different ages have been interviewed; five (5) female and two (2) male industrial designers, as well as three (3) female and two (2) male engineers. They all work in the manufacturing industry and their experience within the profession varies from just a few years up to thirty years. They all work in different companies and all but one interview was conducted at their respective workplaces.

The industrial designers in the study have the most homogeneous educational background. They all have a higher education with degrees in design or art. One of the designers has an additional degree in engineering. The engineers in the study have a more diverse educational background. One has a doctoral degree in science and one has a master's degree. Three engineers have undergone a four-year technology education at the secondary level and additional courses at their respective workplaces.

Regarding the question of the aims and focus of the work of the interviewees, the industrial designers are once again the most homogeneous group. Some of them are employees and some are entrepreneurs with or without employees. All of the engineers are working in consulting businesses. Accordingly, their work tasks often differ from assignment to assignment. The two engineers with higher education work with project leadership and programming. The three engineers without higher education have work experience as design engineers, which the two others do not have. All of the engineers consider themselves to be engineers who are working with engineering. Experiences from project leadership are represented among both the engineers and the industrial designers.

Due to the limited sample, this study does not claim to generate general knowledge. Instead, the aim is to, as accurately as possible, report the interviewees' views of what they, as professionals, consider to be important knowledge and skills in their work practice.

Data Collection – Interview Questions

The interviews are based on a questionnaire with open-ended questions. The questions were read to the interviewees and, if needed, follow-up questions were asked. The interviews were recorded and later transcribed. One interviewee did not want the interview to be recorded and therefore notes were made in a printed version of the questionnaire.

Questions 1 to 4 of the questionnaire (Appendix) give information about the interviewees' educational background. Questions 5 to 7 (ibid) highlight reasons for becoming engineers or industrial designers, and if they are satisfied with their career choice. Questions 8 to 13 (ibid) focus on the interviewees' views on what skills and knowledge they consider to be important professional skills and knowledge (to themselves in their profession and to others/colleagues), including reflections regarding the education that they have undertaken in school, university and working life.

The answers to questions 8, 9, 10, 12 and 13 seemed to reveal key issues relevant to the research question and so were more closely examined. Questions 8 and 9 focus on education. Question 8 concerns what the interviewees have learned "of importance to the profession" during their training. Question 9 is about what they lack from their education. Questions 10, 12 and 13 are about the profession; what the interviewees do and what they think are important. Question 11 was discussed during the interviews supplementary to question 10. The interviewees found it difficult to make the ranking as requested in question 13. The answers to question 13 are taken into account in the analysis, but the ranking is not, since it does not provide additional information. The questionnaire questions examined are:

1. Give three examples of knowledge or skills that you learned during your education that you consider are of special importance for you in your profession. Explain why these skills or knowledge have been of particular importance.
2. Are there any skills or knowledge that you did not learn during your education that would have been useful in your professional practice?
3. Can you give examples of skills or knowledge that you learned in your professional practice that you have not learned during your education?
4. Give three examples of tasks that you perform frequently in your work.
5. Rank the three most important items of knowledge or skills for practitioners of your profession.

COMMENTS

This study obviously does not cover the complete life world of the interviewees. The focus is placed upon their roles as engineers or industrial designers and on their ideas about knowledge and skills that are related to their professions. The context is of great importance for the interpretation, not in the sense that the workplace has been studied, but rather as an important base in the interviewees' descriptions of their practice. It is in this context that they use the skills and knowledge that are of interest to this study.

According to Månsson (2003), hermeneutic analysis can be used for all kinds of written reporting. It is important to note that the object of interpretation in this study is *the transcripts of recordings* made. If the transcriptions have been unclear, the recordings have been re-listened and, if needed, the text adjusted.

As explained earlier, my experiences as a design teacher have influenced my choice of profession for investigation. My pre-understanding of engineers' and industrial designers' work in manufacturing is somewhat uneven. I have no work experience as an industrial designer, but I do have an education and work experience from other design domains. Accordingly, my understanding of industrial designers' concepts and methods is deeper than my understanding about engineering. However, during my time as a graduate student, my knowledge about technology and engineering has increased.

Analytical Procedures

As mentioned above, the questions were read to the interviewees. The interviews thereby developed into quite dynamic discussions and the questions were not necessarily answered in a certain order. Some issues were discussed several times and sometimes a response to one question could provide answers to several questions.

According to Marshall and Rossman (2006), the process of bringing order and structure to collected data is messy. To provide an overview of the analytical process underlying the results, a linear and simplified model was made (figure 1). The letters A, B and C represent three different phases of the analytical process: A = organizing the data, B = generating categories and themes, C = interpretation phase. The dashed lines in the same colours as the letters show that the phases overlap. This model does not show the dynamics in the analysis as well as a hermeneutic circle or spiral illustrates this (Ödman, 2004), but it does show the procedure for this study in more detail.

Marshall and Rossman (2006) describe the generation of categories as a search for patterns in the data. The interviewees' responses were arranged in accordance with the questions, industrial designers and engineers separately (Figure 1, yellow). Questions 8, 9, 10, 12 and 13 from the questionnaire were chosen to be further examined (Figure 1, blue). The questions were used as categories and are shown in figure 2 as C Q8, C Q9, C Q10, C Q12 and C Q13. The categories were scrutinized

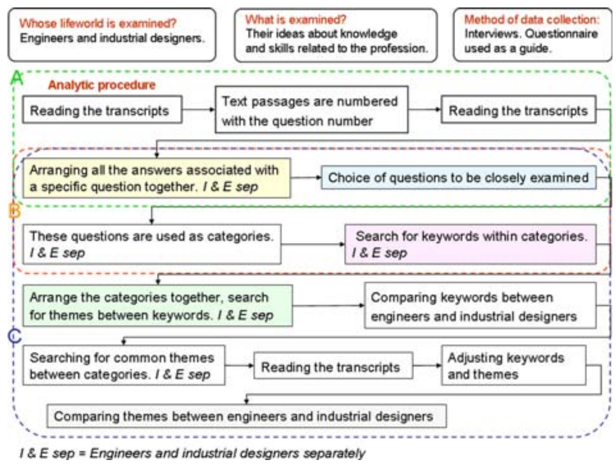

Figure 1. Simplified description of the analytical procedure.

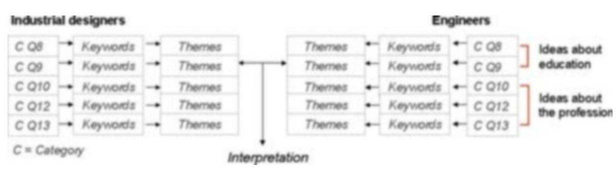

Figure 2. Analysis model.

in search for keywords that summarised and illustrated the interviewees' responses (Figure 1, pink). The search continued for patterns between keywords (Figure 1, green) and the patterns were organized into themes (Figure 2). The identified themes from the various categories were compared and an interpretation was made (Figure 1, grey; Figure 2).

The result of the pink and green steps in figure 1 are presented in figures 3 and 4. The names of the themes and examples of keywords that characterise them are presented for each occupational group. The themes will be further described in the Results section.

RESULTS

The results are presented in the following way. Figure 5 (below) provides an overall picture of the different themes identified in the collected data. This figure is used as a starting point for my presentation of the results. The different themes are described and quotes are chosen to illustrate the meaning of each of them. The results/ statements from the two groups of interviewees (engineers and industrial designers) are presented separately.

ENGINEERS	
Key words	Themes
Be curious, be resourceful, Not get stuck in old ways of thinking. Work with problem solving. Be able to understand and use technology in a practical way.	An engineering approach
Mathematics, physics, programming, design engineering, technical drawing, knowledge of materials.	Basic vocational knowledge and skills
Skills and knowledge needed in work to solve vocational specific tasks. Learned in education, further developed in work. Needs to be used in an engineering way.	Specific vocational knowledge and skills
Have a holistic view. Leading project team members toward a common goal, team interaction, communication, presentation.	Leadership and teamwork
Develop the product in detail. Work with CAD-tools.	Design engineering

Figure 3. Themes and examples of keywords for engineers

INDUSTRIAL DESIGNERS	
Key words	Themes
Be curious, put the user in focus, turning facts into aesthetics, understand form, visualise and communicate form, design process, creative within a timeframe, produce creativity.	The profession itself
Techniques for visualisation such as sketching and modelling.	Basic vocational knowledge and skills
Skills and knowledge needed in work to solve vocational specific tasks. Learned in education, further developed in work. Tools for visualisation such as sketching with pencil and paper, Photoshop, CAD tools, foam materials, clay.	Specific vocational knowledge and skills
Framework, collaboration, compromise, project, project leader, communication, presentation.	Teamwork

Figure 4. Themes and examples of keywords for industrial designers.

Categories/Questions	Themes: engineers	Themes: industrial designers
Q8: learned in education that is of particular importance in the work.	• Basic vocational k and s • An engineering approach	• Basic vocational k and s • The profession itself • Teamwork
Q9: missing from education that would have been useful in the professional practice.	• Specific vocational k and s • Leadership and teamwork	• Specific vocational k and s • The profession itself • Teamwork
Q10: learned in working life.	• Specific vocational k and s • Leadership and teamwork	• Specific vocational k and s • Teamwork
Q12: tasks performed frequently in work.	• Specific vocational k and s • Leadership and teamwork • Design engineering	• Specific vocational k and s • Teamwork
Q13: most important knowledge or skills for practitioners in the profession.	• Specific vocational k and s • Leadership and teamwork • Design engineering • An engineering approach	• Specific vocational k and s • The profession itself • Teamwork

k and s = knowledge and skills

Figure 5. Results

Themes: Engineers

An engineering approach (Figure 3; Figure 5). What is the core of being an engineer? The engineers believe that an engineer needs a specific approach in her or his work. According to them, it is important to be *curious*, *resourceful* and to be able to learn new things and *not get stuck in old ways of thinking*. The interviewees describe their education as an introduction to the profession itself. When engineer O8 is asked what she learned during her studies that have been of particular importance in her work, she describes learning how to approach *problem solving* in an engineering fashion. There is no such thing as a complete solution to a problem and an engineer must be able to work with reasonably correct solutions. Problems are, according to her, 'good'.

> O8: What did one do (in education, author's note); yes problems are there to be solved.
>
> Interviewer: Problem solving?
>
> O8: Well, how you approach a problem. Problems are good. If you have found a problem, you have something to work with. If you don't find one, then you have a real problem. [...] With this approach, you will reach quite far. [. . .] you realised at school that there are not always complete solutions. You sometimes must use something (pause) that is good enough.
>
> Interview with engineer O8, 01.10.2009, p. 3

Engineer O9 emphasizes that the basis of her work is the 'client's needs'. When the interviewer asks her to describe the essence of being an engineer, she explains how an engineer uses special skills such as mathematics, fluid mechanics and electronics as means to be able to work towards the goal, the development of products. She and her team colleagues need to *understand technology*, but not always in detail. O9 sees the engineer as a pragmatist who needs the ability to combine specific vocational knowledge in such a way that the end product meets the client's needs and generates money for the company.

> O9: To [...] understand technology, to quickly gain an understanding [...] not always in a very detailed way, but being able to understand in general, mathematics, mechanics, fluid mechanics, electronics, to be able build things into products that work. Being able to be practical and pragmatic, that's an engineer to me.
>
> [...] But now it's obvious that if you cannot make money from it, in the long run, in any way, you should not keep on with it.
>
> Interview with engineer O9, 12.10.2009, p. 7–8

Basic and specific vocational knowledge and skills (Figure 3; Figure 5). *Basic vocational knowledge* is used in this study to describe important knowledge that engineers learned in education. The engineers points to basic subject fields as mathematics, physics, programming, mechanical engineering, strength of materials, technical drawing and knowledge of materials.

The term *specific vocational knowledge* is used to describe skills and knowledge that engineers *need in their daily work to solve vocational specific tasks*. When engineer O1 is asked what she learned during her studies that are of particular importance to her work, she has difficulties in giving a precise answer because the knowledge she needs and *learned in education has been further developed in work*.

> O1: Strength of materials [...] all these basic, core subjects. And [...] drawing and engineering tolerance [...]. When I learned it or how I learned it [...] when you leave school, you have a base, but you are not completed, so to speak.
>
> Interview with engineer O1, 01.10.2009, p. 3

When engineer O9 is asked to give three examples of skills and knowledge that she learned during her studies that have been of particular importance in her work, she first mentions programming and then mathematics.

> O9: And the second is that I have gained a very good understanding of mathematics. Interview with engineer O9, 12.10.2009, p. 3

Later on when she is asked about what skills and knowledge she considers as being most important for practitioners in her profession, she answers;

> O9: Well, you need to have the engineering approach, but at the same time to be very good at mathematics … thus, being able to use maths in an engineering way. Maybe that is a good wording.
>
> Interview with engineer O9, 12.10.2009, p. 4

Engineer O9 considers that mathematics is an important subject that she learned during her studies, but mathematics *needs to be used in an engineering wa*y, mathematics is to engineer O9 a specific vocational knowledge.

Leadership and teamwork (Figure 3; Figure 5). The interviews show that the leadership of projects in product development is of major important to the engineers. Engineer O9, the engineer with least work experience, is the only engineer who did not discuss leadership during the interview. When the interviewees talk about leadership, it is leadership that relates to teams or project groups. Engineer O1 describes the character of the product development team that she is a part of.

> O1: (laughter) Yes, that's thousands of people, in different roles. There [...] are the high positioned project leaders that keep it all together, you have a styling department, you have testing, you have people calculating [...] crash simulations [...] engineering designers [...].
>
> Interview with engineer O1, 01.10.2009, p. 15

As the team behind the development of a product consists of different professions and project groups, *interaction* and *communication* are of major importance.

> O9: And thirdly, to go to (laughter) meetings. Communicate what you do. Discuss with others.
>
> Interview with engineer O9, 12.10.2009, p. 4

Presentation as a means of demonstrating results and gaining support for ideas is also a form of communication. Engineer O8 argues that she has learned presentation skills to some extent during her studies, but more through trial and error in working life. She remembers when she for the first time presented her results at the workplace.

> O8: I remember this first time; it went completely wrong. Stood there and was going to present [...]. Standing there and almost stammered and there sat high positioned bosses and said, it cannot be like this [...].
>
> Interview with engineer O8, 01.10.2009, p. 4

The project leader does not need to be a specialist. It is more important to have a *holistic view*, like having good product knowledge and knowledge of the various steps involved in the product development process. In the following quote, engineer O2 describes his view of the goal for the project leader:

> O2: To work in a project is to get the project to function as machinery. A well-oiled machinery that works well – everything from personal chemistry to technical competence […]. That is something completely different from a creaky one, wrong people, wrong competences that are not comfortable with each other, it could hardly succeed.
>
> Interview with engineer O2, 02.04.2010, p. 8

The engineers did not mention leadership as something that they had been taught during their studies. Instead, instruction in leadership has been provided by their employer (courses) or learned within projects ('learning by doing'). O8 describes how she learned about leadership during her schooling outside of the regular education.

> O8: One became very good at arranging, organising parties [...]. So I did a lot of stuff like that too because it was great fun. It is clear that you benefit from that, putting people and tasks together.
>
> Interview with engineer O8, 01.10.2009, p. 4

O8 summarizes her views of project management; the project leader must have the ability to *lead project team members towards a common goal*.

> O8: Well, to get people to work together towards a common solution or a common goal.
>
> Interview with engineer O8, 01.10.2009, p. 6

Design engineering (Figure 3; Figure 5). In addition to leadership, design engineering is a task that three of the engineers have experienced. When engineer O1 describes why she is satisfied with her career choice, she emphasizes that the engineer's profession is varied. She exemplifies this by describing her experience of project leadership and design engineering.

> O1: [...] I can do many different jobs. I can get design engineering assignments, to sit and ponder with CAD and do tolerances, but you can also get this type of project leader assignment and it involves more action and decisions and keeping track of a thousand million things and Excel spreadsheets, [...] it's two completely different occupations.
>
> Interview with engineer O1, 01.10.2009, p. 3

Working as a design engineer entails developing the product in detail, completely ready for production. She or he develops products by working with digital models in CAD. The interviewees are using the word CAD as a generic term for software that simulates a three-dimensional space, in which three-dimensional digital objects can be created. Engineer O8, without design engineering experience of her own, describes the design engineer's role in the product development process as follows.

> O8: Then there are, [...] what I consider to be 'pure' designer engineers. The kind of engineers who are doing what many people think all engineers do all the time. Those who sit and run CATIA (CAD tool, author's note), they are a sort of craftsmen who are damn good at their field [...].
>
> Interview with engineer O8, 01.10.2009, p. 7

The design engineers have experienced a shift in tool standards from physical drawings and models to digital and it has been necessary for them to learn CAD during their career. Engineer O1 describes this shift.

> O1: When I came from school, in the beginning, you made your draw ... (drawing, author's note) now it's built around CAD tools, but at that time there were CAD tools, but they were not the basis.
>
> Interview with engineer O1, 01.10.2009, p. 6

Themes: Industrial Designers

The profession itself (Figure 4; Figure 5). The interviewees describe qualities that characterise the professional demands on industrial designers. Industrial Designer O5 emphasizes the importance of being sensitive and interested in seeing and listening. She sums this up, stating that it is important to be *curious*.

O7 thinks that she learned the 'core' of the profession through education. She specifically mentions work methods and industrial designers' way of thinking. She also emphasizes that she learned to *put the user in focus* instead of herself. Later, she states that industrial designers are really good at *turning facts into aesthetics*. She believes that aesthetics add a positive value to the product, but it is important that it is the target group's aesthetics that is in focus and not the designer's.

The interviewees also stress that it is really important to *understand form*. When they discuss this matter, they use the Swedish words "form" and "formgivning", which are related to styling. It is about how to work with, and express, ideas through the shaping of objects. According to the interviewees, it is important not only to be able to understand form, an industrial designer must also be able to *visualise and communicate form*. The working method of industrial designers is the *design process*. Industrial designer O11 describes how the design process is practiced at her office. The product is developed through various phases from a sketch phase to the realization phase, where a model is ready to be passed on to the design engineers.

In industry, time is an important factor. Regarding the question of what O6 lacks from her education, she can only think of one thing: learning how to *be creative within a timeframe*. She calls it *producing creativity* and she thinks it is impossible to learn this in school; it is something one learns at the workplace.

Basic vocational knowledge and skills (Figure 4; Figure 5). When the industrial designers talk about what they learned during their studies that has been of importance to their profession, they emphasize *techniques for visualisation*, such as two – and three-dimensional sketch and modelling techniques. *Practice* is needed to learn this and education has facilitated this by providing workshops and equipment. Industrial designer O6 points out that school also provided her with *time* for this practice. Industrial designer O5 also appreciated having the *freedom* to develop her work by exploring and testing, something she does not have time to do now when she is working. O3 believes that her education differs somewhat from the more traditional education in that it used collaboration and project work as pedagogical tools and focused more on the process than on the finished results.

Specific vocational knowledge and skills (Figure 4; Figure 5). The term specific vocational knowledge is used in this study to describe skills and knowledge that the industrial designers need in their daily work to solve specific vocational tasks when they work with product development. Knowledge from education is a base for interviewee O11. She describes how she uses knowledge from her training in professional projects and how this knowledge has been further developed.

> O11: Yes, we had technology at university and all that, but it's when you start practicing that you understand what it means and then you take it further from project to project.
>
> Interview with industrial designer O11, 27.01.2009, p.4

The interviewees points at various specific vocational knowledge that they miss from their educational training. They mention interaction design, manufacturing methods and theories about colour and composition. The interviewees who have been trained in the 1990s or earlier also lack training in digital tools. These interviewees have learned these tools in working life. Of these digital tools, software for three-dimensional modelling is most prominent. It should be noted that the interviewees use the word CAD as a generic term for software that can generate three-dimensional models.

The industrial designers stress that sketching and /or modelling are important skills in the profession and something that they frequently do. Sketching and modelling are means for them to visualise their ideas. Industrial designer O5 describes her tools for visualisation, and when she talks of the CAD-tool, she uses it as a verb, 'I CAD'.

> O5: [...] it's so much, but ... [...] I visualise. [...] first, I thought to say that I CAD and make sketches, but it's just a kind of tool to get the...
>
> Interviewer: So, it is part of visualisation?
>
> O5: It's part of visualisation, [...] CAD and sketches and models [...].
>
> Interview with industrial designer O5, 23.03.2009, p. 5

The interviewees argue that there are different *tools for visualisation*. They mention *sketching with pencil and paper*, *Photoshop*, *CAD tools*, *foam materials*, *clay* etc. Industrial designer O3 emphasizes the importance of being skilled with the visualisation tools. Industrial designers often work in teams and the designers that are 'fast and good' have an advantage in communicating their ideas. O3 describes here her experiences of working in a designer team.

> O3: [...] that's why say you can push through your ideas more easily if you are very good at visualising, because if you sit three designers together who are working in a team, the first to present an idea or who can communicate their thinking to the others – that is what gets developed further [...].
>
> Interview with industrial designer O3, 20.03.2009, p.6

Teamwork (Figure 4; Figure 5). A team of different occupational groups are needed to develop a product. The interviewees describe their work in teams. Industrial designer O5 believes that her work is constrained by time, finance and clients and that she has learned to work within this *framework* from the others involved in the process. She points out that *collaboration* is more common in working life than she experienced in her education. In working life, you need to learn to *compromise*, as opposed to school where you can develop freely. O7 also learned about teamwork in her working life, but she believes that it is important to learn about teamwork in school.

