Technology Education in New Perspectives

Research, assessment and curriculum development

_Festschrift for Witold Rogala_

_Ed. Lars Lindström_

Stockholm Library of Curriculum Studies Vol. 14
Stockholm Institute of Education Press (HLS Förlag)
Technology Education in New Perspectives

Research, assessment and curriculum development

Festschrift for Witold Rogala

Ed. Lars Lindström

Stockholm Library of Curriculum Studies Vol. 14
Stockholm Institute of Education Press (HLS Förlag)
Preface

In honour of our friend and colleague Witold Rogola – retiring Head of the Department of Technology Education, Stockholm Institute of Education.

It is open house at the Stockholm Institute of Education. Students are coming and leaving. Some of these have decided to combine teaching with their fascination in arts and literature; others are interested in teaching a new generation to become enlightened participants in a democratic society. Or they believe in the old Greek saying that with a healthy body, trained in various sports, your mind will be sharp and vital. Rather few, in these days, look upon themselves as prospective teachers of technology.

However, this very day is not like other days during the year. As soon as the visitors enter the main building, or what was once the main entrance to the institute, they meet a tall and athletic man, with a curious glance in his eyes and a warm smile at his lips. By his side, there is a younger, female colleague. One of the students passing back and forth, stops at the poster behind the couple and asks: “What’s this?” – “Design and Technology”, says the man, with a slight Polish accent. “Uh, hum. That’s something having to do with numbers, isn’t it”, the student responds, making herself ready to leave. “Not primarily; technology comes from the Greek word techne, having to do with practical knowledge”, the man goes on: “Now, why don’t you take a cup of coffee and a cookie with my colleague here, and look upon our exhibition of the students’ works”. Half an hour later, the student has changed her mind about technology and asks, when leaving the building, for still more information on the technology curriculum.

This episode tells something about Witold Rogala, in a nutshell. First of all, he never gives up. When newspaper headlines tell us that interest in technology is declining, especially among female students, Witold proved that the subject could very well be taught in a way that raises the curiosity of young students, and especially female ones. In Stockholm, during the leadership of Witold Rogala, the downward trend has been broken, and even reversed. Secondly, Witold has been very successful in recruiting young, able and dedicated colleagues. The attraction has much to do with Witold’s keen interest in creativity, research and an international exchange. This book is a result of these ambitions, since it has been grown out of a couple of international meetings. However, Witold doesn’t forget the importance of the coffee and the cookies. That is, he knows how to create a warm atmosphere of trust and inspiration, constantly supporting his colleagues to move on, to involve themselves in research, etc.

Then, what happened to the student, after her visit to the open house?
The story doesn’t tell that. Back in 1999, her acquaintance with technology would have been very superficial, since the subject only existed as a five-week course for students in mathematics and science. Today, the Stockholm Institute of Education offers two technology programmes, one academic year each. One of them is oriented towards younger children and the other one towards older children and the upper secondary school. In addition, students can choose to specialize in technology for still another term. Thus the chance that students like the one in the vignette, would choose to include in-depth knowledge of technology into her teacher exam is higher than ever.

As the introductory episode was observed a few years ago, the student would be likely to encounter Witold as her teacher. Then she would have the privilege to be taught by a highly skilful and dedicated educator, one of these rare personalities that make former students return to the Institute saying that here they found the best teacher they ever met.

Stockholm, January 2005

_Lars Lindström_

On behalf of Witold Rogola’s colleagues at Stockholm Institute of Education, Department of Technology Education
Contents

Introduction ................................................................................................................. 9

New Modes of Assessment

1. Assessing Design Innovation ................................................................. 17
   Richard Kimbell

2. Technological Development and Development of Technology Education ................................................ 36
   Gabriel Graube, Walter E. Theuerkauf

3. Proposal of a Model of Competence for Technological Education ............................................. 47
   Gabriel Graube

4. Novice or Expert? Conceptions of Competence in Metalwork ............................................. 61
   Lars Lindström

Curriculum Development Today

5. Perspectives on Technology Education in Germany and the situation today ............................................. 87
   Wilfried Schlagenhauf

6. Updating Technology in the Comprehensive Schools of Ukraine ............................................. 97
   Victor Sidorenko, Jevgen Kulyk, & Igor Zhernoklieiev

7. Towards a Philosophy of Technology Education Based on Heidegger and Dewey ............................. 103
   Eva Blomdahl

8. Technology and Innovation as an Attractive and Crucial Discipline for Tomorrow ............................. 127
   Michael Lindgren
9. Learning in Technology: a Design Theoretical Approach to Architecture Education ......................... 144
   Jan Åke Granath

10. Addressing Modern Technology, a Systems Approach ................................................ 161
    Lars Björklund

   What Research adds up to

11. The Shaping of School Technology – Research on Technology Education from a Swedish Perspective .. 179
    Jan Erik Hagberg
Lars Lindström

Introduction

Ten years ago, at a German conference on ”Technology and environment”, Swedish technology education was regarded as a potential ”model also for other European countries” (prof. E. Merz). The Swedish curriculum looked upon technological phenomena from multiple vantage points: The system and its components; Technical operations and actions; Functions of technical systems and processes; Consequences for the individual; The history and development of technology.