> O7: And then I think you should learn in school much, much more that if you are going to work in the industry, you have to understand that this is teamwork. It is a huge teamwork ... uh, design engineering, marketing, the quality department and everything.
>
> Interview with industrial designer O7, 10.09.2009, p.4

The project is the working method for team work. All of the industrial designers describe how they work in projects and also that it is common to work as *project leaders*. O4 misses project leadership training from her training:

> O4: Um ... Well, I think that ...team leadership, project management training ... I didn't know any of that when I finished school, but you often end up in that role as a designer because you have knowledge of all concerned.
>
> Interviewer: You mean that you have knowledge of all involved?
>
> O4: Yes, ... you are between marketing and design engineering and ... and users ... and it's really good to be able to take that role, I mean you can sit and just be a quiet designer too, but then this will not result in a good project.
>
> Interview with industrial designer O4, 27.03.2009, p.3–4

The industrial designers have learned to work in projects in various ways. Only two of them mention education as a context in which they learned this. One of them, O10, learned to work in projects with other students outside of the regular training. O3 has experience from an education in which project work was included as an explicit pedagogical tool. She believes that knowledge about collaboration and project work are among the most important experiences that she gained from the education.

> O3: When we were interns, I noticed that it was the only thing of importance. That you can collaborate. Everything else, you can just learn ... in some way, but the other is so … you must get help to find out [...].
>
> Interview with industrial designer O3, 20.03.2009, p.3

Communication is important in team work. The industrial designers communicate with users, clients and the various occupational groups involved. One form of communication that is described by the interviewees' as being important within team work is presentation. *Presentation* means showing the results from previous work, but also persuading others and winning support for ideas. Much time is spent on communication and presentation; sometimes too much. Industrial designer O6 describes this as follows:

> O6: And then actually, this with presentation ... is quite big, because you have to be able to present it (the results, author's note) for those you are to convince or work with or pass on to. So often, it's unfortunately so ... we think we spend too much time mediating or selling or communicating what we have done, one would like to spend this time to ... produce and generate ideas [...].
>
> Interview with industrial designer O6, 01.10.2009, p.4

ANALYSIS

The two occupational groups: similarities and differences. So far, the results regarding each occupational group have been presented separately. The following summary presents an analysis of similarities and differences among the interviewees in their work with product development. The team is a concept of great importance in the interviewees' descriptions and the context in which they practice.

The team. The interviewees describe the product development process as an extensive process in which the different occupational groups are interdependent. These occupational groups form the team that realises and produces the final product. In the team, both industrial designers and engineers must be able to compromise and adapt to other people and to the process as a whole. The team shares the goal of delivering marketable products that match the original ideas for the new product and meet the clients' expectations and demands. The interviewees describe a hierarchy through which the product is realised step by step. Industrial designer O7 describes how one occupational group defines the boundaries for another.

> O7: The design engineers also have the freedom to find solutions within their problem set. We have the freedom to find solutions within our problem set. So the freedom is probably the same. But we are ahead of them and we tell them, these are your outer limits. We have others who tell us, these are your outer limits.
>
> Interview with industrial designer O7, 10.09.2009, p.2

The project leaders define the project's outer boundary and work with the product when it is still an abstraction. The industrial designer then works with the visualisation of the product and the engineering designer with the product more in detail, one step closer to the end production.[2]

Project and leadership. The project is the working method for the team and leadership is of major importance to the interviewees. When the interviewees refer to leadership, regardless of which question of the questionnaire they answer, it is linked to their work in projects or teams. The goal of a project is to develop the whole or parts of a product; consequently the final product can be a result of several projects. What a project leader is and does varies depending on the character of the project. Engineer O2 thinks that the concept of "project leader" is difficult to explain.

> O2: [...] you can be a project leader for an Excel spreadsheet, it's a difficult concept, and you can be the project leader for [company name] or [company name] for a billion kronor (Swedish currency, author's note) project.
>
> Interview with engineer O2, 02.04.2010, p. 2

Communication and Presentation

Communication is of great importance to project work and interaction in the team. The interviewees describe that they communicate a great deal in their daily work. Communicating is, according to the interviewees, to interact and to be in dialog with others; listening, asking, discussing and compromising. Presentation is also a form of communication that both engineers and industrial designers highlight. It is important to master presentation techniques, because presentation is the means to show work that has been performed or gain support for ideas.

The interviewees' experiences from their studies. Both the engineers and the industrial designers believe that they learned their basic knowledge and skills in their education (Q8, Figure 5). They also learned "the spirit of the profession" in their education; to think like and have the approach of an engineer or an industrial designer.

One engineer and one industrial designer claim that they have learned about leadership and project work in an educational setting, however outside of the regular training, together with their friends. Just one of the interviewees emphasizes that her school used project work as an explicit pedagogical tool and method. Other interviewees claim that collaboration and project work could only be learned through experiences in working life and that it is not possible to learn these things in school.

The interviewees and working life. In working life, the interviewees have deepened their basic knowledge and added new skills and knowledge, and thereby have gained the specific vocational knowledge that they need to carry out their work tasks. The interviewees learned about teamwork, project work and leadership by working in projects with colleagues and clients. Although their work tasks are different and engineers and industrial designers work in different development phases of the product development process, and therefore need different specific knowledge, there is one tool that they have in common.

CAD – the tool for digital modelling. The interviewees visualise different aspects of products by creating and developing digital models. The interviewees refer to this process as CAD (Computer-aided design) or as using a CAD tool; they even use the term as a verb. CAD models seem to have replaced most of the other methods for the visualisation of products (drawing, sketches and physical models). The terms CAD and CAD tool are used in this study because this is the terminology that the interviewees use.

The actual software that the interviewees use differs, but common features of the CAD tool are an interface with a three-dimensional space in which three-dimensional digital objects can be created, and the ability to add materials and lighting to simulate reality. The software mentioned in the interviews are Catia (Dassault Systèmes, 2011) and Rhino (Rhinoceros).

Industrial designers use CAD tools to work with form and function, so that the product meets the requirements of the users and clients. They work with virtual models in CAD and materialise them through various printing techniques, such as rapid prototyping. Design engineers develop the model at the detail level. Their CAD models are used as prototypes for production and are to correspond to the industrial designer's intention and to comply with requirements and standards. A dilemma that both engineers and industrial designers experience is that the CAD model and its physical representation do not match; engineer O1 emphasizes the importance of understanding this. The end product is not as perfect as the CAD model and this is a circumstance that needs to be taken into account when working with the digital model.

> Exactly, because you must understand this […] if you say that something should be 11.3 mm, it will not be 11.3 mm. It will be 11.3 mm plus or minus something. In CAD, it will be 11.300.000.0000, but in reality it will not be like that, […]. So it does not become perfect in reality just because it is absolutely perfect in CAD.
>
> Interview with engineer O1, 01.10.2009, p. 7

Industrial designer O3 describes the difficulty of predicting how the physical result of a CAD model will turn out. Even if she is an experienced designer, the result may sometimes be a surprise to her.

> [...] you work with it in 3D and it looks amazing, and then you get it out (as a physical model, author's note), and oh, was it so big? (laughter) [...] It may not match what you imagined. So you must try it in real life, I was about to say. That's obvious.
>
> Interview with industrial designer O3, 20.03.2009, p. 5

There are different opinions among the interviewees about how to become proficient in CAD. Is it a natural ability, or is it necessary to have embodied experience? Engineer O1 believes that it might be a special talent. She learned CAD because the skill was required in the profession. She believes that it was easier for her to learn CAD than it was for others; not everyone has a "CAD gene".

> Interviewer: You learned CAD at work?
>
> O1: At work, yes, yes. I felt that it was real fun. Different people have … some have CAD genes and others do not, and I have a CAD gene.
>
> Interview with engineer O1, 01.10.2009, p.3

Industrial designer O10, on the other hand, believes that young people who only work in CAD, and lack experiences of fixing and building things, are missing important insights, an understanding which, according to O10, is 'in the hands'. O10 explains this by describing how he developed a wooden model to find the right shape for an armrest.

DISCUSSION

This study focuses on the question of what skills and knowledge industrial designers and engineers consider to be of importance in their work with product development. The interviewees in this study describe how they, in addition to knowledge specific to their vocation, also need knowledge of a more general nature. Engineer O1 summarises her work as a design engineer as follows:

> You have to interact a great deal with other people and get along. [...] compromising and tweaking and discussing to arrive at a – we'll test this

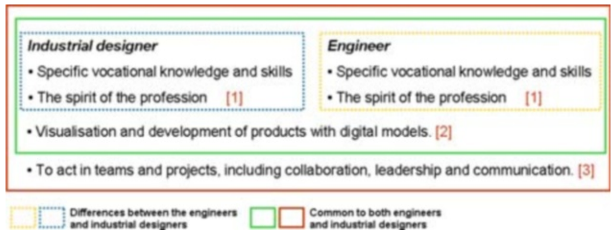

Figure 6. Summary of the knowledge areas that unite and separate engineers and industrial designers.

solution then.

Interview with engineer O1, 01.10.2009, p.14

This knowledge can be classified as key qualifications (Höghielm, 2005; Höjlund, Göhl, & Hultqvist, 2005; Kämäräinen, 2002). Both vocational knowledge and key qualifications are used in and associated with a particular context, the team.

The goal of the team is to produce products for the commercial market with a quality that meets the demands of clients and users. To be qualified to work in this context, the interviewees need knowledge and skills that are specific to the profession (Figure 6, [1]). For engineers, specific knowledge can be, for example, mathematics, problem solving or matters linked to design engineering. For industrial designers, sketching and modelling are prominent competences. These basic skills and this knowledge are provided by education, but the interviewees have in working life developed them further.

Although engineers and industrial designers possess and use different specific knowledge and skills to solve their specific vocational tasks, they do share the ability to visualise artefacts (Figure 6, [2]). Models are of great importance and both engineers and industrial designers need the ability to work with and understand digital models.

Visualisation

Although the engineers and the industrial designers belong to different occupational groups, they work towards the same goal. The realisation of products and digital models is of considerable importance in this process. When the interviewees work with digital models, they use a tool they refer to as ‘CAD’. A CAD tool is software for making three-dimensional digital models that represent physical products in development. Even though engineers and industrial designers use different software and work with different aspects of the product, they have these CAD tools as common features. The interface has a three-dimensional space in which three-dimensional digital objects can be created and properties such as materials and lighting can be added. Engineers and industrial designers need special knowledge and skills to work with the three – dimensional digital model and to anticipate the outcome so that it meets quality demands.

The interviewees with an older education have lived through a shift in visualisation tools, in which tools for drawings and models have been digitized. The digital three-dimensional model has become a standard tool that has replaced physical models in other materials like wood and wax. Even if the tools have changed, the aim of the visualisation is the same; to present representations of artefacts in different stages of development. De Vries (2005) describes a special knowledge, the ability to construe artefacts, recognize and understand the knowledge that made the artefact to what it is. One of the interviewees describes her understanding of digital images.

> [...] images are just [...] just a bunch of figures [...] each pixel is just a figure, [...] and each figure or each number is a colour so to speak. So one can actually see the images as – it is just a lot of figures, so there is a lot of mathematics.
>
> Interview with engineer O9, 12.10.2009, pp. 5–6

Schön calls product designers and industrial engineers classical *design professions* (Schön, 1987, 2003 [1995]). Others describe design thinking as knowledge based in both head and hands, for which the abilities of reading and of making sketches, drawings and models are essential (Cross, 2000, 2007 [2006]; Kroes, 2009; Ferguson, 1978; Kimbell & Stables 2007; Stiftelsen Svensk industridesign, 2007).

In Sweden, design is not obviously associated with engineering; when discussing design with engineers in this study, they did not think that they were engaged in designing. One of the informants in the study explains that she does not work with design because a design activity, according to her, is related to artistry.

> O1: No, no, no, no, no, I think that I work more with construction and not design, for me these are different dimensions. I would say that design is artistic.
>
> Interview with engineer O1, 01.10.2009, p. 11

Another way to understand the knowledge that is shared by the engineers and industrial designers in this study is to describe it as *making knowledge* (Dunin-Woyseth & Michl, 2001). *Making knowledge* derives from Ryle's (1949) *knowing how* and is the concern of diverse *making* disciplines. Gerosa argues "we can call them praxical-poietical disciplines, after the classification of Aristotle, because they belong to *praxis* or acting and to *poiesis* or making" (Gerosa, 2001, p. 103).

To Act in a Team

To fulfil the purpose of the team, producing an end product, it is not enough just to have the specific knowledge and skills needed to solve specific vocational tasks (Figure 7). The interviewees also interact; they collaborate, compromise, communicate, and so on, with other engineers, industrial designers, occupational groups and clients (Figure 6, [3]). The need for abilities to *act within the team* is

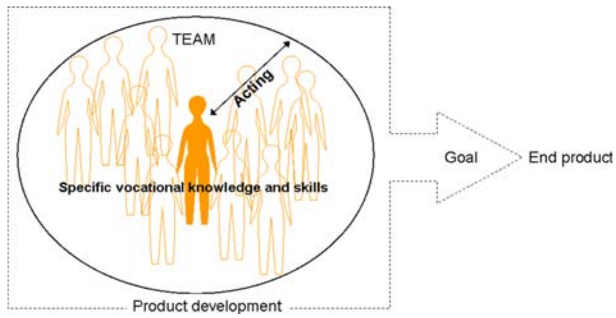

Figure 7. Both specific vocational knowledge and abilities to act within the team are needed in the team context.

stressed by the interviewees as being a necessary requirement when navigating and positioning oneself in the team context (Figure 7).

The results presented in this study contribute by expanding Höghielms' definitions (1998, 2005) of vocational knowledge by describing how specific vocational knowledge and key qualification are intertwined. The interviewees do not stop being engineers or industrial designers when they collaborate or make a presentation, they need specific vocational knowledge and skills as well as the ability to act in a team.

Nyhan states that key qualifications "[…] cannot be learnt in 'formal teaching settings' […]. Learning 'key qualifications' presupposes a social or organisational learning setting in which people are given the space and supported to develop and use these competences." (Nyhan, 2002, p. 243).

The education of the interviewees in this study did not offer a learning setting suited to develop key qualifications. Several of the interviewees point out that they lack training in teamwork from their education and they have different opinions on how they have learned this. Some emphasize social activities or collaboration with other students outside the regular training. Others stress experiences from working life or from life experiences, such as this interviewee.

> But it is more a matter of life knowledge. That one actually learns teamwork gradually. You learn to work in groups. And that applies whether it is an industrial designer, or whatever occupation you have. It is something you learn.
>
> Interview with industrial designer O7, 10.09.2009, p.4

Even though she is satisfied with her education, one interviewee points to her internship as being of great importance to her learning.

> While on internship ... there I probably learned everything that I am able to do [laughs], it feels like that.
>
> Interview with industrial designer O3, 20.03.2009, p.5

The Power of Education

Although the interviewees' educational training took place long ago, the interviewees emphasize that their education has been a source of their basic skills and knowledge and was the first insight into the nature of their profession (Figure 5). This is a reminder of the long term impact of education. What we learn in school has an impact not only in relation to the skills attained, it also influences our views, definitions and expectations concerning what it means to be an engineer or an industrial designer. What educators present to students today will accordingly affect not only the students as individuals, but also their view of what counts as important knowledge in a specific knowledge field. The power that educators and providers of education have in deciding what knowledge and skills characterize a profession or knowledge field is great.

Within higher education, a knowledge field can be quite specific, as is the case in programmes leading to specific degrees, such as the *Bachelor of Science in engineering* with *specialisation in mechanical engineering* or the *Bachelor of fine arts* with *main field of study in industrial design* (Swedish National Agency for Higher Education, 2012a; Umeå University, 2010a; Umeå University, 2010b). Even at the upper secondary level, the link to possible future professions is often quite clear. The Technology Programme, for example, is presented by the Swedish national agency for education as a programme suitable for *'those who want to work with technology or the technological processes'* (Swedish National Agency for Education, 2011b).

Educators influence students' views on professions and what counts as significant knowledge in these knowledge fields, but they act in another context and with other objectives. In education, the objective is, in accordance with the steering documents, to mediate knowledge and prepare students for a future life in society as well-educated citizen. In product development, occupational groups are interdependent, whereas this is not necessarily the case in educational environments. Collaboration and teamwork among educators is not a necessity in order to fulfil the goals. However, this study shows that vocational knowledge and key qualifications should be intertwined and of equal importance. Education can learn from this, even if the traditional model for educators is influenced by Socrates; the teacher personifying all wisdom and possessing the ability to mediate all the knowledge that the student needs, independently of others (Platon, 1996).

Closing remarks. The research question raised in the study has now been answered. Through interviews with a selection of professional industrial designers and engineers, we now know what skills and knowledge they consider to be important to their work with product development. However, these results raise a number of new questions. The interviewees in this study value the basic knowledge and skills they received from secondary or higher education (depending on their educational background). When it comes to abilities to act in a team context, education was seldom the source of knowledge and the interviewees had different experiences regarding how they learned this.

That education shall provide such abilities is stated in curricula and other steering documents for upper secondary schools and higher education (Swedish National Agency for Education, 1994, 2011a; Sweden, 1993). It is hard to argue against school/education as an excellent arena for developing these (and other) key qualifications. Education is a safe environment and mistakes are not costly; it can, with support and feedback, be an excellent environment to experience and learn these abilities. The question of how teachers approach issues related to collaboration, communication and leadership needs to be addressed (and studied). What methods and strategies are used in school today? Is working in teams included in the working traditions of the teachers of today, or do teachers see Socrates, the independent master teaching Theaetetus in solitude, as their model?

Another area for further research is to study three-dimensional digital modelling as a source for learning. In the process of transforming an idea to a product, the models created with CAD tools are of great importance. Both engineers and industrial designers need to understand and develop them. What teaching strategies do teachers use when they teach three-dimensional digital modelling? From a learning perspective, how do we become proficient in three-dimensional digital modelling? Is it easier to understand three-dimensional modelling if we have experiences of making physical objects with our hands, or is it enough to be skilled in using software in order to understand relations between objects on and off screen?

The aim of this study was to answer a specific research question. Hopefully, the reading of the text has brought the reader's attention and interest not only to product development as a subject and profession, but also to the important link between school education and the student's career/working life.

NOTES

1 All eighteen (18) national programmes give general qualifications for higher vocational education.

2 This type of hierarchy, in which interdependence and communication create boundaries between different occupational groups, has been described before by Bechky (2003). She examines in an ethnographic study the dynamic of boundaries between three different occupational groups; engineers, technicians and assemblers at a manufacturing firm. Engineers create representations of a new product in the form of drawings, technicians use the drawings to make a prototype and assemblers use the prototype to understand how the product should be assembled. The engineers that have carried out the mental creation of the product own the artefact and are highest in the hierarchy.

REFERENCES

Alvesson, M., & Sköldberg, K. (1994). *Tolkning och reflektion: vetenskapsfilosofi och kvalitativ metod*. Lund: Studentlitteratur.

Bechy, B. A. (2003). Object lessons: Workplace artifacts as representations of occupational jurisdiction. *American Journal of Sociology*, *109*(3), 720–752.

Cross, N. (2000). *Engineering design methods: Strategies for product design* (3rd ed.) Chichester: Wiley.