This model, which in Germany is called ”mehrperspektivisch” (the multi-perspective approach) offers great freedom for the teacher in choice of content. However, the responsibility given to the individual teacher requires great talent and deep insights. Considering the present day fiscal crisis, some would say that the demands are too high. Others argue that more resources should be channeled into teacher training, modern workshops in the municipality schools, extended relationships with science centres, museums, state-owned and private enterprises, etc.

Whatever option chosen, we have much to learn from our European colleagues, who struggle with similar problems as our own. There is no master model to emulate or quick fix to apply. We think that progress is a result of dialogue and reflection based on the practice of teachers and students of design and technology. The Stockholm Institute of Education wants to play an active role in stimulating this on-going dialogue on a national and a European level.

The chapters in this book were originally presented as papers at a conference at the Stockholm Institute of Education, October 8 or another one at the National M. Dragomanov Pedagogical University Kiev, Ukraine, October 10-11, 2003. To these conferences some of the major scholars in Europe in the field of design and technology education were invited. The focus was on research, assessment and curriculum development. During the following months, several of the papers have been substantially revised and two invited papers have been added.

New Modes of Assessment

In Chapter One, Prof. Richard Kimbell, Goldsmith College, London, presents a research project called “Assessing Design Innovation”. The project was launched as a response to criticism of the design and technology education in Britain for its approach to student assessment. The assessment
procedures were widely regarded as being formulaic, routinized and predictable. As a consequence, it was felt that the hard-working rule-followers were rewarded at the expense of the risk-taking design innovators. The research project has moved through three phases: initially exploring performance descriptors of design innovation, then examining classroom practices that encourage it, and finally developing assessment activities that promote the evidence of innovative performance. The research team developed a “structured worksheet approach”, including a collaborative element and a story-line of digital photos. The pupils work concentrated for seven hours and are encouraged to develop interesting ideas, knowing that they will not be judged by the craft quality of the final outcome. This approach was very well received. However, it still remains to be proven that this procedure accurately identifies those students who are really good at design innovation.

In Chapter Two, Dr.-Ing. Gabriele Graube, TU Braunschweig and Prof. Walter Theuerkauf, TU Braunschweig, Chairman of the European Society of Technology Education (EGTB), initially observe that technological change has become an increasingly dynamic and complex process. Having this in mind, they take a fresh look at technology education. Although modern technology cannot be understood in its full complexity, they say, its underlying structures and functions can be illustrated by examples. After having discussed technology as a part of general education, the authors present some main traditions of technology education: manual skills, polytechnics, work orientation, general technology/systems theory, science & technology, and design & technology. Graube and Theuerkauf conclude by advocating that technology should be introduced in a playful manner at the primary level and taught until the pupils leave school, thus preparing all citizens for life-long learning.

In Chapter Three, Dr.-Ing. Gabriele Graube presents a model of competence to be used in technology education, especially in connection with international comparisons. Such a model should be useful at different grade levels and should not favour any particular didactical approach. Graube’s model includes three dimensions: technological action (i.e. the process of formulating goals, developing ideas, prototyping, production, distribution, use of products, and finally their disposal), technological systems (e.g. systems made up by the flow of materials, energy and/or information), and relationships between the human being, nature, technology and society. Graube illustrates how competence along these dimensions can be assessed. In one of her examples, students have to design and make a lamp made
of metal. By a coincidence, this assignment and the criteria used to assess it, have been studied in depth by the next author.

In Chapter Four, Prof. Lars Lindström, Stockholm Institute of Education, studies conceptions of competence in metalwork among educators and artisans. It was found that nothing else agreed more with the interviewees’ ratings of expertise than the demonstration of good craftsmanship. Sound knowledge of the craft, according to the teacher educators and the artisan, is a necessary prerequisite of a good working process. The expert who is attentive to the properties of the material solves problems “in the process”, in contrast to the novice who is controlled or distracted by external factors which force him or her to makeshift solutions. However, the artisan did not allow himself as much leeway for trial and error as the educators did. This discrepancy is important to keep in mind, Lars Lindström concludes. Ambitions to make schoolwork more “authentic” or “real”, if carried to far, can reduce the freedom and tolerance for failures that are required in order to foster thoughtful learning.