Cross, N. (2007 [2006]). *Designerly ways of knowing*. Basel: Birkhäuser.
Dassault Systèmes (2011). *CATIA V6*. Retrieved December 04, 2011, from http://www.3ds.com/products/catia/portfolio/catia-v6/overview/
de Vries, M. (2005). *Teaching about technology: an introduction to the philosophy of technology for non-philosophers*. Dordrecht: Springer.
Dreyfus, H. L., & Dreyfus, S. E. (2000). *Mind Over Machine: the power of human intuition and expertise in the era of the computer*. New York: Free press.
Dunin-Woyseth H., & Michl, J. (2001). Towards a disciplinary identity of the *making* professions. In H. Dunin-Woyseth & J. Michl (Eds.). *The Oslo millennium reader: towards a disciplinary identity of the making professions*. Oslo: Oslo School of Architecture.
Ferguson, E. S. (1978). The mind's eye: Nonverbal thought in technology. *Leonardo: Journal of the International Society for the Arts, Sciences and Technology*, *11*(2), 131–139.
Gerosa, P. G. (2001). The study of the city as an artifact. In H. Dunin-Woyseth & J. Michl (Eds.). *The Oslo millennium reader: towards a disciplinary identity of the making professions*. Oslo: Oslo School of Architecture.
Hartman, J. (2004). *Vetenskapligt tänkande: från kunskapsteori till metodteori*. Lund: Studentlitteratur.
Höghielm, R. (Ed.). (1998). *Från Wittgenstein till degknådning: – om yrkeskunskap och yrkeskultur.* Stockholm: HLS.
Höghielm, R. (2005). Yrkesbaserat *lärande : erfarenheter från PEOPLE delprojekt i Söderhamn 2002 till 2005*. Söderhamn: Centrum för flexibelt lärande.
Höjlund, G., Göhl, I., & Hultqvist, E. (2005). *Utbildningsmodeller och läroprocesser i brytningen mellan skola och arbetsliv: en kunskapsöversikt*. Stockholm: Myndigheten för skolutveckling.
Kimbell, R., & Stables, K. (2007). *Researching design learning: Issues and findings from two decades of research and development*. Dordrecht: Springer.
Kroes, P. (2009). Foundational issues of engineering design. In A. Meijers, (Ed.), *Philosophy of technology and engineering sciences 9* (pp. 513–541). Amsterdam: North Holland.
Kämäräinen, P. (Ed.). (2002). *Transformation of learning in education and training: Key qualifications revisited.* Luxembourg: Office for Official Publications of the European Communities.
Nyhan B. (2002). Promoting learning in and for organisational contexts – the development of key qualifications/key competences. In P. Kämäräinen, (Ed.), *Transformation of learning in education and training: key qualifications revisited* (pp. 242–254). Luxembourg: Office for Official Publications of the European Communities.
Marshall, C., & Rossman, G. B. (2006). *Designing qualitative research* (4th ed.). Thousand Oaks, Calif.: SAGE.
Månson, P. (Ed.). (2003). *Moderna samhällsteorier: traditioner*, *riktningar*, *teoretiker*. Stockholm: Prisma.
Platon, (1996). *Teaitetos* ([New ed.]). Nora: Nya Doxa.
Rhinoceros. *Modeling tools for designers*. Retrieved December 04, 2011, from http://www.rhino3d.com
Ryle, G. (1949). *The concept of mind*. London: Hutchinson.
Schön, D. A. (1987). *Educating the reflective practitioner: [toward a new design for teaching and learning in the professions]* (1st ed.). San Francisco: Jossey-Bass.
Schön, D. A. (2003 [1995]). *The reflective practitioner: how professionals think in action*. Repr.[= New ed.] Aldershot: Arena.
SCB, Statistics Sweden (2010). *Befolkningens studiedeltagande*. Retrieved December 04, 2011, from http://www.scb.se/Pages/ProductTables____9611.aspx
Skogh, I. (2010). Teachers becoming researchers = A way to bridge the gap between academy and practice. In H. Middleton (Ed.), *Knowledge in Technology education*, *proceedings of the 6th Biennial international conference on technology education* (pp. 128–136). Griffith University: Griffith institute of educational research.
studera.nu (2011). *Sök och jämför utbildning*. Retrieved December 04, 2011, from http://www.studera.nu/2.328ff76512e968468bc80005926.html
Sweden. Government of Sweden. (1989). *Regeringens proposition 1988/89:90 om ingenjörsutbildning*. Retrieved December 04, 2011, from http://www.riksdagen.se/webbnav/index.aspx?nid=37&dok_id=GC0390

Sweden. Government of Sweden. (1992). *Förordning om programmål för gymnasieskolans nationella program* (SKOLFS 1992:5). Retrieved December 04, 2011, from http://www.skolverket.se/lagar_och_regler/2.3134/2.5007?_xurl_=http%3A%2F%2Fwww4.skolverket.se%3A8080%2Fwtpub%2Fws%2Fskolfs%2Fwpubext%2Ffs%2FRecord%3Fk%3D52
Sweden. Government of Sweden. (1994). *Skrivelse 1993/94:183 Utvecklingsplan för skolväsendet*. Retrieved December 04, 2011, from http://www.riksdagen.se/webbnav/index.aspx?nid=37&dok_id=GH03183
Sweden. Government of Sweden. (1998). *Proposition 1997/98:169 Gymnasieskola i utveckling kvalitet och likvärdighet.* Retrieved December 04, 2011, from http://www.riksdagen.se/webbnav/index.aspx?nid=37&dok_id=GL03169
Sweden. Gymnasieutredningen (2008a). *Framtidsvägen – en reformerad gymnasieskola: betänkande* (*SOU 2008:27)*. Retrieved December 04, 2011, from http://www.riksdagen.se/webbnav/index.aspx?nid=37&dok_id=GW03199
Sweden. Gymnasieutredningen (2008b). *Proposition 2008/09:199 Högre krav och kvalitet i den nya gymnasieskolan*. Retrieved December 04, 2011, from http://www.riksdagen.se/webbnav/index.aspx?nid=37&dok_id=GW03199
Sweden. Ministry of Education and Research. (1993). *Högskoleförordning* (*1993:100)*. Retrieved March 14, 2012, from http://www.hsv.se/utlandskutbildning/arbetaisverige/hogskoleverketsbedomning/sokbedomningar.4.539a949110f3d5914ec800060424.html
Swedish National Agency for Education (1994). *Curriculum for the Non-Compulsory School System – Lpf 94*. Retrieved March 14, 2012, from http://www.skolverket.se
Swedish National Agency for Education (2011a). *Läroplan*, *examensmål och gymnasiegemensamma ämnen för gymnasieskola 2011*. Stockholm: Skolverket.
Swedish National Agency for Education (2011b). *Technology Programme*. Retrieved December 04, 2011, from http://www.utbildningsinfo.se/content/1/c4/13/53/Teknik_en_korr.pdf
Swedish National Agency for Higher Education (2012a). *Högskoleverkets författningssamling* (*HSVFS 2012:1–3)*. Retrieved March 14, 2012, from http://www.hsv.se/download/18.1413da98135538a93ad80001000/HSVFS-2012–1-3.pdf
Swedish National Agency for Higher Education (2012b). National qualifications framework. Retrieved November 24, 2012, from http://hsv.se/highereducationinsweden/nationalqualificationsframework.4.5dc5cfca11dd92979c480001476.html
Stiftelsen Svensk industridesign (2007). *Under ytan: en antologi om designforskning / [redaktion: Åsa Harvard ... ; introduktionstexterna är skrivna av Sara Ilstedt Hjelm]*. Stockholm: Raster.
Umeå University (2010a). *Local qualification descriptor.* Retrieved March 14, 2012, from http://www.umu.se/digitalAssets/63/63817_hgskoleingenjrsexamen-inr-maskinteknik.pdf
Umeå University (2010b). *Local qualification descriptor.* Retrieved March 14, 2012, from http://www.umu.se/digitalAssets/63/63786_konstnrlig-kandidatex-industridesign.pdf
Ödman, P. (2004). Hermeneutik och forskningspraktik. In B. Gustavsson, (Ed.). *Kunskapande metoder inom samhällsvetenskapen*. Lund: Studentlitteratur.

APPENDIX

Questionnaire questions

1.	Name	Man	Woman
2.	What is your profession?		
3.	For how long have you worked in the profession?		
	Number of years		
4.	Education and training	Degree	Year
4a.	Educational programme		
4b.	Educational programme		
4c.	Educational programme		
5.	Do you think you have the right education for your profession? Explain your answer.		
6.	Why did you choose your profession?		
7.	Are you satisfied with your career choice? Explain your answer.		
8.	Give three examples of knowledge or skills that you learned during your education that you consider are of special importance for you in your profession. Explain why these skills or knowledge have been of particular importance.		
8.	Example 1		
	Explain your answer		
8.	Example 2		
	Explain your answer		
8.	Example 3		
	Explain your answer		
9.	Are there any skills or knowledge that you did not learn during your education that would have been useful in your professional practice?		
10.	Can you give examples of skills or knowledge that you learned in your professional practice that you have not learned during your education?		

11.	How did you learn this?
12.	Give three examples of tasks that you perform frequently in your work.
12.	Example 1
12.	Example 2
12.	Example 3
13.	Rank the three most important items of knowledge or skills for practitioners of your profession.
13.	1
13.	2
13.	3

SECTION IV

TEACHERS' PERSPECTIVE

EVA HARTELL

12. LOOKING FOR A GLIMPSE IN THE EYE

A Descriptive Study of Teachers' Work with Assessment in Technology Education

INTRODUCTION

In order to position yourself with a Global Positioning System (GPS) device, you need (1) to have a GPS device with (2) accurate software, (3) the knowledge to use and interpret it, and last but not least (4) information from at least three different satellites in order to determine a position. Depending on the model and the coverage in the area, you can get different accuracy levels. Being a technology teacher myself, I can see many similarities between the traveller's need for milestones along the road and the teachers' need for several clear benchmarks to support the assessment work that supports the student's progress. The importance of navigating at sea is familiar to me, after years of sailing on our family boat. Teaching could, in my experience, be seen in many respects as a similar activity, which put demands on all the participants. Neither teaching nor sailing is an easy, laid-back activity.

To 'navigate' students towards the goals of the curriculum, while making sure to keep every student 'on-board', is a challenge worthy of a world sailor. Despite thorough planning, you still need to make frequent check-ups, since you know neither exactly what will happen during the journey in advance nor which way to take to reach the wanted destination. This, I find, is part of the excitement/allure with travel, both as a sailor and teacher. In this study teachers' day-to-day work with assessment to support the student's progress is highlighted from the perspective of technology education. How does a technology teacher gather information in order to position her/his students before deciding on what step to take next?

Assessment and evaluation of student performance and progress in school is an ongoing process and far from consisting of only grades and test scores. Teachers make assessments/assess their students all the time with the intention of moving their students forward on their learning journey (Kimbell, 2007). They ask questions and they look for signs of response ('a glimpse in the eye') in the faces of their students. This subtle evaluation and appraisal work, which takes place every day in every classroom, is the focus of this article.

I.-B. Skogh & M.J. de Vries (Eds.), Technology Teachers as Researchers, 255–283.

PURPOSE AND RESEARCH QUESTION

My research interest is to explore how teachers make sure that their students reach the goals in the national curricula, which the students, according to the regulations, are entitled to. The focus in this present study lies upon the participating teachers' (two primary school teachers) work with technology education. I am interested in their description of their assessment practice (interviews) as well as their work in the classroom (classroom observations). The question of whether the teachers are discussing assessment with colleagues is also highlighted. According to Pettersson (2009), such discussions increase the validity of assessments made. My intention, however, is not to question the validity of the studied teachers' assessments. Neither am I interested in the inter-reliability or the intra-reliability of their assessment (Gipps, 2004; Pettersson, 2009). The main purpose of this study is to observe the assessments which occur in the daily life within the classroom walls; the minute-by-minute, day-by-day part of assessment for learning (formative assessment). The following research question is put forth:

How is Teachers' Minute-by-Minute Follow-up Enacted in the Classroom?

The focus is set to capture and identify traces of the five key strategies for formative assessment (Black and Wiliam, 2009). The purpose is to find traces of them within the classroom walls, during some technology lessons referred to by Black and Wiliam as 'engineering effective classroom discussions and other learning tasks that elicit evidence for student understanding and feedback that moves the learners forward.

TECHNOLOGY EDUCATION IN SWEDEN

To provide a picture of the content in which this study is performed, I start with a short presentation of technology education in Sweden. A more extensive description is given in Inga-Britt Skogh's chapter in this book. I am aware of the fact that technology education in Sweden differs in various respects from technology education in other countries. I have chosen not to discuss those similarities and differences here.

Despite the fact that technology education has been a mandatory subject for 30 years, it is still lacking a strong teaching tradition and roots (Fabricius et al., 2002). The teachers in technology are not always aligned with the national curricula and syllabus (Bjurulf, 2008; Klasander, 2010). Numerous supervision reports from different municipalities conducted by the Swedish Schools Inspectorate (2009a, 2009b; 2009c) confirm this. The inspectors state that the teaching of technology is not even accomplished enough (in quantity) to give the pupils the opportunity to reach the goals. It should be noted that these inspectors talk about quantity, not quality! The supervision reports are in agreement with a study performed by the Association of Swedish Engineering Industries (Teknikföretagen, 2005). This study concludes that the situation is most alarming, in particular in the early years of schooling. Nothing much (regarding technology education) is going on at all. This undoubtedly questions the students' possibility to learn technology. In order for students to consolidate concepts, principles and perspectives, they at least have to be given time to practice in different contexts (Lindström, 2006; Dakers, 2007). It should be noted that as of today (January 2012) no national statistics exist regarding younger pupils' performance in technology (school years 1–5) as marks are given from year eight.[1] Despite all the above-mentioned circumstances, students in Sweden are, according to national statistics compiled by the National Education Agency, performing 'well' in technology; 93.9% (above average) of Swedish ninth graders exceed the goals to achieve in the syllabus (SIRIS, 2009; Hartell, 2011). How can the situation be like this, one might ask? Very limited time and resources designated for technology education and still remarkably good grading. There is something not right!

MONITORING SYSTEM IN COMPULSORY SCHOOL

In this section a brief overview of the Swedish monitoring system in compulsory school in general and in technology education in particular is presented.

Decentralized School System

The educational system in Sweden is currently going through some major changes. In 2011 a new school law, a new curricula and syllabuses, and newly introduced teacher training were implemented. This study, however, was undertaken during the previous regulations.

According to the former and current regulations, each school can decide when, how and by whom a student should be tutored in any subject matter, as long as the student achieves the targets set by the national curricula. Each teacher interprets the syllabus and makes the student assessments in relation to their interpretation of the targets. Hence teachers have great freedom and responsibility to plan their teaching as they please (Klapp-Lekholm, 2010).

In Sweden the monitoring system is based on individual teachers' assessments of the students' positions in relation to the goals in the curriculum. In the Swedish assessment system most of the teacher assessments are made during 'teaching situations' in the classrooms (Klapp-Lekholm, 2010). As the Swedish school system allows teachers to choose methods and subject content instructions (and monitoring procedures), they vary from teacher to teacher. However, teachers' assessments of the students' positions compared to the national curricula are not to vary (ibid.). According to the regulations, teacher assessments should be based on the students' knowledge and abilities and nothing else. However, Klapp-Lekholm (2008) shows that grades are based on things other than students' knowledge (e.g., students' personality or background). There are small differences but these differences vary among students, subjects and teachers. The grading of pupils that are high achievers, for example, seems to be more content-knowledge related than that of low achievers, who seem to be graded in a more compensatory manner (ibid.).

External Assessment Instruments

There are external assessment instruments – national tests – available to teachers in Sweden in some (e.g., mathematics, Swedish, science and English) but not all subjects. The tests are externally produced, but no external referees are involved in the grading process. Grading is undertaken by the teacher her/himself. The national tests are designed to support the teacher in her/his assessment work/grading (Skolverket, 2010). However, when there is an external test several reports show that there is a considerable difference between the grade on the test and the teachers' final grades (Forsberg & Lindberg, 2010). There is no national test in technology.

In Sweden there is yet another instrument called the Individual Development Plan with written assessments, IDP, available to teachers. It is to be used by teachers as a tool for the documentation of the pupils' development of skills and knowledge in all school subjects (Hirsh, 2011). Data collected in the IDP is to be presented and discussed with the pupils and their guardians during reoccurring meetings a minimum of twice a year.

TRAINING IN ASSESSMENT

According to Lundahl (2009), most teachers in Sweden lack training in assessment. Some interventions have been undertaken by the National Agency for Education, and in some municipalities local intervention initiatives have been undertaken. The target groups for these interventions has primarily been, however, teachers in secondary school, where grading is required. Teachers working in the early years of schooling are unfortunately seldom considered to be a target group (Fagerlund & Högberg, 2010; Holmgren, 2010).

ASSESSMENT FOR LEARNING

Formative Assessment or Not

According to Wiliam (2011), assessment is the bridge between teaching and learning. However, the aims and purposes of assessment obviously differ. Making sure the students are following the intended path towards the goals is one aim. Evaluative reporting to the authorities is another (Newton, 2007; Gipps, 2004; Pettersson, 2009). If the purpose of the assessment does not include the students' future progress, one might question the usefulness of it (Nyström, 2004). The focus of this study is assessment that aims to move the students forward on their learning journey, sometimes called assessment for learning or formative assessment. The framework for the study is the work of Leahy et al. (2005), Kimbell (2007), Black & Wiliam

(1998, 2009) and Wiliam (2009, 2011). Below I present their contributions to the understanding of formative assessment, which I have found useful for this study.

Wiliam (2009) suggests a difference between assessment for learning and formative assessment regarding intention and actual function. Assessment is formative when, and only when, the information gathered is used in order to allow for probable change in the gap between the current position and the desired one for the student on her/his learning journey (Wiliam, 2009, 2011).

> Practice in a classroom is formative to the extent that evidence about student achievement is elicited, interpreted, and used by teachers, learners, or their peers, to make decisions about the next step in instruction that are likely to be better, or better founded, than the decisions they would have taken in the absence of the evidence that was elicited. (Black and Wiliam, 2009a, p. 9)

Lots of information concerning student performance is gathered but is seldom used (Wiliam, 2009). Teachers often assume that they are able to determine if their students are 'on track' or not. This assumption is often based on what the teacher herself/himself thinks that she/he has (or has not) taught her/his students (Kimbell, 2007). This is somewhat problematic. Firstly, students do not learn everything the teacher has in fact taught. Secondly, students learn stuff in other surroundings as well (ibid., Wiliam, 2011). The teacher's interpretation of gathered information can also be biased by the teacher's prior view of the student. Both the teacher's and the learner's expectations regarding her/his potential to achieve the goals set up may also affect the results (Rosentahl & Jacobson, 1992; Gipps & Murphy, 2010; Kimbell, 2007).

The Time Dimension

In order to distinguish effective and less effective formative assessment it is valuable to distinguish between the long-cycle, medium-cycle and short-cycle formative assessments (Wiliam, 2009). The short-cycle formative assessment takes place in the minute-by-minute and day-by-day work in the classrooms. The medium cycle consists of, for example, tests and other not so frequent check-ups with the duration of a day or maybe weeks or a month. The time factor is also important in another sense. The effectiveness of formative assessment declines as time passes, and it gets increasingly less likely that the learner will move forward. Despite this, the long cycle of formative assessment is not to be disregarded. Wiliam (2009) argues that the effectiveness of long-cycle assessment can be useful on a strategic/comprehensive level. Within the Swedish educational context, the long cycle of formative assessment includes national tests, grading and, according to Hirsh (2011), the previously mentioned Swedish phenomenon, the IDP.

According to Wiliam (2009), the short cycle of formative assessment, the minute-by-minute work in the classroom, is the most effective for the learners and the only one considered as formative in its true meaning.

Five Key Strategies for Formative Assessment

Leahy et al. (2005) have identified different approaches regarding how to introduce assessment for learning to teachers. A set of five broad strategies was identified and named the five key strategies (Leahy et al., 2005; Black & Wiliam, 2009).

- Clarifying and sharing learning intentions and criteria for success;
- Engineering effective classroom discussions and other learning tasks that elicit evidence for student understanding;
- Providing feedback that moves learners forward;
- Activating students as instructional resources for one another; and
- Activating students as the owners of their own learning.

According to Wiliam (2009), not only the teachers are involved in the process of formative assessment and moving the learner forward. These processes involve the teacher, the learner and their peers as entangled agents with different roles on the learning journey. This entanglement is described in the grid in Figure 1, below.

RESEARCH ON ASSESSMENT IN TECHNOLOGY

In this section a brief overview of previous research concerning formative assessment in technology education is presented. The review has been made through Swedish and English literature and selected to fit the theme of this article. Accordingly, the presentation is not intended as a complete review of relevant research on assessment in technology education.

<table>
<tr><th></th><th>Where the learner is going</th><th>Where the learner is right now</th><th>How to get there</th></tr>
<tr><td>Teacher</td><td>1 Clarifying learning intentions and criteria for success</td><td>2 Engineering effective classroom discussions and other learning tasks that elicit evidence of student understanding</td><td>3 Providing feedback that moves learners forward</td></tr>
<tr><td>Peer</td><td>Understanding and sharing learning intentions and criteria for success</td><td colspan="2">4 Activating students as instructional resources for one another</td></tr>
<tr><td>Learner</td><td>Understanding learning intentions and criteria for success</td><td colspan="2">5 Activating students as the owners of their own learning</td></tr>
</table>

***Figure 1.** Description of the five key strategies for formative assessment, and the interrelated relationship/entanglement between the teacher, peer and learner in the shared responsibility for learning. From Black & Wiliam, 2009a, p. 8.*

What is Assessed?

Technology teachers' assessment practices do not reflect technology classroom activities (Bjurulf, 2008). Most of the work undertaken in the technology classroom is 'hands on'. Still, teachers seem to value theory more than the 'practical work' pupils do during the lessons, especially when grading (Bjurulf, 2008). Teachers often emphasize criteria connected with 'the self' as a person, for example, working individually and being thorough in the so-called lived curricula (ibid.). Klapp-Lekholm (2008, 2010) supports this in her study concerning grading for personality instead of knowledge. Bjurulf (2008) questions the notion of praising theoretical knowledge rather than practical skills. This is, according to Bjurulf, a bit peculiar or even odd, since most of the time shared in the classroom is dedicated to practical work. Bjurulf suggests that there might be a 'hidden agenda' among technology teachers. Technology teachers also express the wish for their students to work individually, and this is understood, according to Bjurulf, by the students who aim for the higher grades. These students accordingly avoid asking questions of the teacher. Discussions about grading occasionally occur towards the end of a theme, but otherwise such grading discussions between teachers and students are unusual, according to the study undertaken by Bjurulf (2008).

In an article presented by Black (2008) and in a booklet by Moreland et al. (2008), the issue of assessment in technology education is addressed. In these studies the importance of discussions among students and the use of their questions are highlighted. The importance of giving students opportunities to ask questions, to receive feedback and to learn from experiences (including their own mistakes) is also emphasised. Black (2008) also highlights the importance of a permissive social climate in the classroom and of what he calls 'wait time'. He refers to a study by Rowe (1974) stating that teachers wait, on average, 0.9 s for pupils to answer a question. By increasing the amount of wait time to 3 seconds the possibilities for learning increase significantly (Black, 2008).

FEEDBACK

The Origin of Feedback

Feedback is an integral part of assessment for learning and suggested as one of the five key strategies (Leahy et al., 2005; Black et al., 2009; Lindström, 2009; Wiliam 2009). Feedback is provided not only by the teacher, but also by peers and by the learner her/himself through self-assessment (ibid.). What is feedback, then?

The concept of feedback has its origin in engineering (Wiliam, 2009). In engineering, feedback is only considered as feedback when the information is fed back into the system and used to make the process progress by altering the gap between the current position and the targeted one. The classic example is that of the thermostat, where reading it and finding *it is cold* is not feedback, in an engineer's point of view, unless some regulations have been undertaken.

Feedback has Lost its Origin

Wiliam (2009) argues that the concept of feedback is used, and too often misused, within the educational context, in which all kinds of information and comments given to the students are considered as feedback, that is, it has lost its origin. Lots of information is gathered and kept, but it is rarely used to change the situation around the student during her/his learning journey, and thus it is not to be counted as feedback, no matter what the intention was. Previous research concerning feedback in the classroom context shows that most of the feedback given in classrooms is not fed back into the system, that is, it is not to be considered as feedback (Wiliam, 2009).

Different Kinds of Feedback – the Focus

In a review of feedback, Hattie and Timperley (2007) have identified three questions to keep in mind for effective feedback.

1. Feed up. Where am I going?
2. Feed back. How am I going?
3. Feed forward. Where to next?

International research is concurrent about the findings regarding the effectiveness, for students' progress, of feedback and assessment for learning where feedback is an integral part (Black & Wiliam, 1998; Lindberg, 2005; Hattie & Timperley, 2007). They are also concurrent about related difficulties; not all feedback given improves student performance (Gipps, 2004; Wiliam, 2009). The importance of what is said and what is assessed is identified (Hattie & Timperley, 2007). Hence it is not always helpful; in some cases it even hampers learning.

Feedback falls into four categories: feedback about (1) the task, (2) the processing of the task, (3) self-regulations, (4) the self as a person (Hattie & Timperley, 2007). Information given to students which only consists of judgments or grading and therefore does not give any information regarding how to improve performance is not considered to be feedback. When feedback focuses on the person and not the task or process, the risk of hampering learning is increased. When feedback is focused on 'the self' as a person or given as praise it can even be counterproductive. It is indeed a problem that, according to research, most of the feedback given in classrooms is focused on the self as a person (no. 4; Lindström, 2006; Hattie &Timperley, 2007). Feedback should be linked to opportunities for improvement, including opportunities to work with the feedback. The most powerful feedback is focused on the processing of the task and self-regulations when it comes to mastering the task.

In conclusion, the assessor (teacher, peer, and learner) must focus on the task, process and/or self-regulation, instead of focusing on the self as a person or just give 'feedback' on routine (Lindström, 2006; Hattie & Timperley, 2007; Black & Wiliam, 1998, 1998b; 2009; Wiliam, 2009, 2011). Generally speaking it is better to keep quiet than to say something not completely thought through. If a child always, no matter what, receives the response 'How nice, can you tell me more about it?' she/he will soon come to the conclusion that what she/he is doing is not important. For children criticism is much better received, as it proves that the teacher is taking them and their work seriously (Lindström, 2006).

METHOD

In this section a description of the collection and selection of data is given, including ethical considerations.

The study was performed in the school year of 2010/2011 when the 1994 curricula were mandatory (before the implementation of the most recent curricula in 2011). Data presented are based on observations and informal interviews with two teachers in primary school during their work with thematic studies in technology.

The study focuses on the teachers' work with assessment for learning during a number of technology lessons. The educational impact from the teaching (pupils' achievement and knowledge development) is not an issue here.

Selection of Informants

I have chosen teachers working in the lower years of schooling, due to my prior experience as a teacher in – middle and secondary school. The teachers themselves decided what theme/task of technology they would teach during my observations/ data collection. By letting the teachers chose what task/theme, I acknowledge the teachers' privilege (stated in the curricula) to interpret the curricula and decide what path to take together with their students. I have tried to protect the identity of the informants by changing all names and places to fictional ones, and the municipalities are considered as one group, ABC, in order to further protect the informants.

In Sweden the municipalities are the entities for the schools. The selection of municipalities was made in accordance with statistics from the Swedish Association of Local Authorities and Regions (SALAR, 2007, 2008, 2009, and 2010). Three similar municipalities were initially identified and two were then selected. The similarities consist of four background variables; SALSA (30%), population (30%), standard cost (30%) and median net income (10%). These three municipalities are also similar in relation to the number of inhabitants and the number of students in year 9 (about 1000).

Finding Schools and Teachers

A top-down approach was used. I started by asking the school board in the two chosen municipalities to appoint schools for me/the study. The heads of the two schools suggested teachers at their respective schools. The appointed teachers were regarded as being competent representatives for their respective schools. To what extent they in fact are 'representative' for their school has not been questioned. My intention was not to find a 'representative' teacher, whatever a representative teacher might be (?). My intention was to find teachers who were willing to participate in the study.

Case 1: Lake school

The school

Lake School is located in a multicultural housing estate location in a socio-economically challenged area. There are in total about 285 students ranging from preparatory class to year 5 (6–11 y olds). Most teachers are female and a majority of them have several years of teaching experience. Most teachers teach all subjects (with a few exceptions) in one class. The Lake School is known (in its municipality) for good results on external tests. No information was found on the school website about their work in technology.

Karen – the teacher

Karen was born in Sweden and has 30 years of teaching experience. She has been educated for teaching in primary school (years 1–3) in various subjects but not in technology. Karen has, however, two days in-service training in technology education. She teaches mathematics, natural science and technology to a group of 47 students. The students are 10 years old (4th graders). The group of children is divided into two classes. Karen shares the responsibility for the group with a colleague who teaches the other subjects. The decision to share responsibility for the group, instead of organizing the children into two separate classes, is their own. Most classes in Lake School are taught in the 'traditional' way, in which one teacher is teaching one class in all subjects for a two – or three-year period.

Karen expresses very high expectations of her pupils and sees it as her duty to make sure that her pupils learn what they are entitled to. She expresses awareness of the family background, situation and context they bring with them. She had taught the class for about three months when studied and will continue to teach this group over the next school year as well.

The premises

The classroom is located on the top floor (2nd) of a temporary school building (barracks). There are two regular classrooms; one is for mathematics, science and technology education, and the other is for English, Swedish and social science. The classroom visited is covered with books, inspirational material and the students' work (science, mathematics and technology). It is an ordinary classroom that is, not explicitly designed as a technology or science classroom. There are limited resources available. There is an evident lack of materials and tools. Karen's students mostly worked with papers, straws as materials and scissors as tools during the studied period.

There is no particular teacher's desk and no obvious front or back of the classroom. There is a whiteboard in one end of the classroom and a screen to show overheads on the other end. Each student has a box of her/his own on a shelf and they share seats in the classrooms. The seats are arranged in groups, from four up to six or seven. Students seem to have a special place designated for them from which to start the lesson, but they also have the option to change seats when they feel like it. The students are encouraged by Karen to change seats and work with different partners. Occasionally other adults or pupils come into the classroom. This seems natural to all of them, both pupils and adults. The pupils are not disturbed in the sense that they stop working with the task. I experienced a welcoming, mutually respectful and tolerant atmosphere when visiting them.

Karen had chosen to teach about simple mechanics, pneumatics and hydraulics in the near vicinity during the studied period.

Case 2: River school

The school

River School is located in a multicultural area with both housing estates and private houses. The school has almost 800 pupils ranging from prep-class to year 9 (6–15 y old). The multicultural background could be described as dominated by one major cultural group. Most inhabitants are second generation immigrants. Most teachers are female and a majority of them have several years of teaching experience. Most teachers teach all subjects (with a few exceptions) in one class. The local work plan (found on school's website) states (regarding performance in S&T, grades 4–6): 'the student builds, makes and follows instructions.' The River School is involved in the NTA-program (www.nta.se).

Karl – the teacher

Karl was born in Sweden and has over 30 years of experience as a teacher. He was educated as a middle-school (years 4–6) teacher for various subjects not including technology education. Karl teaches 28 fifth grade students (11 y olds) in all subjects (including technology) except for sloyd and physical education. He has no in-service training in technology education. He expresses awareness of the different cultural backgrounds within the class. He has taught the current class since the beginning of the last school year and will continue to do so for the next year. He and his pupils are used to having teacher training students in the classroom.

The premises

The classroom is located on the top floor (2nd) of the main school building. It is a regular, quite small classroom not explicitly designed for technology or science education or any other subject. The walls are covered with student work: pictures and poems and such. There is an evident lack of material and tools. When, for example, demonstrating/showing that electricity can cause fire, Karl had to put a plastic bag over the fire alarm in order to prohibit it from going off. The 28 students have nine (!) batteries to share during the electricity experiments. During the plaster activity scissors and compasses were used to carve in the plaster.

All pupils have lockers in the narrow corridor outside of the classroom and they all have a school desk of their own in the classroom. The school desks are arranged (by Karl) in groups of three or four, sometimes in gender groups and sometimes not. In one corner of the classroom Karl has a teacher's desk. It is covered with a variety of material. During the lessons observed, he never sat there. There is a whiteboard at the front of the classroom and a projector in the ceiling. There is one computer in the classroom. I felt very welcome and experienced a creative atmosphere in the classroom when visiting.

Karl had chosen a historical theme concerning communication, transfer of information from past to present, and including some electricity, during the period studied.

Observations

A pilot was undertaken to test the design and the equipment. 'Ocular' observations and annotations were made during all the observed lessons, every tenth minute, together with snapshots. Inspired by Kimbell and Stables (2008), an observation chart with the focus on the teacher instead of the students was developed (Appendix 1). The chart helped me to organize the observations further. Initially, I intended to include moving pictures, but due to ethical considerations these plans were changed and I chose to not video record the sessions. The observations were complemented with some extra photos or annotations on some occasions.

All lessons were sound recorded using an mp3 sound recorder. The recordings have been carefully transcribed word by word with high accuracy. I have listened to the sound recordings while reading all transcripts several times and some of the transcripts have been cross-checked by another person. There was some shortfall with the sound recording, mostly of the students' voices, due to the limitations of the equipment and the activities in the classroom. Since the focus in this study is on the teachers and since the sound recording was combined with observations and photos, this shortfall has not affected the results presented here.

In total, six lessons, with the total length of 6.5 hours, were studied. Each lesson varied in length, from about half an hour to two hours. The lessons observed at Karen's were longer than at Karl's, and thus the data from Karen is larger in scope. This was not intentional but a result from the capturing of real-time education.

Observation Analysis

During the observation I used a specially designed observation chart (Appendix 1). My 'lens' was sharpened in the search for the five key strategies for formative assessment. The collected data was analysed in the following way. After concluding the observation sessions I analysed the data in four steps: (1) listening to the recordings of each lesson repeatedly. After this (2) all annotations/notes from the observations and from the listening sessions were matched and compared with the snapshots taken

Who/What	Teacher
Where the learner is going? Where am I going?	(1) Clarifying learning intentions and criteria for success.
Where is the learner right now? How am I going?	(2) Engineering effective classroom discussions and other learning tasks that elicit evidence of student understanding.
How to get there? Where to next?	(3) Providing feedback that moves the learners forward. 4) Activating students as instructional resources for one another. 5) Activating students as the owners of their own learning.

Figure 2. *The teacher column highlights the elements used as spectacles in this study.*

and the transcript of the recordings for every lesson. The next step in the analysis process was (3) to go through the data again using a 'check list' (Figure 2) based on the above-mentioned template presented by Black & Wiliam (1998). The check list was used as spectacles/raster when I looked for the key strategies and possible patterns in the procedure undertaken in the classroom. Finally, (4) I controlled my interpretation with the transcripts of the lessons.

Interviews

As a supplement to the observations, interviews were made. The two informants are busy, working teachers with a limited amount of time available for interviews. Despite this they agreed to answer my questions and bring clarity to what had happened during my observations. I met the teachers both before and after the observed lessons.

The interviews were informal and could be described as conversations rather than interviews. The interviews/conversations were semi-structured with some questions prepared in advance supplemented with new questions that emerged during the conversation and/or the observations (Kvale, 2008). Some of interviews were recorded and sometimes I took notes. The interview data (the recorded and annotated data) were compared to the findings from the observations.

Ethical Considerations

I have carefully followed the regulations presented by Vetenskapsrådet (2005). The teachers were informed about the study and agreed to participate. My main informants are the two teachers, but their students are indirectly involved. Since these students are underage, their guardians were informed, in writing, about the study as well. All students were allowed by their guardians to participate, one student with the exception that (s)he not be photographed and interviewed, which of course (s)he was not. The collected data is kept in a safe place to serve the ethical principal of confidentiality (Vetenskapsrådet, 2005). Finally, all names (persons and schools) are fictitious.

Concept Use – Pupils vs. Students

When translating the word pupil from English into Swedish, the translation will be student (elev) in this educational context. It can also be translated into the apple of the eye or even sweetheart (ögonsten). Throughout my study, I have had the privilege of experiencing how two teachers express and show love, trust and expectations, through small gestures, glimpses in the eye and so on, to their students themselves and their ability to learn. This is hard to capture and describe in a text (Eisner, 2007), and in order to somehow share this experience/moment with the reader I consistently use the word pupil instead of student in the following text.

RESULTS

Traces of the Five Key Strategies for Formative Assessment

There are many things going on in a classroom and many stories to be told. Findings from the study regarding how teachers work with assessment and how the minute-by-minute follow-up is reflected in the classroom will be presented by using the five key strategies for formative assessment. For each key strategy examples will be presented. The examples have been chosen with the intention of inviting the reader into the classroom situation. There are no boundaries between the five key strategies, and the examples are not chosen to be explicit only for each key strategy. The mutual respect experienced between the teachers and the pupils is presented by using *pupil* instead of student.

Key strategy no. 1 – Clarifying and sharing learning intentions and criteria for success (K1)

This key strategy is reflected in two ways. In the beginning of the work with a theme, relevant parts/goals in the national curricula were presented to the students, by the teacher reading them out loud. Other additional goals and criteria for success were then added by the teacher 'along the way'. It appears as if the learning goals are primarily to 'be creative' and 'to fulfil the task', but it is not evident where the goals in technology are.

Illustrative examples:
Karl starts the first lesson of the theme/task by going through the curricula (reading the text out loud). The criteria for success are not explained explicitly, other than by stating that the pupils must 'complete the task'.

Karen also starts by going through the curricula. She adds 'being creative' as an additional criteria for success (in addition to the ones stipulated in the curricula). By 'being creative' she means for students to come up with their 'own ideas' (individually or in groups). Later on another criterion was added during the activities (clip below):

> Kl - CLIP FROM LESSON
> The pupils tell Karen that they have made Jumping Jacks with their previous teacher. This comes as a surprise to Karen, but she 'saves' herself/the situation by asking her pupils if they or the previous teacher did all the work. Karen continues to say that this will be a rise in severity, since they are now going to learn how to read a description with a blueprint and then work it out for them selves. The pupils have during previous lessons cut templates which they now use when following the instructions to make a Jumping Jack.

Key strategy no. 2 – Engineering effective classroom discussions and other learning tasks that elicit evidence for student understanding (K2)

Within K2 the planning and the execution of the activity in the classroom is included, as are the managerial procedures in the classroom (ensure a safe social climate among involved students and teachers). The results show an inviting and mutually respectful climate among the participants in the two classrooms studied. Both teachers frequently use gestures (big as well as small) and both teachers are constantly moving around in the classroom among their pupils to ensure that everyone is involved and task oriented.

Neither of the two teachers (both having more than 30 years of teaching experience) is trained in technology. Karen has had a two-day in-service teacher conference and Karl has experienced one day of NTA in-service training. As far as they recall they have not received any training in assessment or about the Individual Development Plan with written assessment. They also state that there are no organized discussions about technology education and/or assessment in technology in their schools.

A non-documenting practice is found in the study. Both teachers kept their knowledge (information) about the pupils' progress 'within themselves'. No notes of any kind were presented. When asked how they kept control over the progress they both stated that they base their assumptions regarding the pupils' position on their learning journey on what they see and hear during classroom activities. Karl says he sees the progress in 'the glimpse in the eye' of his pupils. None of them used written tests or diagnoses during the observed period.

Illustrative Examples – Non-documenting Practice

Karl presented a lesson plan in writing to me. The plan included a headline, a description of what to do during the theme, for example, historical exposé, construction, skills and experience. However, it is not evident what the pupils are expected to learn nor is information provided on strategies on how to follow up the results. Karl describes the planning and the preparation of the theme.

He first gathers the tools and materials needed. Some are (in this case) found in the school's supply storage and some he has had to get from elsewhere. Secondly, he makes preparations for the theme by making a form and casting the 28 rune stones (1 per pupil) in advance; he reads and prepares PowerPoint slides for the historical exposé. During the theme he takes pictures, which he included in the slides and then showed during the recapitulation in the next lesson.

Karen did not present a written plan of the theme or of the follow-up procedures. In her case the planning of content and work methods is implicit and not accounted for verbally or in writing. Instead Karen highlights the practical preparations. According to Karen, the planning process is dominated by efforts to collect the material needed. Karen borrows (in this case) needles from the sloyd teacher in the school. She collects pens, toys and other items from her own home for the pupils to investigate, disassemble and reassemble. She points out that there is a severe lack of material in the school. To ask the children to bring items from their homes due to the situation in school is not an option. She solves the problem herself by bringing material from home. A lot of time is spent collecting the material needed. She also prepares extramural activities included in the theme, for example, a visit to the fire station, looking at trucks. No extramural activities occurred during the observed lessons.

Both teachers perform their teaching in regular classrooms not explicitly designed for technology or science education. There is, in both classrooms, an evident lack of access to material and tools. The conditions for engineering effectively in order to elicit evidence for the pupils' understanding (K2) are, to say the least, in this respect limited.

The execution of the lessons follows a repeated pattern of activities. The lessons start with an introduction, during which the teacher introduces the theme/content/disposition of the session. After this the hands-on activities start. The lesson ends with a conclusive gathering before exiting the classroom. This pattern was found in both the classrooms.

Karl starts every lesson standing in the very same spot. He uses pictures and shows PowerPoint slides, while talking and asking questions, in order to recapture the previous lesson. His pupils express an interest and seem to be curious about what is said and shown. They are literally standing on their chairs and desks when watching the PowerPoint presentation, with their mouths open. Karl tries to put the lesson in context by using examples. He talks about Morse's SOS by connecting it to the song by ABBA and the Estonia tragedy. He asks the pupils to knock SOS on their desks. Is it possible? He invites them to try and discuss it. Then he turns off the light in the classroom and flashes the SOS signal with the flashlight from his 'boat'. After the introduction the practical work starts, and the pupils seem eager to start working with their assignment.

Karen also starts her lessons located at specific spot in the classroom. She starts by recapturing the previous lesson by posing questions and statements to refresh the pupils' memories about what was going on the last time. She is evaluating and positioning the pupils' understanding and knowledge (where they are on their learning journey), hereby investigating from where she can 'take off'. She waits for her pupils and works a lot with language concepts as well. She is sorting out technology concepts like pneumatics and hydraulics, using both 'what' and 'why' recalls questions and tries to situates it.

Karen often repeats the pupils' answers with a clearer pronunciation. She says she has gotten into the habit of doing so due to her experience working with pupils with Swedish as their second language. She continues the lesson by reading a story from a textbook. She also pauses from time to time when she is reading the story. She reads out loud clearly and pronounces some of the technology-related concepts as well as words like *attic* which occur in the story. The majority of her pupils are learning Swedish as their second language and some of the pupils did not know what an attic was. They also discuss safety issues regarding visiting the attics at the pupils' housing estates. The pupils listen closely to Karen during the reading. They are quiet but occasionally, when Karen notices a pupil not paying 100% attention, she monitors him or her carefully. With small gestures, lowering her voice, she gets the attention of the pupil in question, who immediately responds with mutual respect. After the introduction phase, the lesson continues with the pupils working hands-on with the task/assignment. The pupils are instructed to work individually and to think for themselves. Karen encourages cooperation several times to pupils but also encourages them to think for themselves as well as to ask when they do not understand.