**Curriculum Development Today**

In Chapter Five, Prof. Wilfried Schlagenhauf, PH Freiburg, presents the present situation and different concepts of technology education in Germany. Schlagenhauf belongs to a board, commissioned by the Association of German Engineers to develop national standards for technological literacy. He is appalled by the fact that the German high school (Gymnasium), attended by 40% of all pupils, still ignores technology education to a large extent or look upon technology merely as applied natural science, thereby missing its human and social dimensions. According to Schlagenhauf, standards for technological literacy will be helpful only if they are based on a broad consensus regarding fundamental ideas. He argues that this may be even more important for technology education than for other school subjects, because technology seems to be highly endangered by misunderstandings (e.g. understood as applied natural science or as merely manual work).

In Chapter Six, Prof. Victor Sidorenko and colleagues at the Dragomanov Pedagogical University Kiev, identify an urgent need to reconsider the traditional approaches to the teaching of technology in Ukrainian comprehensive schools. Its contents and general orientation must be updated, they conclude. The school workshops have deteriorated and there are no money to supply them with new machinery and other necessary equipment. It will be necessary to create an essentially new techno-cultural subject for grades 5 to 9 in the comprehensive school. The new subject should focus on the
transforming activity of the human being, which penetrates every area of
the modern society: everyday life, recreation, studying, the industrial sphere,
and management.

In Chapter Seven, Lecturer *Eva Blomdahl*, Stockholm Institute of Educa-
tion, discusses the essence of technology education by drawing upon Mar-
tin Heidegger’s philosophy of technology and John Dewey’s philosophy of
education. Dewey observed at the beginning of the last century, already,
that the world of children and young people was becoming more and more
opaque. The school, he said, therefore should make it visible anew. Build-
ing upon this insight, Blomdahl defines the task of technology education as
being that of ”re-presenting” technology. Heidegger made it clear that no
technical device can be understood in isolation. Thus technology cannot be
identified with individual artefacts, but must be regarded as part of increa-
singly complex socio-technical systems. In Eva Blomdahl’s view, the phi-
losophies of Heidegger and Dewey support the idea that education in tech-
nology should be directed towards understanding and reflection. It is not a
matter of training pupils to become technicians but making them able to
understand and evaluate technology, to reach an insight into the tradition
and development of our technical culture, and to assess the consequences
of the impact of technology on man and his environment.

In Chapter Eight, Dr.-Ing. *Michael Lindgren*, Halmstad University Colle-
ge, Sweden, provides a set of guidelines for teachers and others working
with technology education. He is sharing his experiences from teaching
technology to students in higher education with various backgrounds and
specializations. When teaching, he is combining different media such as
story telling, artefacts, visual aids, construction tasks, experiments, case
studies, study trips, discussions, oral presentations, role playing and rea-
ding/writing. Science, ideas, inventions, innovations, products, processes,
marketing etc. are brought to the students’ attention by teasing their intel-
lects with, e.g., stories of personalities like Marie Curie, Henry Ford, Isaac
Newton, Andreas Vesalius, Hildegard of Bingen and Christopher Pol-hem.
By using examples from history and integrating technology with other dis-
ciplines, Michael Lindgren has been able to make technology and innova-
tion seem interesting and relevant to the students.

In Chapter Nine, Prof. *Jan Åke Granath*, Chalmers University of Technolo-
gy Gothenburg, points out that engineering education is based on structural
knowledge that is not dependent on the context. E.g. rules for how to calcu-
late a concrete beam are the same regardless whether it will support a church
or a soccer stadium. However, in the late 1960’s real-life problems were introduced in a few programmes, where students intervened in and co-operated with people in various everyday settings, such as work, housing and public facilities. Today, real-life contexts, or at least simulated such, are increasingly used as a basis for professional training. In this chapter, Jan Åke Granath presents a case study in architecture. Many students in higher technology education only expect solving well-defined problems and learning about facts. Others put too heavy emphasis on artistic self-fulfilment. However, these expectations are confronted in the architecture curriculum, by an exercise that the students will meet during the first semester. Here the students will have to approach problems that are not well defined and do not have optimal solutions. The aim of the exercise, described and analysed by Granath, is to make the students aware of the dynamics and uncertainty of problems in real life.

In Chapter Ten, Lecturer Lars Björklund, Linköping University, argues that in order to understand modern technology one has to look at functions rather than structures. Furthermore, individual technologies become meaningful only as parts of complex multi-level systems. In engineering, as well as in education, it is of vital importance to choose the appropriate system level. Electronics, as part of the science curriculum, is mostly about atoms, electrons, charges, electrical fields, current, conductors, isolators, resistors, capacitors, transistors, amplifiers, integrated circuits, etc. Thus textbooks and teachers try to explain the inner structure of the chip, instead of concentrating on its functional properties on a higher system level. As a consequence, students find electronics being complex and difficult to comprehend. However, as part of the technology curriculum, electronics could be used as a basis to understand how everyday technologies work. Lessons of this kind have been developed and tested by Lars Björklund with 15 and 16 year-old students. Preliminary results have been very encouraging.

What Research Adds Up To

In Chapter Eleven, Senior Lecturer Jan-Erik Hagberg, Linköping University, describes how the subject of technology in Swedish compulsory schools has grown out of several different traditions of knowledge, including those of science and manual arts. He also discusses how new technologies redefine what should be regarded as general knowledge in the domain. In reviewing Swedish research in an international perspective, Jan-Erik Hagberg is struck by the low degree of publication, by Swedish researchers, in leading international journals. Still, he concludes that Swedish research on learning and teaching in technology is extensive, differentiated, dynamic and rele-
vant to central issues in the international discussion. Important dissertations and other major papers have been published since the early 1980's. Some study the development of technology education at an institutional level. Others discuss the subject in relation to a specific social issue, such as democracy or the gender system. There are also studies that focus on children’s learning and interest in technology. Summing up, in terms of recommendations, Hagberg finds the key to high quality research be lying in the combination of research on aspects that are specific to learning in technology with participation in the broader discussion within education and social sciences, e.g. on theories of learning.

**Acknowledgements.** Financial support for the conferences in Stockholm and Kiev and for the publication of this report was provided by the Swedish Institute and the Stockholm Institute of Education, Department of Curriculum Studies and Communication.
NEW MODES OF ASSESSMENT
1. Assessing Design Innovation

In 2000, the most recent version of the UK national curriculum was published, marking the latest development of design & technology in schools. At the same time, the Department of Education & Skills (DfES) launched a new Strategy Group to oversee the further development of design & technology in the following decade, and the first focus of their attention was to examine the statement in the National Curriculum (NC2000) concerning the distinctive contribution of design & technology within the curriculum.

“Design and technology prepares pupils
... to intervene **creatively** to improve the quality of life
... to become autonomous and **creative** problem solvers
... as individuals and members of a **team**
... to combine practical skills with an understanding of aesthetics, social and environmental issues and industrial practices.
... to reflect on and evaluate present and past design and technology, its uses and effects.”

It was noted that whilst much of the development of design & technology had been very creditable, a serious weakness was evident in the approach to student assessment that was widely regarded as having become formulaic, routinised and predictable. In short, in the General Certificate of Secondary Education (GCSE) 16+ national assessments, the wrong students were getting the best marks: those that were hard-working rule-followers. The risk-taking design innovators were being penalised by the assessment arrangements. The importance of this situation could not be ignored, since almost the entire 16 year old cohort of students (approx 500,000 students per year) take these examinations, and the national perception of design & technology in schools (with teachers, students, and parents) is shaped by the demands of these national examinations.

**Understanding design innovation**

The Technology Education Research Unit (TERU) at Goldsmiths College, London, was asked to undertake a review of the assessment arrangements and develop an alternative system of assessment to be used within the GCSE framework that would measure and reward design innovators. The basis for its inclusion in the assessment frame-work was one of the issues to be tack-
led in the research. Currently the assessments require a timed written examination (2 hrs) and a piece of assessed designing/making coursework – the result of approx 25 hrs of workshop/studio curriculum time. The timed exam typically contributes 40% of the marks and the coursework 60%. We were asked to consider how these demands might be revised in the light of our alternative proposals.

Our approach to this research project moved through three phases: initially exploring performance descriptors of design innovation, then examining classroom practices that encourage it, and finally developing assessment activities that promote the evidence of innovative performance.

The tradition of performance assessment in coursework projects in the UK has been to use the stages of design projects as elements for assessment:

- outlining the brief
- detailing the specification
- undertaking research
- generating ideas
- making choices
- manufacturing a prototype
- evaluating in context

In this project, we used a model of the design & development process that was first developed for the Assessment of Performance Unit (DES 1991). That model describes the process of design & development as a continuous iteration of ideas in the mind with expressions of those ideas in the external world.
... the act of expression is a crucial part of the development of thinking... the concrete expression of ideas not only clarifies them for us, but moreover it enables us to confront the details and consequences of them ... Cognitive modelling by itself - manipulating ideas purely in the mind’s eye - has severe limitations when it comes to complex ideas... It is through externalised modelling techniques that such complex ideas can be expressed and clarified, thus supporting the next stage of cognitive modelling. It is our contention that this interrelationship between modelling ideas in the mind, and modelling ideas in reality is the cornerstone of capability in design and technology.