Both Karen and her pupils work very calmly and quietly, not in the sense of silence (there is a lot of talking and there are discussions going on between Karen and her pupils, in groups and individually, and also among different groups of pupils) but with low voices. The pupils appear focused during the observed lessons. Karl's pupils are task oriented and working and are verbally active (talking to each other and wanting to get attention from Karl). The pupils often nag at Karl for his attention. When asked about this, Karl expresses concern and some disappointment about this constant seeking for his attention. However, he claims to have the ability to discern when his attention is needed.

Key strategy no. 3 – Provide feedback that moves the learner forward (K3)

Due to the sound recording, some of the conversations during the activities were lost, but some results regarding the feedback provided can be presented. Two kinds of feedback deliverance are identified in the collected data; or rather the absence of them is identified.

K2 – CLIP FROM LESSON
Karen – We have talked a little bit about pneumatic ... what is it? (Pauses) Yes, air, it could move with some help from air, is that right?
Karen – Hydraulics, then? What is that? (Pauses)
Karen later – What have they changed the water into?
Karen – Why did they change it [water] into oil?
Karen – Eh ... We were away looking at the bus. What did it have? How was it that it could rise and descend?

– Was it pneumatics or hydraulics?
– And then we looked at the garbage truck. Correct/Right?
– How could it tip over the garbage cans? Because it could lift the garbage cans right?
– Was it hydraulics or pneumatics?
– OK .... What else have we done?
– Why did we build cars, anyway? What did we study/look at then?
– How did we start our work with the cars? We did not start building the cars, we did something else first.

The first kind of feedback is praise. Both Karen and Karl are sparse with praise. Karen often replies by repeating her pupils' answer in order to clear concepts and pronunciations. Karl elaborates on the pupils' comments and questions during the introduction. Karl sometimes answers his own questions in the same breath, before the pupils have a chance to reply. Secondly, there is the feedback Karen is supplying by not 'fetching' things the pupils are asking for. Instead she supports them by telling them to 'take a look for themselves' and/or then 'get it themselves'. (This is considered as a trace also for K5).

Wait time is part of giving feedback, and previous results have identified the importance of proper wait time. A rough estimate shows that Karen waits longer than 0.9 s for her pupils to answer her questions. When a pupil has answered a question she also waits before continuing. Estimates show that Karen waits longer for an answer to come than after the answer is given. Karen is deliberately waiting on her pupils. She has identified this as an area for improvement for herself. She has deliberately been working with this for a long time. She is somewhat surprised by my attention to this issue concerning wait time. She still finds it difficult and says she wants to improve even more with this and sees it as an ongoing process.

Key strategies nos. 4 and 5 –Activating students as instructional resources for one another and activating students as the owners of their own learning (K4, K5)

Karen encourages her pupils to 'think for themselves' and to discuss their work with a friend. She says herself that she chooses not to give complete answers to questions asked. When her pupils ask her, for example, where to find the scissors, she does not facilitate by going and getting the tool requested. Instead the pupil has to look for her/himself. The pupils are also encouraged to seek partners with whom to collaborate and discuss their work and even to change seats to facilitate the conversation.

Illustrative example 1
Karen encouraging through voice/intonation – 'Christine if you need to talk with Saleh, it might be better to sit beside her.'

This comment can be interpreted as a smart comment, but her intonation says otherwise.

Karen does not lay the responsibility among the pupils. She does not leave them when stuck. She goes back after a while when she notices someone is still stuck. During the interviews she expresses the notion of making them owners of their own learning by doing this and not supplying them with the correct answer immediately or by providing the direction on where to find material and such. This is reflected in the classroom as well. She waits for the pupils and returns to the pupil after a while to make sure (s)he has got it. If the pupil still has not got it/understood or found a particular object (overcome the obstacle), she tries another way and then, if still needed, delivers the answer.

K4 and K5 – CLIP FROM LESSON
Karen – Then you look, Mario, how to get it [Jumping Jack] to flounlder. (Inviting and prompted)
Karen – There are needles in the box?
Mario – Needle?
A little while later
Karen – Mario, watch the sketch carefully on how to do it. How can it work and flounder?
Kim – Look it flounders!
Karen – Can you (Mario and Kim) discuss this with each other?
Karen – Watch this! Here Mario … Sarah (another pupil) … look carefully … come closer … what have they done here? … Do you think? ... Between the legs (of the Jumping Jack) … Watch carefully! (Inviting and encouraging intonation)

She is identifying the pupil (Mario) who is stuck with the task. She first lets him know that she is there to support him without telling him what to do. She comes back after a while when she sees he is still stuck. And, finally, when she notices he is not getting any further by looking at the sketch she tells him to come and look at one of his peer's Jumping Jack and then guides him on where to look. Mario then continues his work successfully.

The examples presented are not only relevant to the particular key strategy. They have also been chosen to show the interactive relations between the key strategies for formative assessment through the interaction with feedback, providing feedback and not, and at the same time elaborating by activating the pupils as learning recourses for others as well as themselves.

DISCUSSION

The results show that the teachers in the study work constantly with assessment. They ask questions, look for 'glimpses in the eye' and so on. They spend a lot of time and effort to, in various ways; establish a view of the status of their pupils' knowledge development. This is consistent with Kimbell (2007).

Traces of all five key strategies were found during the observed lessons. There are indeed many signs of the teachers' intentions to move their students forward (gestures, comments, intonation), but the effect on the pupil has not been investigated. However, prior research shows that they are not likely to be as successful as intended (e.g., Black et al., 2008). Although the results show that they are working with assessment in principle 'all the time', they are probably not always working with formative assessment or even assessment for learning. Let's look into some of the findings and see what can be learned from them.

Non-documenting

The results show that the pathway and milestones for the leaning journey are not evident to the teachers (and her/his students). The destinations are not explicit during the lessons observed. The overarching goal to enhance the pupil's interest in the technology is present in the way that the pupils engaged in the task. The results show that the teachers' conclusions on the pupils' progress are based on the teachers' own findings/reflections gained from of the activities during the lessons. This is conclusive with Klapp-Lekholm (2010).

Wiliam (2009) argues that even though teachers gather a lot of information, this information is seldom used. Hence the impact on learning from short-cycle assessment, which, according to the findings in this study occurs frequently, is becoming increasingly important. Neither of the two teachers in the study used tests and/or similar activities during the lessons observed which could have provided evidence for the importance of minute-by-minute follow-up. The documentation of the pupils' achievement is instead concluded with 'ticks in boxes' in the Individual Development Plan form indicating whether the pupil has or has not achieved the goals set in the curricula. This is done afterwards, and the template form is presented by the school head. The goals of the themes presented by the teachers in the study are vague, and the goals regarding the knowledge/skills to achieve are not clearly specified. So what are the consequences of this non-documenting practice? What happens when there is a change of teacher in the class? One consequence found in the data is the 'Jumping Jack situation'. A pupil in Karen's' classroom tells Karen that they (the pupils in the class) have already made Jumping Jacks in a previous lesson with another teacher. To Karen it is clear that the pupils have not gained the full understanding of the phenomena illustrated in the example of Jumping Jacks. At least not the (unknown) learning objectives that she thinks are included in the task. Teachers sometimes expect that their pupils ‘are’ at a certain spot and that they will be ‘travelling’ at the same speed as the teacher is teaching. Kimbell (2007) argues that teachers need to be aware of the difficulties of assessment in order to deal with teaching properly and consciously.

Engineering Effective Classroom Discussions and Other Learning Tasks that Elicit Evidence for Student Understanding

First, for effective discussions to happen the social climate in a group needs to be safe enough for the pupils to reveal their thoughts and to take chances and even make mistakes to learn from. From the visits with Karen and Karl, the conclusion is that they have created a welcoming and mutually respectful atmosphere, both between teacher and pupil and between pupil and pupil.

This important perquisite is undoubtedly present in the observed classrooms. By stating this it is time to look for other aspects of importance.

Planning and Execution

Karen did not present a plan in writing to me. However, this is not the same as not having a plan. For her to be able to gather all the material and tools she needed she must have had some sort of plan. Moreland et al. (2008) emphasize that the structure of lessons and the embedding of assessment for learning strongly influence how the students undertake the task. A pattern of structure was identified in the collected data, as was the presence of a planning process (themes/lessons). However, the planning of themes/lessons did not focus on subject content, working methods or follow-up strategies. (Sic! They are not only teaching technology.) Instead a lot of time and effort was spent on gathering tools and material. The planning of the actual learning goals and the preparation of questions was not as evident. Asking questions, and also encouraging pupils to ask questions, is one way suggested to elicit evidence of learning; based on the answer the teacher decides what step to take next and in what direction. To be able to decide what step to take next and also deal with the unexpected answers, teachers must plan their questions in advance (Kimbell, 2007; Black & Wiliam, 2009b). The fact that there were no signs of the two teachers in the study planning their questions in advance is not surprising. With no training in technology and with no/limited resources (hereby forced to solve their supply needs themselves) nothing else is to be expected.

I argue for further studies concerning what teachers are able to use their time for. Highlighting the fact that in order to prepare the tutoring the amounts of time spend on ‘getting stuff’ is far too time-consuming for the teacher. Instead of preparing for technology education (content, questions and work methods) the evident lack of material and tools means that the teacher is facing an impossible work situation with very limited possibilities for planning the key strategies.

Questions and Answers

Both Karen and Karl start their lessons by rehearsing the previous lessons, in order to elicit evidence of where their pupils currently are in relation to the next milestone. Most of the questions they ask are questions of recall. This is consistent with previous research. The results, however, differ from previous research when looking at the long waiting time experienced in Karen's classroom (e.g., Black, 2008). Without having measured every single 'answer time' (the time between a question being asked and a pupil's answer and continuation after pupils respond) the conclusion is that she generally waits longer than the 0.9 s, which is the average 'wait time' experienced in classrooms (Black, 2008).

Wiliam (2011) points to the importance of making regular check-ups during the learning journey, by the teacher but also by the learner. One way of doing regular check-ups, for the teachers, is to use so called 'hinge questions' in order to decide where to go next during the lesson (Wiliam, 2011). A hinge question is to be asked at a crucial point during the lesson. Depending on the pupils' response to the hinge question, it allows for alternative ways of teaching. The continuance of the lesson pivots to better fit the students' needs. The result shows that most of the questions asked by the teachers in the study are questions of recall put forward to the whole group of pupils. A 'hinge question' is to be built on common misinterpretations concerning the subject matter in question. The teachers in this study are not trained in the subject matter and common misinterpretations are not, as far as I know, familiar to them. The teachers in the study are not trained and they are not attending any organized discussions concerning the subject matter of technology nor concerning assessment in general or assessment in technology in particular. What we ask for from our pupils is dependent on what we want out of them. Our prior experience and subject knowledge is influencing what we are able to ask for. This goes for both teachers and pupils. What implications does this have for the teacher's minute-by-minute follow-up practice? *I argue that there is a need for more research concerning teacher's minute-by-minute follow-up practice in technology education.*

In order to ask good questions you need to know the fundamental principles of the subject in question and have an understanding of the common misunderstandings that pupils might have and the creativity to formulate questions that promote thinking (Leahy et al., 2005; Black et al., 2009, Wiliam, 2009). The high-order knowledge gained from advanced studies is not needed (Hattie, 2009), but to be able to challenge the pupils the teacher needs an insight regarding the understanding of the fundamental principles of the subject and an understanding of the kinds of difficulties that pupils might have (Black et al., 2008; Wiliam, 2011). Asking hinge questions to decide which way to go during the lessons requires this kind of 'pedagogical' knowledge (Wiliam, 2011). Black and Wiliam (2009b) found that the ways which formative assessments manifest may vary in different subjects, even if the general principles apply across subjects. The only reasons for a teacher to ask a question are to either cause thinking or to elicit evidence on what to do next (Wiliam, 2011).

Based on the interview and the classroom activities, Karen expresses a notion that her pupils are inquisitive and questioning, working together and discussing their work with their classmates. According to Black et al. (2009) this is one of the main activities needed to engineer an effective learning environment (using activities that demand collaboration so that everyone is included and challenged) and also to create situations in which the pupils can tutor themselves, and to listen to and respect one another's idea (compare this with strategy no. 4, activating students as instructional resources for one another). According to Karen, the former teacher wanted them to do as they were told and work in silence with the textbooks. Karen's approach and interpretations of the syllabus are due to her prior experience. This causes different experiences for the pupils and is also a sign of different types of attitudes towards learning (Elwood, 2008). Karen's prior experience and background are reflected in her interpretation of the syllabus. With Karen the pupils are supposed to be questioning and actively working together, whereas the previous teacher wanted them to work alone in silence.

Teachers also need to be able to interpret pupils' responses to questions. And last, but not least, they also need the ability to interpret questions asked by the pupils (ibid.). This requires a thorough knowledge of the common misconceptions and student difficulties in learning the subject. My prior teaching experience tells me that content knowledge makes it easier to interpret the pupils' answers. The two teachers in the study have many years of teaching experience and a great interest in their pupils' well-being. From their 30 years of experience, it may be possible for them to rephrase and interpret the curricula for the pupils, but for most teachers this is a great challenge. To elaborate using the traveller metaphor presented at the beginning of the article, the hinge questions will, in this context, be regarded as milestones along the learning journey towards the desired destination. The teacher is the guide with some local knowledge about the surroundings, who might be able to elaborate on the pathways and surroundings during the journey. The importance of teachers sharing ideas and examples through discussions with each other is obvious. The sharing is not an end in itself, but the discussions are important for the alignment with the curricula. The pupils who have Karen or Karl for teachers are OK. They have a long history of teaching experience. But what of all the pupils who do not have teachers with this experience?

I argue that the school heads have to take greater responsibility when it comes to what happens (or does not happen) within the classrooms wall.

Both teachers are sparse with praise. Moreland et al. (2008) argue that when the teachers are focused on technological aspects they are more likely to provide feedback about that. They also highlight the fact that teachers who lack appropriate content knowledge risk not being able properly assess their students. Neither Karl nor Karen is trained in the subject, and they do not attend any organized discussions concerning the subject. Both Karl and, especially, Karen elaborate on concepts during the lessons. Leahy et al. (2005) question the amount of time used by teachers' instructional time in whole-class discussions; these sessions tend to rehearse existing knowledge rather than create new. Leahy et al. (2005) suggest that when working with teachers and introducing the assessment for learning techniques, the teachers should also become more aware of the importance of planning their questions in advance. Kimbell (2007) highlights the importance of making adjustments 'along the way' towards the destination set in order to enhance the opportunity to elicit evidence.

I see a great need here for increasing knowledge about questioning in technology education. Questions, and in particular the so-called 'hinge questions' used during the lessons to decide what direction the next part of the lesson might take is vital (Leahy, 2005; Wiliam, 2011). By asking this kind of question, the teacher can and will make their teaching more adaptive to the needs of the pupils in 'real time', during the lessons, and accordingly make necessary adjustments 'along the way'. This is a sign of good practice (Black et al., 2009).

Encouraging the Pupils

Karen seems to be able to pick up when(ever) a pupil (e.g., Mario) is stuck. But when dealing with the reality of teaching about 25 pupils at the same time is it possible to know for sure that Karen is not missing someone? Although it seems that she keeps track of her pupils' progress in general and that they are not left alone, for too long, on their own during their learning journey, even though the destination is unknown to me. She encourages her pupils to talk to a friend, even to change seats to sit beside the ones they are talking to. She is touching K4 explicitly by encouraging the pupils to serve as resources for one another more explicitly than the teachers described in Bjurulf (2008). It is worth highlighting that the risk of certain interpretations of key strategy no. 4, activating pupils as learning resources (students as instructional resources for one another) is that the result will be the same as leaving the pupils working on their own and asking only their fellow pupils instead of the teacher (compare to Bjurulf, 2008).

No Training and Limited Resources; No Technology?

These two teachers teach whole classes of about 25 ten to eleven year olds, and they have limited access to material, tools and equipment. They are not trained in technology education and they are not attending organized discussions together with others teachers. I believe they are in control of the progress, and traces of the five key strategies for formative assessment are present. Without questioning their intention to move their pupils forward on their learning journey, I am confident that their ability to teach technology could be enhanced even more.

According to regulations, the head of the school is responsible for the quality of the teaching, and she/he must make sure that their staffs possess proper content and pedagogical knowledge. Neither of the experienced teachers in this study has received any teacher training in technology. When teachers lack knowledge in a subject, there is an evident risk that they will not assess their pupils properly (Moreland et al., 2008).

This study also questions the limited amount of equipment accessible to the teachers and students, for example, nine batteries for 28 students. The question of all pupils being entitled to meet trained technology teachers with sufficient resources of different kinds available in school must be raised on both a national and local level. We know that teachers teaching technology in Swedish schools lack training (Teknikföretagen, 2005; Bjurulf, 2008; Klasander, 2010). We know that teachers who do not discuss their teaching with others are at risk of becoming unaligned with the current regulations and left to their own prior experience (Skolverket, 2008a, 2008b; Pettersson, 2009). We know that pupils' attitudes towards technology and technology education is influenced by the teacher (Blomdahl, 2007; Bjurulf, 2008; Skogh, 2012). How does all this affect the teacher/teaching and the learner/learning? And what happens to the important minute-by-minute follow-up in the technology classrooms? Further studies are needed, but it is probably safe to suggest that the conditions under which technology is taught today must be changed.

Input Versus Outcome

The focus in this study is the output of the teacher and not the input or response from the pupil/learner. Therefore I can only speculate on answers regarding the results of the learning outcome. Previous results show that working formatively (with the five key strategies) is successful. However, the misuse of concepts and the somewhat simplified discussions concerning the concepts of 'feedback' and 'formative assessment' should be taken into account. The outcome of the students in one of the classes is known through the results on external tests, for example, in mathematics and chemistry, but not in technology.

Feedback (K3)

When it comes to the feedback given in the classroom, it gets a bit tricky. When I Googled feedback, I got 2 450 000 000 hits (6 September 2011). I did not make any attempt to go through all this information in my search for the meaning of the word feedback. When going through literature, a variety of definitions are found, indicating the deliberate use and sometimes misuse of the word and concept of feedback. Feedback is feedback when it causes thinking and hopefully action by the learner and is not just delivered by the sender.

Wiliam (2011) stresses how important it is that the feedback provided should cause thinking in order to be considered as feedback. It should also provide more work for the recipient than the provider. The results presented here focused on the provider and thus cannot foresee the effect on the receiver. Previous results argue for the dual effectiveness of feedback regarding the impact on the individual pupil. It can both help and hamper, depending on the delivery and on the reception of it.

When feedback is focused on the self as a person or even given as praise, it stresses the notion of an ability being fixed and out of the control of the individual person instead of being something that can be developed (Black & Wiliam, 1998; Wiliam, 2011). Instead, feedback should be linked to opportunities for improvement and should encourage the notion that mistakes are a part of learning and linked to effort, not to a fixed ability (Black & Wiliam, 1998).

CONCLUSIONS AND FINAL REMARKS

In this article the question of how teachers' minute-by-minute follow-up is enacted in the classroom has been explored. Findings show that the teachers in this study constantly do minute-by-minute follow-up assessment during the lessons observed. Teachers spend a lot of time and effort establishing the 'current position' of their pupils in order to further the pupils' progress. However, findings also show that working with assessment does not necessarily mean working with formative assessment.

Based on the inviting, mutually respectful climate experienced in the classrooms observed there is no question regarding these teachers' intentions to move the learners (their pupils and sweethearts) forward on their learning journey. The somewhat problematic part is that the direction of this 'journey' seems to be somewhat unclear, and further studies are required.

The results show a disturbing lack of opportunities for common discussions among (technology) teachers. The two experienced, untrained (in technology) teachers in this study and their colleagues never discuss issues concerning technology education and/or assessment. To assume that this lack of discussion among teachers teaching technology is more of a rule than an exception is probably not controversial. But it is definitely both disturbing and alarming.

Also disturbing is the evident lack of material and tools available for the teachers, which causes a lot of effort to be spent collecting these, which in turn influences the possibilities for qualitative planning of the theme.

Assessment in technology is not frequently investigated, and I argue for the need of further investigations. This exploratory and descriptive study is a starting point for more, and the results create more questions to build upon.

So what about the GPS allegory mentioned in the beginning of the text? Well … the teachers in the study are definitely aware of the need to position the pupils, but are they properly equipped? Without having proper training and access to equipment in technology they have difficulties tuning in to the signals available 'in the air'. One could describe it as having a GPS device that is fully tuned in on satellites concerning 'general' pedagogical issues but with limited access to satellites sending 'technology education signals'. We all know that when using information from only one satellite the vulnerability increases of not being able to determine the position; add in not knowing the destination and it is even harder to decide what step to take next to decrease the gap between the current and the targeted destination. The extradition to educational context shows the risk of getting lost increases when the teachers are left alone. We can't have that. Technology education is far too important to individuals and to society.

NOTE

[1] The Swedish school system is currently going through some overwhelming changes, and from autumn 2012 the students will be graded twice a year from school year 6.

REFERENCES

ASEI see Teknikföretagen further down.

Black, P. J., & Wiliam, D. (1998). Assessment and classroom learning. *Assessment in Education: Principles, Policy and Practice*, *5*(1), 7–73.

Black, P., & Wiliam, D. (1998b). *Inside the black box. Raising standards through classroom assessment. Department of Educational & Professional Studies*. GL Assessment the measure of potential. Kings College London.