Choosing the most appropriate form of modelling involves thinking not only about what the idea is that needs to be expressed, but equally about how the modelling is supposed to help.

...discussion (verbal modelling) ...diagramatic, or computer simulated ... graphic ... 3D models... There are many ways of modelling ideas and each has its advantages and disadvantages. Accordingly pupils
need a rich awareness of the diversity of possibilities for modelling to enable them to grapple with the particular requirements of their task. 
(Kimbell et al 1991 p. 20-21)

Using this model, we developed the booklets-based activities which are described below. So (for example) the sequencing of sub-tasks is very deliberate; each *reflective* sub-task being followed by an *active* sub-task, supporting the continuous iteration that we believe is central to effective designing.

Our work in phase 1 suggested that the key to innovative performance lay in the ability to generate and develop *ideas* for new, better and different solutions. Accordingly our provisional framework for criteria developed around the ability of students to *have* ideas, to *grow* their ideas, and to *prove* their ideas.

**Examining effective classroom practices**

Subsequently, our focus in phase 2 was to examine the approaches used by teachers to foster and support creative intervention by students. We undertook a series of short, concentrated projects run over 2 full days in schools throughout the UK. Teachers ran their own tasks with their students – but were explicitly encouraged to forget about existing assessment criteria, and to concentrate instead on encouraging students’ design innovation. Some amazing projects were observed, leading to equally amazing student outcomes in just 2 days, including the folding chair (below) that used CAD/CAM production technology, and that was designed for visitors to carry around in an art gallery.

But for assessment purposes there remained a major problem that the students’ design evolution was not evident in the final outcome and existed only through a series of (sometimes) scrappy paper and card models. And none of their reflective design thinking was captured in any of the work.

Accordingly we moved into phase 3 with the belief that short-sharp projects were the key to developing the performances that we were seeking –
but additionally we needed a paper format within which students could develop and record their thinking as it happened in the designing process. This paper-based evidence could then support the prototype outcome and enable us to make good assessments of their levels of design innovation.

**Implementation of valid assessment activities**

In the first 6 months of 2004, phase 3 focussed on creating and developing a response booklet – a new kind of design worksheet – that both enables a recording process and (at the same time) helps the students by prompting and supporting the growth of their design ideas.

The activity evolved into a 7 hour task: two consecutive mornings of 3.5 hours. In that time, students start with a task and work through to the development of a prototype solution – a ’proving’ model to show that their ideas will work. The whole 7 hours is run by the teacher – following a script that choreographs the activity through a series of sub-tasks – each of which is designed to promote evidence of students’ thinking in relation to their ideas. These ’steps’ in the process all operate in designated spaces in the booklet. The following structure is characteristic of the activities so far developed.

1 establish the task
2 explore a series of ’idea-objects’ in a handling collection designed to promote thoughts about the task
3 put down first ideas in a designated box in the booklet
4 working in groups of 3, students swop their booklets and each team-mate adds ideas to the original
5 team-mates swop again so that each team member has the ideas of the other two members of the team
6 booklets return to their ’owner’ and team members discuss the ideas generated
7 the teacher introduces the modelling/resource kit that can be used throughout the 2 mornings
8 students develop their ideas in the booklet – and/or through modelling with the resources
9 students stop to reflect on the user of the end product and on the context of use
10 photographs are used at approx 1 hr intervals to develop a visual story line to illustrate the evolution of models & prototypes
11 at the end of the 1st morning, students reflect on the strengths and weaknesses of their evolving ideas
12 the 2nd morning starts with a celebration of the work emerging from day 1 and then moves into further prototype development with regular hourly photos and pauses for reflective thought on strengths and weaknesses until the final team reflections, when (in turn) team members review each others’ ideas and progress individually, students then ’fast-forward’ their idea and illustrate what they think the product will look like when completely finished and set-up in context and they finally review their own work from start to finish.

The finished booklet is a folding A2 sheet that ends up packed with ideas, drawings, notes and photos. It is an immensely rich data source and a vivid record of the students’ experience of 7 hours of (often) frenetic activity.

Its success in recent trials appears to hinge upon the immediacy of the work – with a carefully structured and very specific series of demands being placed upon students – demanding responses in designated (small) boxes in the booklet and with very little time (3 mins for this; 5 mins for that etc.). It is a format that students appear to enjoy – and that teachers find manageable in the school workshop /studio. Using various versions of this structured worksheet approach, we have now undertaken trials of 10 different tasks ranging from product/packaging design, fashion/textile design, electro-mechanical systems design and food product design. In total we have responses from approx 300 students in 11 schools spread across the UK.

Comments from teachers:
• The layout and the way it (the worksheet) folds so that the pupils can see what they have done is great,
• Students enjoyed the challenge. Great atmosphere in the room. Students were totally engaged for the majority of the time. Loved the photographs!
• The inspiration table was a really successful way to motivate / excite the students by showing them, and getting them to think about the ’wow’ factor within a successful product.
• Students were developing products that were more interesting and creative than those that materialise from the brief, specification, research, ideas, development route!
• Through a highly focused activity, students had the opportunity to experiment with a concept that may or may not work. Given permission to take a risk and not to be too worried about a quality outcome
• The pupils think the support team is very helpful in achieving their task and a lot more critical commentary is going on that is recorded.

• One of the remarks that I recall from reading the self assessment sheet was “it shows what I can do in a positive way” – this was written by a pupil who is a school phobic and finds school work difficult.

• The set task appealed to their imagination. The whole process is “pacey” and nothing becomes overworked or laboured – the quick response time sharpened pupils decisions and hence pushes achievements/attainment. Taking a chance/risky – as it is a prototype it matters but we can learn from the process. The end product is not just the key aspect of this task – it is how the task is undertaken. The exchange/evaluation of ideas in the initial part orientated pupils to be aware that other people opinions could help and more importantly they function as a team. Pupils felt a range of emotions during the project – apprehension, edgy, risky, exciting, familiar but also a sense of achievement and pride. The photos spurred them to work at a pace and also a sense of achievement. The task is divided into two morning – pupils have a gap to reflect on the previous days thinking.

From the students involved, the message was equally clear. They loved the collaborative element of design development – sharing ideas in their group at the outset and reflecting on them later. And they appreciated the storyline of digital photos that had the effect of showing them their own progress. They also enjoyed working at a fast pace through a concentrated 7 hour activity and having the encouragement to develop really interesting (and somewhat risky) ideas with the confidence that they would not be judged by the craft quality of the final outcome.

**Hull**

AB112 - Had other people to give their opinions on your ideas
AB114 - Helping my group with different ideas
AB117 - The sheet was helpful, as it helped you know what you had to do
AB119 - Being able to use my own ideas how I wanted to
AB1111 - These have been the best two days in school
AB1117 - Its easier to understand when you try it out for yourself
AB1119 - The pictures help, cos I could always look back and see how good I’d done
Leicester
AB214 - You had more time to get on with it
AB215 - Working in groups but having the ability to work independently
AB216 - You can make things you didn’t expect
AB218 - The regular photos
AB219 - Working in groups helped for inspiration with ideas
AB2110 - Its fun designing
AB2111 - Using different materials
AB2116 - I could show people my ability

Staffordshire
AB226 - Good layout of worksheets
AB228 - You got to show your ability
AB2210 - Starting from scratch to make you think

Wales
AB314 - Using your own ideas; making models instead of drawing – they work better
AB315 - It was fun to design something and actually make it
AB319 - Seeing your idea develop
AB3110 - Only having a limited time to work
AB3111 - We got to try out different things, using our ideas
AB323 - Being able to make something by myself and what I wanted to make
AB324 - I realised that I could do more than I thought I could
AB326 - The photos was the best way to show the steps, which I think was good

Berkshire
AB411 - I liked getting my imagination go wild
AB4110 - It was a very good way in finding how many skills you have
AB4112 - I learned how to make a lot more stuff

Northumberland
AB423 - It made you think about how you could do things and with different materials
AB4214 - It is more laid back than a test - which is better

The teachers have further commented on the extent to which the experience has affected their own classroom practice.

• This trial has had an real affect on my teaching. It has reinforced things I do, reminded me of things that I have done, and prodded me to think of things I have never done. My PGCE student is completely ’gob smacked’ with the method of working and is implementing many of the principles in the trial in his teaching. His lessons are showing real pace and focus.
We found the project to be a very rewarding experience – we have had time to reflect and it will enrich our learning style considerably.

But despite this obvious support from teachers and students, the real test for us (The Technology Education Research Unit, TERU) now is whether the work can reliably be assessed and whether it accurately identifies those students who are (in their teachers judgement) really good at design innovation. This is the focus of work over the next three months as we develop the assessment matrix into a marking structure and train a team of markers. Each piece of work will be double marked – with some being also marked by the team (effectively treble marked). This will lead into a phase of data analysis and writing-up in time for us to report our finding at the end of the project in December 2004.

But the real counter-intuitive conundrum of this project – and the process of working that we have developed for youngsters – is that they are effectively frog-marched (by the teacher script) through a series of steps that are tightly timed and within which they have to put their thoughts in tightly delineated sections of a pre-printed worksheet. At first glance it might be thought to be a bit like painting-by-numbers. And yet the comments of both teachers and students all talk of the freedom they feel in developing their own ideas. Why is it that such a tightly structured and choreographed experience can feel like freedom?