Black, P. (2008). Formative assessment in the learning and teaching of design and technology education: Methods and techniques. *Design and Technology Education: An International Journal, 13*(3), 19–26.

Black, P., & Wiliam, D. (2009a). Developing the theory of formative assessment. *Educational Assessment, Evaluation and Accountability*, *21*, 5–31

Black, P. J., Harrisson, C., Lee, C., Marshall, B., & Wiliam, D. (2009/ 2003). *Assessment for learning. Putting it into practice*. Open University Press.

Blomdahl, E. (2007). Teknik i skolan – en studie av teknikundervisning för yngre skolbarn, HLS förlag. Stockholm

Bjurulf, V. (2008) Teknikämnets gestaltningar. En studie av lärares arbete med skolämnet teknik. Karlstad University studies, nr 2008:29 Doctoral thesis.

Dakers, J. R. (2007) Incorporating technological literacy into classroom practice. In de Vries, Custer, Dakers, Martin (Eds.), *Analyzing Best Practices in Technology Education*, (pp. 125–138). Rotterdam: Sense Publishers

Eisner, E. W. (2007/1991). *The enlightened eye: Qualitative inquiry and the enhancement of educational practice*. New York, N. Y.:Toronto.

Elwood, J. (2008) Gender issues in testing and assessment. In P. Murphy & K. Hall (Eds.), *Learning and practice. Agency and identities* (pp. 87–101). The Open University. SAGE

Fabricius, T., Malm, I., & Pisilä, S. (2002). Skolinspektörernas årsrapport 2001/2002: Grundskolan (Utbildningsförvaltningens rapportserie, nr.2002:5). Stockholm: Utbildningsförvaltningen.

Fagerlund P., & Högberg B., (2010/2007), Bedöma är inte att döma. In A. Petterson, (Eds.), Sporre eller otyg (pp. 125–130). Mölnlycke: Lärarförbundets förlag.

Forsberg, E. och Lindberg, V., (2010). Svensk forskning om bedömning – en kartläggning. Rapportnummer 2:2010. Vetenskapsrådet.

Gipps, C. V., (2004/1994). *Beyond testing. Towards a theory of educational assessment*. London & New York: LaVergne, TN USA: The Falmer Press.

Gipps, C. V., & Murphy, P (2010/1999). *A fair test? Assessment, achievement and equity*. Open University Press.

Hartell, E. (2011). Hur sätter man betyg i teknik? In Hansson, Nordlander, Skogh (Eds.), Teknikutbildning för framtiden – perspektiv på teknikundervisningen i grundskola och gymnasium (pp. 75–87). Stockholm: Liber AB.

Hattie, J., & Timperley, H. (2007). The power of feedback. *Review of Educational Research*, *77*(1), 81–112.

Hirsh, Å. (2011). A tool for learning? An analysis of targets and strategies in Swedish Individual Educational Plans. *Nordic Studies in Education, 2011*(1), 14–30. Universitetsförlaget.

Holmgren, A. (2010). Lärargruppers arbete med bedömning för lärande. In Lundahl & Folke-Fichtelius (Eds.), Bedömning i och av skolan – praktik, principer, politik (pp. 168–181). Lund: Studentlitteratur.

Kimbell, R., & Stables, K. (2008). *Researching design learning*. Springer.
Kimbell, R. (2007). Assessment. In de Vries, Custer, Dakers, Martin (Eds.), *Analyzing best practices in technology education* (pp. 247–258). Rotterdam: Sense Publishers
Klapp Lekholm, A. (2008). Grades and grade assignment: effects of student and school characteristics http://hdl.handle.net/2077/18673 (Retrieved 11–12-02)
Klapp-Lekholm, A. (2010). Lärares betygssättningspraktik, in S. Eklund (Eds. Bedömning för lärande – en grund för ökat lärande. Forskning för undervisning och lärande (2010:3) 20–29.
Klasander, C. (2010). Talet till tekniska system. PhD thesis, Linköping University, Department of social and welfare studies, Norrköping, Sweden.
Kvale, S. (2008/2007). *Doing interviews*. The SAGE Qualitative Research Kit. SAGE.
Leahy et al (2005). Classroom assessment: Minute by minute, day-by-day. *Educational Leadership*, *63*(3), 19–24.
Lindberg, V. (2005) Svensk forskning om bedömning och betyg. Studies in Educational Policy.
Lindström, L. (2006). Creativity: What is it? Can you assess it? Can it be taught? *The International Journal of Art & Design Education, 25*(1), 53–66.
Lindström, L. (2009/2005). Pedagogisk bedömning. In L. Lindström & V. Lindberg (Eds.), Pedagogisk bedömning. Om att dokumentera, bedöma och utveckla kunskap. (pp. 11–27) Stockholm: Stockholms universitets förlag.
Lundahl C. (2009). Varför nationella prov? Framväxt, dilemman, möjligheter. Lund: Studentlitteratur.
Moreland et al (2008). Design and technology inside the black box. Assessment for learning in the design and technology classroom. Booklet in The black box series Black et al rEds. GL assessment the measure of potential. Kings college London.
Newton, P. E. (2007). Clarifying the purposes of educational assessment. *Assessment in education; Principles, Policy & Practice, 14*(2), 149–170.
Nyström, P. (2004). Rätt matt på prov. Om valideringar av bedömningar i skolan. Umeå universitet, Pedagogiska institutionen, No 71.
Pettersson, A. (2009/2005). Bedömning – varför, vad och varthän? In Lindström & Lindberg (Eds.). Pedagogisk bedömning. Stockholm: Stockholms universitets förlag
Rosentahl & Jacobson (1992). *Pygmalion in the classroom. Teacher expectation and pupils' intellectual development*. P x-y Crown House Publishing Company. USA.
SALAR Öppna jämförelser – grundskola. a) 2007, b) 2008, c) 2009 and d)2010 http://www.skl.se/vi_arbetar_med/oppnajamforelser/oppnajamforelser_grundskola Accessed on 23 November 2011.
Skolinspektionsmyndigheten (School Inspectorate) (2009) 2009a) http://www.skolinspektionen.se/Documents/Rapporter/Mora_Inspektionsrapport.pdf?epslanguage=sv Accessed on 23 November 2011. 2009b) http://www.skolinspektionen.se/Documents/Rapporter/Hofors_tillsynsrapport.pdf?epslanguage=sv Accessed on 23 November 2011.
2009c) http://www.skolinspektionen.se/Documents/Rapporter/Falkenberg-inspektionsrapport.pdf?epslanguage=sv Accessed on 23 November 2011.
SIRIS (2009), www.skolverket.se (retrieved 10–10-21).
Skolverket (LpO94) (The National Agency for Education) (2009). *Syllabuses for the compulsory school* (2nd ed.). Skolverket and Fritzes.
Skolverket (2008a) Matematik. En samtalsguide om kunskap, arbetssätt och bedömning. Downloaded from http://www.skolverket.se/2.3894/publicerat/2.5006?_xurl_=http%3A%2F%2Fwww4.skolverket.se%3A8080%2Fwtpub%2Fws%2Fskolbok%2Fwpubext%2Ftrycksak%2FRecord%3Fk%3D1952 Accessed on 25 November 2011.
Skolverket (2008b). Naturorienterande ämnen. En samtalsguide om kunskap, arbetssätt och bedömning. http://www.skolverket.se/2.3894/publicerat/2.5006?_xurl_=http%3A%2F%2Fwww4.skolverket.se%3A8080%2Fwtpub%2Fws%2Fskolbok%2Fwpubext%2Ftrycksak%2FRecord%3Fk%3D1952 Accessed on 25 November 2011.
Skolverket (2010). Ämnesproven 2010 i grundskolans årkurs 9 och specialskolans årkurs 10. http://www.skolverket.se/prov-och-bedomning/nationella-prov/2.1101/2.1181/2.1182/amnesprov_i_arskurs_9 Accessed on 29 April 2012.
Skolverket (2010). Dr 71–2010:4, Om nationella prov. http://www.skolverket.se/sb/d/2853 Accessed on 27 July 2010.

Teknikföretagen (2005). Association of Swedish engineering industries, Alla barns rätt till teknikundervisning, Stockholm: Teknikföretagen

Vetenskapsrådet (2005). Vad är god forskningsed? Rapport 1:2005 http://www.vr.se/download/18.6b2f98a910b3e260ae28000334/god_forskningssed_3.pdf Accessed on 2 September 2011.

Wiliam, D. (2009). *Assessment for learning: why, what and how? An inaugural professorial lecture by Dylan Wiliam. Leading education and social research*. Institute of Education University of London. London: Elanders.

Wiliam, D. (2011). *Embedded formative assessment*. Solution Tree Press

LENNART ROLANDSSON

13. TEACHERS' BELIEFS REGARDING PROGRAMMING EDUCATION

INTRODUCTION

> Beliefs are like old clothes; once acquired and worn for a while, they become comfortable. It does not make any difference if the clothes are out of style or ragged. Letting go is painful and new clothes require adjustment. And so it may be with epistemological beliefs, especially once they are established in adulthood. In short, epistemological beliefs are often unconscious … Change does not come easily. Indeed, a substantial change in an epistemological belief may bring with it discomfort and confusion. (Schommer-Aikins, 2004, p. 22)

This chapter examines teachers' beliefs (Hofer & Pintrich, 1997; Hofer, 2004; Pajares, 1992; Schommer, 1990) about teaching and learning computer programming.

Programming is commonly found to be hard to learn (Meyer & Land, 2003; Boustedt et al., 2007; Male & Baillie, 2011). Computer education researchers therefore argue that programming education is in need of a new teaching approach (Sheard, Simon, Hamilton, & Lönnberg, 2009). Educational practice is however hard to change (Kagan, 1992; Luft & Roehrig, 2007; Olson, 1981; Yerrick, Parke, & Nugent, 1997). One of the reasons for this is found in teachers' beliefs about teaching and learning, *"based on the assumption that what teachers believe is significant*, *while it determines what gets taught*, *how it gets taught*, *and what gets learnt in the classroom"* (Wilson & Cooney, 2003, p.28).

The presented study is based on statements expressed by programming teachers in connection with them participating in a voluntary series of training seminars. Since studies about teachers' beliefs are rare within the field of computer science education, this study can hopefully make a contribution.

BACKGROUND

Teaching and Learning Computer Programming – A Historical Overview

During the 1970s and the 1980s, students at the upper secondary Natural Science Programme in Sweden were offered a specific alignment in informatics. At the Technology Programme informatics was taught in years three and four. Subjects included programming for problem solving, in e.g. Mathematics, Building construction, Electricity and Natural Sciences (Rolandsson, 2010). During the

I.-B. Skogh & M.J. de Vries (Eds.), Technology Teachers as Researchers, 285–309.

1980s, informatics and computer programming was offered as a literacy course (called *Datalära)* to all year one students.

In 1994 (Lpf94) three programming courses aimed at students attending the Electrical Programme were introduced. Within the revised curriculum (GY-2000), these programming courses were optional for all students. In the 2011 curriculum revision (GY11) the programming courses were once again modified. Three courses became two, and the focus of the syllabus objectives was changed.

Programming Courses in Swedish Upper Secondary School Curriculum Today

Today upper secondary schools in Sweden offer programming courses at three different levels – A, B and C. The courses are mainly taken by students who have a major in technology (TE students), natural sciences (NV students) or electrics (EC students).

The Swedish National Agency for Education has divided the knowledge domain of programming into three separate courses, with the following objectives:

– Programming A (level A, 50 points), should provide a basic theoretical and practical knowledge of programming. The course also provides knowledge of some of the common application areas for different programming languages. In addition, the course should also provide basic skills in systems design and structuring techniques.
– Programming B (level B, 50 points), should provide theoretical and practical knowledge in at least one structured programming language. The course should also provide knowledge of the most important data structures within the chosen language. In addition, the course should provide skills in designing algorithms.
– Programming C (level C, 100 points), should provide theoretical and practical knowledge of a goal-oriented programming language. The course should also provide knowledge of analysis and design methods, as well as graphic user interfaces.

In each of these three levels/courses students are expected to attain knowledge and skills in problem solving.

Research About Teaching and Learning Computer Programming

With the aim to refine and improve teachers' instructions in programming, educational research in computer programming has commonly focused on students' learning. According to Schwab (1973), educational research is most commonly carried out using one of the following four perspectives; student, teacher, milieu and subject content. In this study, secondary school programming education is studied from the second perspective – the teacher's.

Sheard et al. (2009) highlight the absence of research dealing with established theories or models of learning for programming education. In a literature review of tertiary programming education studies Pears et al (2007) collect, classify and identify important research work in the domain of learning computer science. They mention e.g. Robin et al. (2003) who performed a psychological/educational study of programming students with the aim of identifying signs/patterns of ineffective novices' deficits. Awareness of such deficits could, according to the study, help students become efficient in programming.

In another study the focus put on syntax and semantics which for many years has characterized instructions in programming is criticised (Papert, 1980, 1985; Linn & Dalbey, 1985; Linn & Clancy, 1992; Lehrer et al., 1999). Instead, design skills and problem solving emerge as recommended competences (Oakley & McDougall, 1997). Oakley & McDougall suggest the use of pedagogical techniques for teaching and learning programming that include a *"balance between guidance and discovery*, *the adoption of an apprenticeship system*, *and extensive consultation and collaboration"* (Oakley & McDougall, 1997, p.110), while self-direction is also strongly recommended (Johanson, 1988).

According to Berglund and Lister (2010) computer science researchers are commonly trained in an "objectivist" or "positivistic" tradition. Therefore, according to Berglund & Lister, there is a need for research covering the "entire didactic triangle" (Teacher, Content and Student) hereby picturing students' learning processes from a students' perspective where context (e.g. culture, values, norms, teacher, content and tool) matters.

Teachers' Epistemological Beliefs

In this study the research domain of epistemological beliefs systems (Schommer, 1994b; Hofer & Pintrich, 1997; Hofer, 2004; Schraw & Olafson, 2008) is used in the discussions about the findings. The beliefs systems is used tentatively to capture teachers' beliefs and values in relation to the organization, acquisition and justification of knowledge within programming education in upper secondary school (c.f. Schommer, 1994b).

Teachers' epistemological beliefs affect behaviours in the classroom just as teachers' practice does (Ernest, 1989; Fang, 1996; Hofer & Pintrich, 1997; Kagan, 1992; Hofer, 2004). Teachers' educational beliefs have been found to be very difficult to change or transform (Kagan, 1992; Luft & Roehrig, 2007; Olson, 1981; Yerrick, Parke, & Nugent, 1997), as they depend on the individuals' personal growth and ability to reflect upon and understand the teaching practice (Baird, Fensham, Gunstone, & White, 1991; Brookfield, 1995; Schön, 2003). However recently graduated teachers are more likely to change their beliefs than experienced teachers. A rational cause of such a phenomenon is suggested by Brownlee et al. (2002). Two types of beliefs are identified; core beliefs and peripheral beliefs. The likelihood of the belief changing depends on what type of belief it is.

Teachers' epistemological beliefs have been studied using a number of different methods. Apart from interviews and observations, multiple choice questionnaires are commonly used in research of epistemological beliefs (Leder & Forgasz, 2002; Schommer-Aikins, 2004) or differentiated within different belief systems of multiple dimensions (Schommer, 1990; Schommer, 1994a). Olafson and Schraw (2006) suggest a model with two dimensions and four quadrants, depicting the teachers as relativists or realists in two dimensions; one for teachers' epistemological belief and one for teachers' ontological belief. Studying the epistemological dimension, a teacher could either hold a *realistic* perspective:

1. There are certain things that students simply need to know.
2. I am teaching information that requires memorization and mastery.
3. There are specific basic skills that need to be mastered.
4. or a *relativistic* perspective:
5. The things we teach need to change as the world changes.
6. The content of the curriculum should be responsive to the needs of society.
7. It is useful for students to engage in tasks in which there is no indisputably correct answer.
8. Students design their own problems to solve.

The other dimension; teachers' ontological beliefs, is best described by a quotation; a teacher with a

> realist world-view would be more likely to endorse a belief in a universal curriculum that is transmitted to students via a knowledgeable teacher; whereas a relativist would be more likely to endorse a constructivist's view that each student constructs knowledge that is relevant to him or her, with help from the teacher. (Schraw & Olafson, 2008, p.32)

Both these dimensions hold different consequences for the instructions given. A teacher with a realistic ontology assumes that there is one underlying reality that is the same for everyone, wherefore students should receive similar instruction at the same time, regardless of individual differences. Teachers holding a relativistic ontology assume different people have different realities, wherefore teachers' instructional role becomes that of a collaborator, co-participant and facilitator of learning.

PURPOSE AND RESEARCH QUESTION

Over the years, the subject matter of computer programming has been diffused and transformed into a school subject in Sweden as well as internationally. The changing educational frameworks together with the rapid development of technology make programming teaching a challenging task. Teachers all over the world therefore face a number of issues in the manifestation of curriculum in classroom based on former experiences and beliefs in relation to computer technology. This study is a first step in a process to understand the beliefs underpinning computer programming education in upper secondary school. The study explores the existence of 'common' beliefs, or rather different beliefs among computer programming teachers. The following research question is addressed:

> What beliefs do programming teachers express regarding teaching and learning computer programming in upper secondary school?

METHOD

The Design

This is an explorative study that aims to capture and describe teachers' beliefs. The research is designed around a series of in-service training seminars offered nationally to programming teachers. In conjunction with the seminars a number of questionnaires were distributed to the teachers. The main reason for offering a seminar series as part of the research design was that teachers with an interest in reflecting on programming education practice would assemble in the same place, at the same time, making the distribution and management of the questionnaires practicable. The seminars were also considered a proper choice for an explorative approach to teachers' beliefs as instructional features, and epistemological beliefs expressed by the teachers would be used in subsequent seminars.

The Seminars

The seminars were offered in partnership with Stockholm University, Royal Institute of Technology (KTH), Uppsala University (researchers from UpCERG), Microsoft Sweden AB, curriculum experts in association with The Swedish National Agency for Education (SNAE) and teachers who were willing to expose their educational practice.

Seminar 1, November 2009 (Sem1)

The invitation to the first seminar was announced via an email request to 250 teachers listed as programming teachers. A questionnaire (Quest 1) was attached to the invitation and responded to by 103 teachers. The seminar was offered at Stockholm University as a whole day seminar in which the SNAE's expert in computer programming education also participated. The day's theme was the (at the time) new programming curriculum, GY11. The seminar was attended by 27 teachers and was a kick-off, presenting information about the research project and the development of the programming curriculum which was in progress at the time.[1]

Seminar 2, January 2010 (Sem2)

The seminar was offered at Stockholm University as a whole day seminar in collaboration with UpCERG (Uppsala University) and teachers from different upper secondary schools. The day's theme was teachers practice and computing educational research (CER). It was attended by 25 people, 22 of whom responded to the questionnaire, Quest2, concerning teachers' perception of their educational practice.

Seminar 3, October 2010 (Sem3)
The seminar was offered at Microsoft Sweden AB. The day's theme was "Why programming in Swedish upper secondary schools?" and "What kind of programming should be offered in Swedish upper secondary schools?" It was attended by 40 teachers, 34 of whom responded to the questionnaire, Quest3. The seminar was considered important as it initiated further discussions on the internet.

Seminar 4, April 2011 (Sem4)
The seminar was offered at the Royal Institute of Technology (KTH) to exemplify what higher education values are important in programming knowledge, and what upper secondary programming teachers should focus on in their instructions, in order to prepare their students for these demands. The day's theme was "Reformed education in Programming". It was attended by 54 people, 49 of whom responded to the questionnaire, Quest4.

Selection of Informants

Based on the number of schools that (in 2009) offered Technology and Natural Science Programmes, the number of Swedish computer programming teachers is estimated at 300 persons. In total, 90 teachers attended one or more of the four seminaries, while 45 teachers attended two or more of the seminars. The first questionnaire (attached to the initial invitation) was responded to by 103 (out of 250). These informants most probably represent teachers with a specific interest in teaching and learning computer programming.

The participating teachers' experience of programming education is distributed in the following way: almost 60% of the informants had received some kind of academic educational training in programming (e.g. academicals degrees), while 40% of the informants reportedly based their classroom practice on educational

Table 2. Background facts about the informants (n = 103). The outcome is based on the analysis of the open-ended question "What kind of educational experience do you have in programming?" (Quest1, question 2A) and "For how many years have you taught programming?" (Quest1, question 2C).

Age	*Gender*		*Experience of programming studies*				*Number of years teaching computer programming (median)*
	M	*F*	*Secondary*	*Industry course*	*University course*	*Academic education*	
56–67	16	2	0	3	10	9	24
46–55	18	4	4	3	8	9	10
36–45	31	11	2	2	11	29	9
20–35	17	4	3	3	4	14	3
Total	82	21	9	11	34	61	

experiences in programming received at upper secondary school. However most of the teachers (33% of the 40%) had studied one or more separate supplementary university course/s.

Quest1 revealed that 99% of the informants had taught courses at beginners' level (Programming A), 97% had taught courses at the intermediate level (Programming B) and 73% had taught courses at the advanced level (Programming C), during the last five years. The number of courses taught is considered important, as there are teachers and schools where programming is offered only at the beginners' level.