We have started to look at parallel creative disciplines to explore this question – and music provides a good example. It is like jazz. There is a rigid 12 or 16 bar rhythm with a clear beat and a predictable series of phases to the music. And within that tight structure, the most outlandish improvisation can be liberated. So too with our design worksheet and the teacher script. By taking away from students the need to think about how they will organise and present their work, they are empowered to concentrate on the ideas that drive their designing. And that is the purpose of the whole project. Thus we believe that we have evolved an assessment system that will provide a measure of students’ design innovation.

In the process of developing these instruments, we have been in discussion with all the Examination Boards that currently run the GCSE assessments in Design & Technology. They have been under-taking trials with us and a revised approach to assessment at 16+ is beginning to emerge. We anticipate an approach that locates our devise somewhere between a written examination and a piece of coursework. It is really neither of these, but can draw from (and towards) both. It is neither a timed exam (with right answers) nor is it an open-ended piece of coursework. Once we have established the technical standards for our approach – ensuring reliability in assessment
and differentiation amongst the student group – the following months will be dedicated to working with the Examination Boards to evolve the optimum location and arrangements for implementing this new hybrid form of assessment.

**Framework for assessing students’ work**

We already know from experience that our assessment system encourages students’ design innovation. What remains to be established is the extent to which it reliably differentiates between students. However good it is as a creative spur in the classroom, unless we can show that it provides reliable differentiation between individuals, it will not be useful as an assessment system. The challenge is to find a way to celebrate learners emerging ideas and to reward those learners that are able to grow their ideas into innovative design solutions.

Our starting point for this began in phase 1 – in two ways. First through the identification of the words associated with innovative performance and the recognition that ideas lay at the heart of this process. Second, we identified the fact that 'ideas' need to be seen in terms of

- having them
- growing them
- proving them.

As early as August 2003, we were developing this framework for analysing portfolios that we had been sent by schools or by examination bodies.

The development process for the framework thereafter operated simultaneously on and through the framework. Initially, the proposed framework was used to examine samples of learners work to see what qualities it did enable us to recognise and reward – and equally those qualities that it did not acknowledge. This resulted in two things; (I) a ‘score’ for the work, and (ii) a list of doubts and uncertainties about qualities that need to be re-organised within the framework or added to it. This generated a further draft and the process was repeated with new samples of work.

By the summer of 2004, we had arrived at a final version of the assessment form, which is shown in full on page ii. This is the form that was used by the team to score all the 400 pieces of work produced by students within this research study.

A number of features of the form are worthy of a brief description.
assessment process (pilot June '04)

step 1
holistic

step 2
headlines

having ideas (sparkiness)
looking for starting points...
risk/comfort zone getting outside conventional constraints

explicitly choosing a risky task or expressing a risky idea - doing on the edge suspending reality - bending rules - courting failure
suspends reality & take on challenge - running with risky ideas towards unknown - but under control
plays at the edge of a safe task or idea sets them on the path to achieve something new - dipping toes in
plays safe - working within existing experience/reality repertoire or relying on support from the teacher

ideas grow through a rich web of thought & action - using a range of modelling techniques in dynamic and unconventional ways
some idea growth through the integration of thought-action with appropriate techniques used and dynamic development as a result
ideas or parts of ideas being explored through modelling and this impacts on development
ideas largely static and unmoving

step 3
categorising details

Overall is the work
risky, new, unexpected, exciting
some risky, some playing safe
generally playing safe but some surprises
routine, formulaic, predictable

Overall is the work
growing ideas (modelling)
looking forward towards a solution..... do their ideas grow and develop

sees complexity and trade-offs and independently manages a way through connecting everything
sees some complexity & need for trade offs & takes effective action with support - evidence of optimising and joined up thinking
takes some action to avoid crises when guided - but limited grip - tendency to compromise / take little action to grow ideas
unable to see complexities and the need for balancing decisions - disjointed - lost the plot

appraising ideas (thoughtfulness)
looking back to confirm the effectiveness of a solution .... do they step outside the design to see it/test it as others might