The Questionnaires[2]

Each seminar was designed to elicit the didactical discourse in computer programming education. However, the seminars were also expected to vitalize teachers' reflection. The questionnaires presented at the seminars therefore became a tool to appreciate the teachers' beliefs.

The principal questionnaire (Quest1) with 50 open-ended questions was inspired by former research in epistemological beliefs. The questionnaire was distributed via e-mail (from February to April 2009), to 250 teachers nationwide who had been teaching at least two out of the three levels within programming courses. Quest1 was designed to unravel teachers' beliefs in relation to three major domains 1) different instructional considerations in computer programming education, 2) interest to participate in in-service training seminars and/or 3) collaborate in networks.

Three other questionnaires (Quest2 to 4) were administrated in connection with the seminars. The second questionnaire (Quest2) was presented to the teachers during the second seminar (Sem2). The outcome of the second and third questionnaires (Quest3), which were distributed to the participants and collected by mail beforehand, was presented at the third seminar (Sem3). The outcome of Quest4 was reported and discussed during its associated seminar (Sem4).

Considerations Regarding the Research Design

The purpose of the seminars was to facilitate inclusion of teachers' input to the research process. Quest1 was intentionally made up of open-ended questions to allow a diversity of beliefs to come through. Because of the openness of Quest1, the consecutive questionnaires (Quest2 to 4) used scales to explore the existence of specific tendencies raised during analysis of Quest1.

Ethical Considerations

Two types of ethical considerations have been made in the investigation: researcher-ethical considerations and research-ethical considerations (Gustafsson, Hermerén, and Peterson, 2005). These two types of considerations are addressed successively as follows.

The study depended on informants' willingness to unravel their teaching shortcomings and experiences. It became a challenge to do more than the ordinary research process with recruitment of informants, data collection and analysis would. The *"interconnectivity between production of knowledge and the ethics of production"* (Traniora & Bouchardb, 2012, p.3) came to be an issue throughout the whole research process as it was considered too time consuming to dispute the intrinsic beliefs of the researcher. Seminars were therefore believed to offer an interactive environment between the researcher and individual teachers for gathering of knowledge.

The investigation has followed the ethical principles for research suggested by the Swedish Research Council (Vetenskapsrådet, 2008); information, consent, confidentiality and use. During the whole research process (in seminars as well as in questionnaires) letters were delivered to provide information about the intention of the research, anonymity and confidentiality, and how the information would be processed. The principle of consent could be questioned, but there was never any sort of obligation to submit answers to the questionnaires, or to participate in the seminars.

RESULTS

The results are reported in the following way: Initially the presence/absence of teachers' confidence in (their) students' ability to learn computer programming is presented. After that, identified themes depicting teachers' epistemological beliefs are accounted for.

Can all Students Learn Programming?

When teachers were asked *"Do you think that all students can learn programming?"* (Quest1, question 4C) the analysis reveals that some teachers state "yes", others state "no" and some teachers believe every student can learn "the basics of programming". However, the answers were sometimes conditioned. Some of the "yes"-answers were attached with a follow-up, as for instance, the importance of students' "interest and motivation" and "only the basics in programming". In summary, results imply that a majority of the teachers, 73.7 %, state that all students are '*not* able' to learn programming,[3] while the remaining teachers express the opposite opinion (that all student are able to learn programming).

The following quotations illustrate some of the statements in each category:

– **Yes-category**
  "Yes, anybody can learn whatever they like. It is just a matter of time" (Quest1, teacher number 54)
  "Yes, but there could be a need to work differently as a teacher with different methods to make the students understand programming. That does not necessarily need to be with the help of an editor." (Quest1, teacher number 47)

– **The basics-category**
  "Anybody can learn the basics of programming. Though all students don't have the interest or motivation … to delve into [programming]. In my experience, programming is not meant for everybody. The reason could be the lack of an analytical vein, and the fact that the threshold before programming gets interesting is quite high (as in mathematics and physics).." (Quest1, teacher number 80)
– **No-category**
  "No, everybody does not have the ability to think logically or the diligence and the interest that is needed to learn programming." (Quest1, teacher number 98)
  "Anybody can learn to some extent, but without patience, an analytical ability and an ability to work systematically it seems hard to become a good programmer." (Quest1, teacher number 59).

Themes and their Rationales

The results of the first questionnaire (Quest 1) indicate a clear dichotomy between teachers who think that any student can learn programming and those who claim the opposite. Further analysis[4] of the responses in these two groups however, reveal that learning is understood as conditional, depending on certain factors. Four themes emerge from the analysis. Teaching and learning of programming is a question of:

1. students' individual time with code,
2. teachers' pedagogy,
3. students' abilities and
4. students' interest and motivation.

The first theme considers students' individual learning as dependent on time invested in reading and writing code. The second theme concerns teachers' perception of the importance of their instruction or enhanced pedagogy. The third theme, student's intrinsic abilities, is perhaps the most compelling theme. The analysis of data exposes high teacher expectations of students' logical and analytical abilities *before and after* the course, which probably causes a significant selection among students going further in programming.

The fourth theme entails the third, as they come hand in hand; a student with suitable abilities is more easily interested and motivated. Cases where the reverse is true certainly occur, but in those cases, the student's general interest would probably depend on external motives.

From here on, the article elaborates on these four conditions as themes, where seminars and questionnaires were conducted to elicit what epistemological beliefs teachers hold regarding their teaching and students' learning.

The final questionnaire, Quest4 is based on the analysis of the Quest 1 and Quest 2 data, to further explore teachers' beliefs about students' ability to pass programming courses. One of the questions in Quest4 rephrased the original question to "*Do*

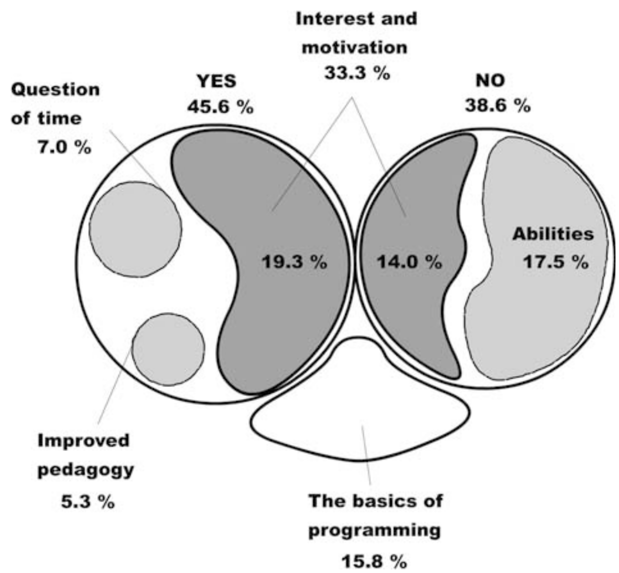

Figure 1. The figure depicts the outcome of question 4C (Quest1). It concerns teacher's beliefs regarding whether or not all students are able to learn programming, and includes important factors related to the acquiring of this ability. The two circles represent the original outcome of the teachers who ticked yes and no.

you consider every one of your students who attend the course, to be able to pass Programming?" which is slightly different to the question posed in Quest1. Results reveal that 25% of the teachers state "yes" and 28% of the teachers state "no". The remaining teachers state that it depends on the level of the course (27%) or that they do not have an opinion (20%).

Altogether, results imply that a majority of the teachers in the study (55%) perceive programming as too hard (not possible) for all students to learn, while 28% of the teachers were more optimistic.[5]

1) It is a Question of Individual Time with Code (Quest1 and Quest4)

Some teachers emphasise the importance of collaboration and programming in pairs among their students. However, due to the importance of individual assessment, collaboration is more commonly used at the intermediate and advanced levels of programming (Programming B and Programming C).

According to Quest1, practice and time on task with code is considered to be important to students' learning. There is a strong emphasis on individual problem-based learning. Only 12% of the teachers design education for collaborative work. For a better understanding of how collaboration is distributed between the three

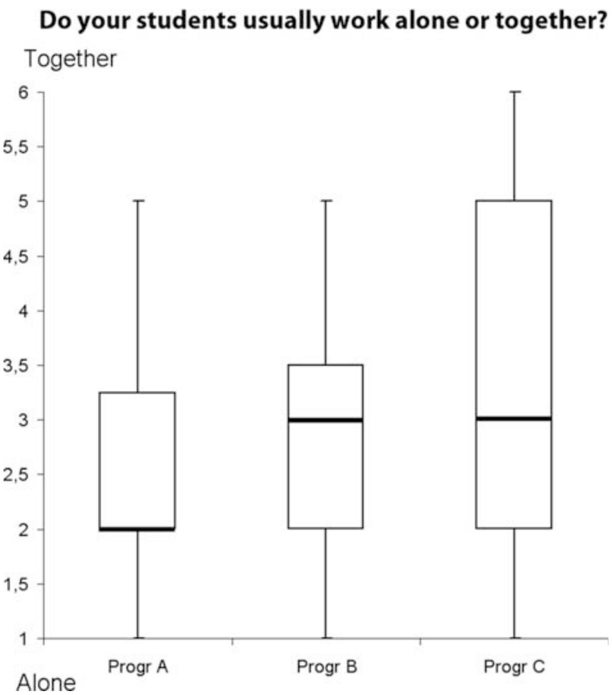

Figure 2 depicts how 56 teachers answered the question"Do your students usually work alone or together" on a Likert scale between 1 and 6 (Quest4, question 4A, 5A and 6A).

courses, a question based on the outcome of Quest1, was asked in Quest4 where teachers had to score a number from one to six on a Likert scale. The box-plot in Figure 2, reveals the perception of 56 teachers. Collaboration is sparsely used as a working method at the beginner's level course, but is used more frequently in the third course. However, data reveals that the use of collaboration for learning purposes varies considerably from teacher to teacher; data from the last course revealed that 50% of the informants' spread between 2 and 5 on the Likert scale, which shows the commonality of collaboration.

One of the reasons behind the pattern revealed in Figure 2 could be found in how assessments are made. According to data from Quest1 (Question 3D, *"Do you benefit from forms of assessment other than examinations, to evaluate and grade students' knowledge?"*) five percent of the teachers consider group-work[6] to be important in the assessment-process. The following quotations expose two opinions among these teachers.

> I don't use examination papers at all as they are clumsy and hard to interpret. I prefer continuous assessment in projects, where I'm looking for the independence and group engagement, individually and in conversation while

> solving tasks. The code gives an impression about their understanding and their development in different areas. I even ask for commented code which facilitates my work [as a teacher]. (Quest1, teacher number 96)

> Yes, we usually end our courses in Programming A with a small single project and in Programming B with a bigger project done in pairs. The basic data for assessment is the documentation they produce (the project plan in pseudo code and UML-diagram), my observations during the development process (autonomy, information from the internet etc.), the final product and the verbal presentation to the class (Quest1, teacher number 5)

Individual Assessment

The teachers were also asked about their views regarding grading (Quest1, question 4I: "*What qualities*, *according to you*, *are the major differences between students who pass and students who pass with particular distinction?").* In their answers the teachers commonly emphasize the individual aspect of learning programming.

> Students who pass with particular distinction are able to independently solve complex tasks. They solve these tasks in a qualitative excellent way and they are able to independently correct errors and deviations to create as good code as possible. They are able to find and use information appropriately on their own. They are comfortable with the basics and they accomplish their tasks in a limited time frame. Students who pass are dependent on aid and tutoring to a higher extent. Commonly they do not understand the basics, and this makes even small tasks and tasks of a simpler kind troublesome. (Quest1, teacher number 94)

> The student who passes with particular distinction independently solves the programming tasks. S/he can also use different approaches and exploit the error messages to correct incorrect implementation. S/he has a lot of experience to draw from when problem solving. The student who passes needs distinct tutoring. The teacher needs to interfere when code doesn't compile. That student commonly needs help with design. (Quest1, teacher number 22)

2) A Question of Teachers' Pedagogy (Quest1, *Quest 3 and Quest 4)*

In the last questionnaire (Quest4) the teachers were *asked "Do you consider pedagogy to be important to programming education"*. The outcome was (to me) unexpected. Here, 95% of the teachers perceive pedagogy as important, while 5.3% of the teachers in another questionnaire (Quest1) specifically express pedagogy as a reason for a better learning outcome.

Among the informants in Quest1, 15% of the informants had a teacher degree of relevance to programming. The percentage number needs to be highlighted as Sem3 with its questionnaire (Quest3), reveals that 23% of the respondents possess a general teacher degree not specifically linked to programming. Based on these two questionnaires (Quest1 and Quest3) at least 23% of the teacher cohort possessed a teacher degree in education, and at least 15% of them had a teacher degree in programming.

On the other hand, when asked *"What kind of education do you perceive as necessary for working as a programming teacher?"* (Quest1, question 2B) the outcome shows that only 23% of the informants consider a degree in pedagogy as important, while 8% perceive personal experiences from programming in the industry as important.

Discussions during the final seminar, Sem4, exposed a diversity of conceptual understandings of pedagogy. The teachers were therefore asked to submit a description of their pedagogy in practice. It resulted in 20 written testimonies (half a page to one page long). The analysis of these testimonies exposed two main instructional strategies: 1) a tutor who supports each student individually for enhanced learning and 2) a teacher who engages and inspires students with meaning, making methods instead of doing thorough work in the technicalities of programming languages (c.f. role-play and learning environments where collaboration is emphasized).

Important factors for teachers' instructional design. For a better understanding of teachers' perception of their instructional settings, Quest3 was made up of 29 statements, extracted from Quest1 and Quest2. Answers to the statements were graded by the teachers on a Likert scale from one to five, where one was considered not important and five very important. The outcome of the statements in Quest3 was to a high extent equally distributed on the scales, except for six statements which at least 50% of the informants considered very important or important.

These statements expose high levels of conformity among informants, wherefore it is reasonable to expect these statements to be deeply rooted within computer programming education. In short, a majority of teachers perceived the importance of education as dependent on students' desire to learn, their interest/motivation and abilities in logic and the creation of structure.

Statement 2D in Table 3 is supported by the outcome of Quest1 and question 3I, *"What sort of education do you perceive as crucial to students learning programming?"* It was an open-ended question where more than 70% of the teachers mentioned the importance of brief instructions followed by students' work on tasks, in relation to the course content. The following quotation mirrors a typical situation in the classroom:

> I give brief instructions every lesson. I sometimes demonstrate hardware and programming etc. on the computer. The majority of time however, the students spend programming by themselves. (Quest1, teacher number 13)

Practice or theory. Based on analysis of data from Quest1 a new question was raised in Quest4 about theory and practice in education. Figure 3 exposes the pattern when going from the beginner's course to higher courses. Data reveals a heavy focus on practice in all three courses, but there is a tendency to embrace more theory in higher courses.

Table 3. The table depicts the statements from Quest3 that received a high coherency. The question they had to grade on a likert scale from one to five was "To what extent are the following statements important to the instructional design?"

Very important
Student's desire to learn (statement 2A)
Student's interest and motivation (statement 2C)
Important
The combined time students are exposed to programming (statement 2D)
The programming language's/development environment's usefulness in higher studies (statement 2E)
Student's logical ability (statement 2G)
Student's ability to create structure (statement 2H)

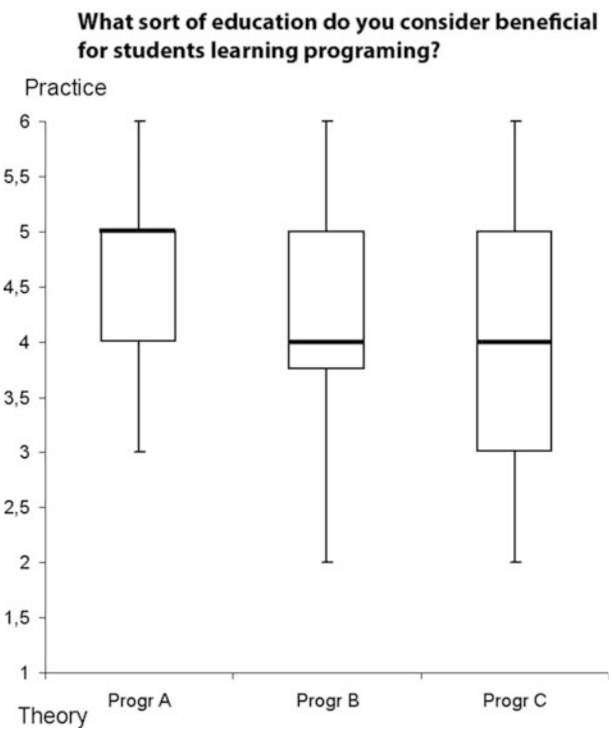

Figure 3 pictures how data was distributed in answer to the question "What sort of education do you consider beneficial for students learning programming?"(Quest4, question 4D, 5D and 6D).

A statement in Quest4, *"Programming is considered to offer more mathematics than the subject matter of mathematics itself"*, exposed that a minority of teachers (10%) believed this to be the case, which could be an indication of a curriculum in which programming is perceived as more practical than mathematics. During discussions in seminars the concept of theory appeared to be heavily associated with teachers' instruction instead of implicit computer science theory, wherefore it was not investigated further.

Specific programming languages vs. Programming in itself. The outcome of Quest1 with specific attention to programming languages in use revealed that programming education in upper secondary school is offered mainly in two industrial programming languages; Java and C++, while educational languages/environments like LEGO mind storms, Kodu, Pascal, PHP, Alice and Python were sparsely used.

Some teachers perceived the question about programming languages as superficial and not important as knowledge in programming was perceived as a general skill not bound to a specific language. Data reveals that a minority of teachers offer education using a multitude of different programming languages to enhance a general understanding of programming. One rationale for such a dichotomy was found when teachers were asked (Quest3) to value the importance of the statement *"The benefits of the language in higher education*". The analysis reveals that there is a high conformation, as 80% of the teachers deem the statement to be relevant and important (See Table 3, statement 2E) to education.

3) A Question of Students' Aptitude to Learn Programming (Quest1 and Quest2)

Beliefs about the necessity of specific students' abilities were investigated with the open-ended question *"What qualities do you consider important for someone to become skilled in programming?"* (Quest1, question 4A). Analyses reveal four different themes:

– ***Thinking abilities***, using keywords such as "logical", "abstract", "syntax", "problem solving" and "mathematical".
– ***Implicit personal abilities***, using keywords such as "accuracy", "interest/motivation", "curiosity", "creativity", "imagination", "patience", "persistence/diligence", "ability to concentrate" and "responsibility".
– ***Structural and analytical abilities***, using keywords such as "analytically", "systematically", "structured", "ability to picture an overview" and "attention to detail".
– ***Interaction abilities***, using words associated with "communication" and "ability to communicate".

Thinking and implicit personal abilities were mentioned by many teachers: approximately 60% of the teachers perceived these abilities as important, while the structural/analytical abilities and interaction abilities were brought up by 23% and 4% respectively, which is indicative of something characteristic that needs further investigation.

Abilities necessary to learn programming. The main purpose of Quest2 was to explore teachers' perception of students' abilities before the course (teachers' expectations of students' prerequisites), during the course (development of students' abilities during class) and after the course had ended (assessment of students' knowledge):

Q1: To what extent do you expect the following prerequisites in Programming? (Prerequisites before class)

Q2: To what extent do you elaborate on students' skills development in Programming? (Development of abilities during class)

Q3: To what extent do you consider the following skills as important to receive the highest grade in Programming? (Assessment of student's knowledge)

Teachers were asked to elaborate on, and grade eight statements based on the outcome of Quest1 and question 4A, concerning different abilities, on a Likert scale from one to five; less important to very important.

The eight statements that teachers were asked to grade were

– ability to communicate skills and programming strategies [to the teacher]
– ability to work in a group
– ability to picture an overview of the problem and construct structures
– ability to break apart a problem into details (analytical thinking)
– ability to think logically
– ability to think mathematically
– ability to think abstractly
– ability to use the syntax of the programming language

The outcome is pictured in Figure 4, with three curves, corresponding to the three questions; Q1 Prerequisites before class, Q2 Development of abilities during class and Q3 Assessment of student's knowledge.

Two statements exposed small differences from curve to curve; ability to work in groups and ability to think mathematically, while ability to create structure, ability to think analytically, ability to think logically and ability to use the syntax of the programming language exposed great differences. However the greatest gap appears in statement number eight which concerns the ability to work with programming technicalities (syntax).

As expected, the prerequisite-curve, Q1 is situated at the bottom, but many abilities are considered important or crucial. The interplay between Q2 and Q3 is interesting; Q2 is lower than Q3, which could be reasonable as question Q3 involves "the highest grade". The two curves seem to follow each other. The "ability

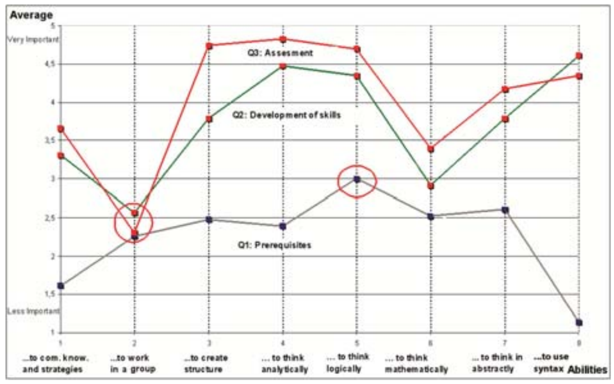

Figure 4. exposes how teachers graded the importance of eight abilities in relation to three questions (Quest2); Q1, "To what extent do you expect the following prerequisites in programming", Q2, "To what extent do you elaborate on students' skills development in programming" and Q3 "To what extent do you consider the following skills as important to receive the highest grade in programming". Each curve represents one of the three questions with an average number for each ability.

to think logically" exposed a peak in association with the prerequisites. It was further investigated in Quest4 when teachers were asked "*To what extent do you consider students' analytical and logical abilities to be important when learning programming?*" Figure 5 pictures teachers' expectations as high in all three courses, which correlates to the peak in Figure 4.

The following quotation (from Quest1, question 4H) exposes the major problem that many teachers are faced with when analytical abilities are lacking:

> Students need to give themselves an overview to better appreciate the different parts of the problem. Many students just perceive an unsolvable problem, as they can't envision breaking the problem into smaller pieces (Quest1, teacher number 16)

4) A Question of Students' Interest and Motivation

No specific seminar scrutinized "interest and motivation" in particular. However, data from two questions in Quest1 expose the importance of 'seeing' and envisioning what you are doing while learning; *"What qualities do you consider important for someone to become skilled in programming?"* (Quest1, question 4A), and "*What qualities, according to you, are the major differences between students who pass and students who pass with particular distinction?"* (Quest1, question 4I):

> Students who pass with particular distinction solve problems easily, beautifully and with added features. Understanding and interest is the difference. (Quest1, teacher number 6)

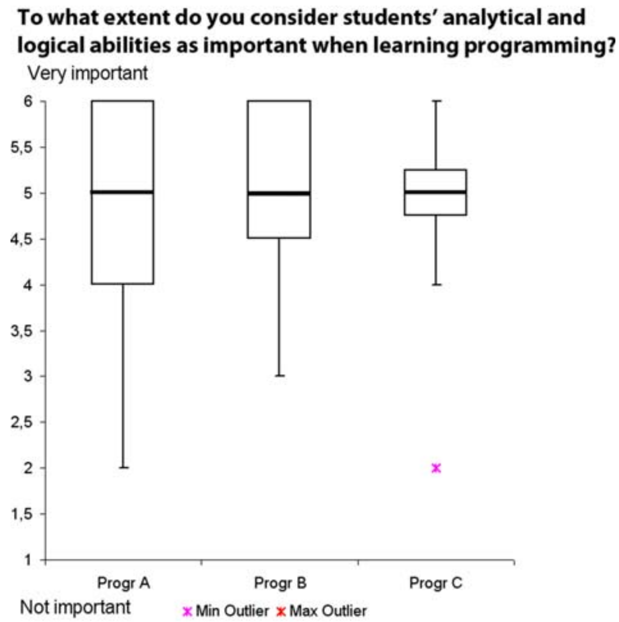

Figure 5. Depicts how teachers answered "To what extent do you consider students' analytical and logical abilities to be important when learning programming" on a scale from 1 to 6 (Quest4).

> The student who passes with particular distinction is more independent… S/he can picture an overview. (Quest1, teacher number 41)
>
> S/he knows how to approach the task with different solutions and possesses the capability to see through the code for better optimized routines and methods. (Quest1, teacher number 47)
>
> The clever ones are able to think differently and envision the problems and the solutions. (Quest1, teacher number 60)
>
> The ability to structure the tasks and explore and improve different types of errors, which in itself draws on the ability to structure a task. (Quest1, teacher number 75)

The quotations show how important teachers believe the students' ability to structure and envision is for the successful completion of a task, which in the long run influences students' motivation. This theme needs further investigation.

DISCUSSION

The investigation unravels four factors of importance in computer programming education; individual time on task, theory or practice, teachers' pedagogy, and students inherent abilities. Based on these factors, computer programming teachers' ontology and epistemology is discussed.

The time in class is commonly divided between teachers' instruction and students work on tasks. Much of the teaching is conducted in a constructivist manner, which mirrors teachers' intentions to offer a balance between guidance and self-directed discovery for learning (Oakley & McDougall, 1997; Johanson, 1988). The concept of teachers' pedagogy and its necessity for students' learning was raised during seminars which revealed some of the implicit nature of pedagogy. During the seminars, the importance of students' specific abilities was discussed. Were the abilities something the students were born with, or was it acquired during class? Figure 4 unravels indications that teachers considered specific abilities to be more important (Q3) than students' skills development (Q2).

The *importance of individual time on task*: a majority of the teachers used short instructions followed by hands-on tasks.[7] The majority of the teachers described the learning process in computer programming as time-consuming. Individualized education appears specifically in beginners' courses. The rationale behind such a pattern is found in the assessment process and the diversity of students' understanding, wherefore individual support is given to a high extent. A larger group of teachers is therefore biased towards individual student support, while a smaller group of teachers was concerned with instructions for understanding instead of technicalities in a programming language.

The *importance of theory or practice*: according to the teachers, the use of theory in class increases in successive courses. This shows in Figure 3, which depicts teachers' beliefs about the time invested in practice and theory respectively. This was not investigated further as discussions during seminars revealed that the concept of theory was heavily associated with knowledge offered by the teachers during the instruction part of the class or individual support, as opposed to computer science theory in itself. Facts and technicalities, syntax and semantics in programming language were also discussed during seminars. The importance of learning programming language's syntax was raised, and Figure 4 and statement 8 depicts teachers' expectations of students learning syntax. The gap shown in statement 8, and the necessity of individual time on task reveals a method commonly used and accepted in computer programming education (Johanson, 1988) where focus is on computer programming languages instead of design skills and problem solving. This method has been criticised for many years (Papert, 1980, 1985; Oakley & McDougall, 1997; Lehrer et al., 1999).

The study suggests the existence of a diversified picture of teachers' beliefs about the *importance of pedagogy*; a minority of the teachers viewed pedagogy as important for improved student learning in general; a quarter of the teachers perceived a degree in pedagogy as important for *teaching programming*, and a majority perceived pedagogy as important for *learning programming*. A contradiction therefore seems to exist among teachers, but could be interpreted as teachers experiencing a distinction between teachers' teaching and students' learning; students with logical /analytical abilities *learn* and students who lack the prerequisites for learning computer programming are *taught to learn*.

Written narratives from teachers exposed two pedagogical descriptions of concern for instruction; the teacher as tutor and the teacher as a designer of students' learning experiences. The former mirrors a typical teacher category which commonly appears in association with computers (Schoefield, 1995); a category of teachers with the intent to offer individualized help (ibid, p.201–202). The latter description appeared in minority, and is made up of teachers with the intent of constructing educational scenarios for engagement and experiences not specifically bound to technicalities in programming languages.

Abilities as Something You are Born with or Something to be Acquired

The *importance of specific abilities* as prerequisites for successful learning is emphasized among teachers, and students' logical and analytical abilities are considered important (see Figure 4 and 5). Social skills like group work and communication between peers, though, is considered beneficial for learning but of minor concern when assessing individuals. The potential of social skills are therefore not fully used among teachers.

The investigation raises the question about whether teachers perceive abilities as fixed and something you are born with (naïve belief) or something that students can acquire by trying (sophisticated belief) (Kardash & Scholes, 1996; Schommer, 1990; Schommer, 1993; Schommer, 1994a). The study suggests that a majority of teachers have a naïve belief while teachers commonly express prerequisites of importance for students' learning. The rationales for such a conclusion needs further investigation, as teachers could hold epistemological world-views in general, as they also hold specific epistemological beliefs about the subject matter – computer programming. Therefore, different dimensions of beliefs are considered a necessity to understand the underpinnings of programming education. Teachers in this study had a strong focus on individual learning in a constructivist manner, which is why many of them, in accordance with the model suggested by Schraw and Olafson (2008), hold a relativistic ontology. The same model makes the teachers candidates for a realistic perspective of epistemology.[8] A realistic perspective of epistemology seems to exist, especially within beginners' courses, as teachers express the necessity of students' ability to work with open-ended problems in advanced courses, which depicts a relativistic perspective on epistemology. However, the existence of rationales which influence teachers' epistemological perspective (relativist or realist) needs further investigation.

CONCLUSION

The study should be considered a first step towards a better understanding of teachers' beliefs about teaching and learning programming. Based on four themes, the investigation reveals four beliefs of importance for computer programming education: 1) students' individual time with code; 2) distinction between theory and practice, 3) teachers' pedagogy; and 4) students' abilities. The world-view (ontology) among computer programming teachers is considered relativistic, which supports the non-importance of lecturing in favour of individual learning in a constructivist manner.

It should be noted that this study is limited in its sample size. There are teachers and schools where programming is offered only at beginners' level and not at all three levels. At these sites one could be expected to find a majority of teachers holding a realistic epistemology, with focus on programming language syntax. In order to verify the research outcome, further investigation is required covering more specific questions and/or individual teacher interviews combined with observations in class (Olafson & Schraw, 2006; Schoenfeld, 2002).

NOTES

1. *The seminar impacted on the curriculum development process in further discussions on the Internet forums organized by The Swedish National Agency for Education. The new computer programming curriculum was released in the autumn of 2011.*
2. *An overview of each seminar, each questionnaire and questions of relevance to the article is described in appendix A.*
3. *73.7% is the sum of 38.6%, 19.3% and 15.8% (See Figure 1).*
4. *The work conducted during analysis is inspired by inductive analysis (Lincoln & Guba, 1985; Miles & Huberman, 1994).*
5. *A similar outcome (yes=27%, no=36% and depends on the level=27%) appeared in Quest2.*
6. *Students' ability to communicate their understanding was emphasized by 15 % of the teachers.*
7. *According to the Swedish Schools Inspectorate, a similar pattern exists among Swedish Mathematics teachers (Skolinspektionen, 2010; Utbildningsdepartementet, 2011).*
8. *Teachers in the study depend on assessment of knowledge in programming language syntax.*

REFERENCES

Baird, J. R., Fensham, P. J., Gunstone, R. F., & White, R. T. (1991). The importance of reflection in improving science teaching and learning. *Journal of Research in Science Teaching, 28*, 163–182.

Berglund, A., & Lister, R. (2010). Introductory programming and the didactic triangle. Twelfth Australasian Computing Education Conference (ACE2010), Brisbane, Australasian, *103*, 35–44.

Beswick, K. (2011). Knowledge/beliefs and their relationship to emotion. Current State of Research on Mathematical Beliefs XVI: Proceedings of the MAVI-16 Conference (pp. 43–59). Tallinn, Estonia: Institute of Mathematics and Natural Sciences, Tallinn University.

Boustedt, J., Anna E., Robert M., Jan E. M., Mark R., Kate S., & Carol Z. (2007). Threshold concepts in computer science: do they exist and are they useful? SIGCSE Bulletin, *39*(1), 504–508.

Brookfield, S. D. (1995). *Becoming a critically reflective teacher*. San Francisco: Jossey-Bass.

Brownlee, J., Boulton-Lewis, G., & Purdie, N. (2002). Core beliefs about knowing and peripheral beliefs about learning: Developing an holistic conceptualisation of epistemological beliefs. *Australian Journal of Educational & Developmental Psychology*, *2*, 1–16.

Bruner, J. S. (1996). *The culture of education*. Cambridge, Mass.: Harvard Univ. Press.

Ernest, P. (1989). The knowledge, beliefs, and attitude of the mathematics teacher: A model. *Journal of Education for Teaching, 15*, 13–34.

Fang, Z. (1996). A review of research on teacher beliefs and practice. *Educational Research, 38*, 47–65.

Hofer, B. K. (2004). Introduction: Paradigmatic approaches to personal epistemology. *Educational Psychologist, 39*, 1–3.

Gustafsson, B., Hermerén, G., & Petersson, B. (2005). Vad är god forskningssed?: synpunkter, riktlinjer och exempel. Stockholm: Vetenskapsrådet.

Hofer, B. K., & Pintrich, P. R. (1997). The development of epistemological theories: Beliefs about knowledge and knowing and their relation to learning. *Review of Educational Research, 67,* 88–140.

Johanson, R. P. (1988). Computers, cognition and curriculum: Retrospect and prospect. *Journal of Educational Computing Research, 4*(1), 1–30.

Kagan, D. M. (1992). Implications of research on teacher belief. *Educational Psychologist, 27*(1), 65–90.

Kardash, C. M., & Scholes, R. J. (1996). Effects of preexisting beliefs, epistemological beliefs, and need for cognition on interpretation of controversial issues. *Journal of Educational Psychology, 88*(2), 260–271.

Leder, G. C., & Forgasz, H. J. (2002). *Measuring mathematical beliefs and their impact on the learning of mathematics: A new approach. Beliefs: A hidden variable in mathematics education?* (In C. Leder, Gilah, P., Erkki, T. Gunther (eds), (pp. 95–113). Dordrecht, Boston, London: Kluwer Academic Publishers.

Lehrer, R., Lee, M., & Jeong, A.(1999). Reflective teaching of logo. *Journal of the Learning Sciences, 8*(2), 245–289.

Lincoln, Y. S., & Guba, E. G. (1985). *Naturalistic inquiry*. Beverly Hills, California: Sage Publications.

Linn, M. C., & J. Dalbey. (1985). Cognitive consequences of programming instruction: Instruction, access, and ability. *Educational Psychologist, 20*, 191–206.

Linn, Marcia, C., & Michael J. Clancy. (1992). The case for case studies of programming problems. *Communications of the ACM, 35*(3), 121–132.

Lister, R. (2008). After the gold rush: Toward sustainable scholarship in computing. ACE '08 Proceedings of the Tenth Conference on Australasian Computing Education, Australian Computer Society, Inc. Darlinghurst, Australia, Australia, 78.

Luft, J. A., & Roehrig, G. H. (2007). Capturing science teachers' epistemological beliefs: The development of the teacher beliefs interview. *Electronic Journal of Science Education, 11*(2), 38–63.

Male, Sally A., & Baillie, Caroline A. (2011). Engineering threshold concepts. September 27–30. WEE2011, September 27–30, 2011, Lisbon, Portugal.

Meyer, Jan., & Land, Ray. (2003). *Threshold concepts and troublesome knowledge: Linkages to ways of thinking and practising within the disciplines.* Technical Report 4, ETL Project Occasional Report.

Miles, M. B., & Huberman, A. M. (1994). *Qualitative data analysis: An expanded sourcebook*. Beverly Hills, California: Sage Publications.

Oakley, J., & McDougall, A. (1997). Issues in the preparation of teachers of programming for children. In D. Passey & B. Samways (Eds.), *Information technology: Supporting change through teacher education* (pp. 108–114)*.* London: Chapman & Hall.

Olafson, L., & Schraw, G. (2006). Teachers' beliefs and practices within and across domains. International *Journal of Educational Research, 45*(1–2), 71–84.

Olson, J. K. (1981). Teacher influence in the classroom. *Instructional Science, 10*, 259–275.

Pajares, M. F. (1992). Teacher's beliefs and educational research: Cleaning up a messy construct. *Review of Educational Research, 62*(3), 307–332.

Papert, S. (1980). *Mindstorms: Children, computers and powerful ideas*. Harvester Press, Brighton, Sussex.

Papert, S. (1985). *Computer criticism vs Technocentric thinking*. Paper presented at Logo 85, Cambridge, MA.

Pears, A., Seidman, S., Malmi, L., Mannila, L., Adams, E., BennEds.n, J., et al. (2007). A survey of literature on the teaching of introductory programming. ITiCSE-WGR '07: Working Group Reports on ITiCSE on Innovation and Technology in Computer Science Education,

Robins, A., Rountree, J., & Rountree, N. (2003). Learning and teaching programming: A review and discussion. *Computer Science Education, 13*(2), 137–172.

Rolandsson, L. (2010). Teacher pioneers in the introduction of computing technology in Swedish upper secondary school. 3rd IFIP WG9.7 Working Conference on History of Nordic Computing, Stockholm, Sweden. 159.

Schoenfeld, A. H. (2002). How can we examine the connections between teachers' world views and their educational practices? *Issues in Education, 8*(2), 217–228.

Schoefield, J. W. (1995). Computers and classroom culture. Cambridge: Cambridge University Press.

Schommer, M. (1990). Effects of beliefs about the nature of knowledge on comprehension. *Journal of Educational Psychology, 82*(3), 498–504.

Schommer, M. (1993). Epistemological development and academic performance among secondary students. *Journal of Educational Psychology, 85*(3), 406–411.

Schommer, M. (1994a). An emerging conceptualization of epistemological beliefs and their role in learning. In R. Garner, & P. A. Alexander (Eds.), *Beliefs about text and instruction with text* (pp. 25–40). Hillsdale, NJ: Erlbaum.

Schommer, M. (1994b). Synthesizing epistemological belief research: tentative understandings and provocative confusions. *Educational Psychology Review, 6*(4), 293–319.

Schommer-Aikins, M. (2004). Explaining the epistemological belief system: Introducing the embedded systemic model and coordinated research approach. *Educational Psychologist, 39*(1), 19–29.

Schraw, G. J., & Olafson, L. J. (2008). Assessing teachers' epistemological and ontological worldviews. In K. Myint Swe (Ed.), *Knowing*, *knowledge and beliefs: Epistemological studies across diverse cultures*. New York: Springer.

Schwab, T. (1973). The practical translation into curriculum. *School Review, 81*, 501–522.

Schön, D. A. (2003). *The reflective practitioner: How professionals think in action*. Aldershot: Arena.

Sheard, J., Simon, S., Hamilton, M., & Lönnberg, J. (2009). Analysis of research into the teaching and learning of programming. *ICER 09*, Berkley, California, USA.

Skolinspektionen. (2010). Undervisning i matematik i gymnasieskolan (Kvalitetsgranskning No. 13). Stockholm: Skolinspektionen. (Diarienummer 40–2009:1837).

Trainora, A., & Kate A. B. (2012). Exploring and developing reciprocity in research design. *International Journal of Qualitative Studies in Education*, 1–18.

Utbildningsdepartementet. (2011). Uppdrag till Statens skolverk att stärka undervisningen i matematik, naturvetenskap och teknik. U2011/2229/G.

Vetenskapsrådet (2008). Forskningsetiska principer inom humanistisk-samhällsvetenskaplig forskning Vetenskapsrådet, Stockholm.

Wilson, M., & Cooney, T. (2003). Mathematics teacher change and development. In G. C. Leder, E. Pehkonen & G. Törner (Eds.), *Beliefs: A hidden variable in mathematics education* (p. 127). Secaucus, NJ, USA: Kluwer Academic Publishers.

Yerrick, R., Parke, H., & Nugent, J. (1997). Struggling to promote deeply rooted change: The 'filtering effect' of teachers' beliefs on understanding transformational views of teaching science. *Science Education, 81*(2), 137–159.

APPENDIX A

Table 1. An overview of seminars, questionnaires, number of informants and questions of relevance to the article.

Seminar	*Questionnaire*	*Questions*
Sem1	Quest1 (open-ended questions), 103 teachers	Q 2A: "What kind of educational experience do you have in programming?" Q 2B: "What kind of education do you perceive as necessary to work as a programming teacher?" Q 2C: "For how many years have you taught programming?" Q 3D: "Do you benefit from forms of assessment other than examinations, to evaluate and grade students' knowledge?" Q 3I: "What sort of education do you perceive as crucial to students learning programming?" Q 4A: "What qualities do you consider important for someone to become skilled in programming?" Q 4C: "Do you think that any student can learn programming?" Q 4H: "Many students are capable of learning the syntax and the facts about the programming language, but fall short when they try to solve more complex tasks. In your opinion, what is the most common reason for these difficulties?" Q 4I: "What qualities, according to you, are the major differences between students who pass and students who pass with particular distinction?"
Sem2	Quest2 (eight statements concerning abilities), 22 teachers	Q 1: To what extent do you expect the following prerequisites in Programming? (Prerequisites before class) Q 2: To what extent do you elaborate on students' skills development in Programming? (Development of abilities during class) Q 3: To what extent do you consider the following skills as important to receive the highest grade in Programming? (Assessment of student's knowledge)
Sem3	Quest3 (statements concerning improved pedagogy), 34 teachers	"To what extent are the following statements important to your educational design? " … followed by 29 statements that teachers valued on a Likert scale …

Seminar	*Questionnaire*	*Questions*
Sem4	Quest4 (likert scale questions), 56 teachers	Q 3D: "Do you consider pedagogy as important to programming education." Q 3F: "Programming is considered to offer more mathematics than the subject matter of mathematics itself." Q 4A, 5A and 6A (at respective level of course): Statement 1: "Do you consider every one of your students [at level X], who attend the course to be able to pass Programming?" Statement 6: "To what extent do you consider students' analytical and logical abilities [at level X] to be important when learning programming?" Q 4B, 5B and 6B (at respective level X of course): "Do your students [at level X] usually work alone or together" Q 4D, 5D and 6D (at respective level X of course): "What sort of education (theoretical or practical) do you consider beneficial for students [at level X] learning programming?"