independently sets up and uses valid and reliable checks - thinks through str & weaknesses & consequences and takes appropriate action
does some valid checks and some recognition of str & weaknesses and others' views and takes some action as a result
aware of the need to check things out prepared to listen to others and make minor changes as a result - esp when prompted
doesn't see need for external tests of any kind - or of others' opinions... uncritical
First, there is an order to the assessment process, which starts with making an overview judgement (in gray) about the whole piece of work, and progressively works down into the detail. The initial overview judgement is (broadly speaking) where the marker notes whether this piece of work is a 'wow' or a 'yawn', or somewhere in between. Initially this judgement is on a 4 point scale, but thereafter is refined so that (for example) if the work is judged to be a 'wow' (i.e. a 4), the marker is then required to say whether it is a REAL WOW (i.e. the top of level 4) or a solid middling 'wow', or only just a 'wow'. So the 4 point sale becomes a 12 point scale. Starting with this holistic judgement is a technique that we have systematically adopted in all our research projects since APU data confirmed our 'belief through practice' that such holistic judgements are not only easier to make but also more reliable than any atomised form of judgement. The holistic judgement creates an overview frame of reference which can then be teased apart to examine elements of detail.

The detail in this case concerns learners ability to have ideas, grow ideas and prove ideas. These judgements are teased out as phase 2 in the process. Once again, an initial judgement on a 4 point scale is refined into a 12 point judgement – supported by criteria that have been drawn from detailed examination of students work.

**Having ideas** is seen as 'sparkiness’, rewarding learners for the quality and quantity of the raw material of ideas that they throw into the melting pot. These ideas may arise at the start of the activity or in the middle of development, or towards the end of the activity. In any case we reward those scripts that demonstrate a rich supply of interesting ideas

**Growing ideas** is seen as the heartland of capability in design & technology and it finally emerged in two forms;

- growing ideas through modelling (eg notes/sketches/3D/photos). This is seen as a kind of horse-power driving the development process forward. Are the ideas growing and transforming and (hopefully) improving? Or, conversely, are they static, unmoving, going no-where.

- growing ideas through optimising. This is a more subtle aspect of growth, and concerns learners’ ability to see (and control) the complexity in their ideas so as to keep the project on the road. Some students are well aware of the complexities that they are consciously managing, Other are driven before the storm of their ideas – unable to control events or even to see the complexities that exist in their ideas.

**Proving ideas** is about criticality and thoughtfulness. In the midst of a development process it is easy to be carried away by the excitement and chal-
lenge of new ideas, but good designers can stand back from their work and view it dispassionately. Some students are autonomously self critical, others only reflect when they are required to (eg when ‘red pen’ intervention are demanded), and others are unable at all to be thoughtfully self aware in their development process.

Having made these judgements in phase 2, we found it useful also to note the content areas of work that students had engaged with in their project. This was phase 3 of the assessment process. The three groupings that we used for this are work that is dominantly aesthetic (A), work that is dominantly concerned with users (U), and work that is dominantly technical (T). We were not concerned to make quality judgements about these categories, but merely to note what areas of content learners were principally grappling with in their work. Whilst this tells us something about learners and their performance, we also recognise that this tells us a good deal about the task that is set. Some tasks are more susceptible to (eg) aesthetic or technical development than others. Ideally tasks would be neutral in this respect – allowing equally for all three forms of development.
Appendix 1

On pages 34 to 35 is the front and back of one of the scripts reproduced. It will be an A2 sheet when fully folded out. The transcription below is made by the editor.

LIGHT FANTASTIC

A light-bulb company wants to minimise packaging waste and extend the product range they offer. The company decides to develop a new range of light-bulb packaging that is not just thrown away when the bulb is taken out and used. They want the package to build into interesting lighting features & structures:

- bulbs come in different shapes and sizes,
- bulbs packaging needs to contain, protect, display,
- the assembled feature can be used to enliven the surroundings of any context you choose: a nursery, a garage, a waiting room, a party, a garden, a bike, a garment, a fish-tank,
- the cost of the packaging needs to be in realistic proportion to the cost of the bulb,
- everything needed (apart from e.g. adhesive and tools) for building the feature must be included in the packaging,
- a possible option would be to encourage buying sets of bulbs or lots of bulbs; in this case lighting feature elements might be part of a collectable set of features or parts of one feature.

At the end of the project (6 hrs) you must have at least:

- a light-bulb package that works as a package and contains everything needed for the lighting feature,
- an assembled lighting feature,
- a persuasive argument about why your product would attract the purchasers you are aiming at.
1. Put down your first thoughts and ideas here
Some sort of construction that can be taken apart and re-assembled of. (Sketch)

2. What would your first partner do if this was their own project?
Work on a principle of nets, that are flexible, so they could be moulded creatively into any shape. (Sketch: rubix cubes etc)

3. What would your second partner do if this was their own project?
(Illigible handwriting; sketch)

4. What will your design have to do and be like to be successful?
- Cheap, colourful, fit well, strong enough for purpose, display the bulb, be safe to use
- Creative, easy to assemble

TASK
Today’s task will involve: having ideas, growing ideas, proving ideas. Your task today is to come up with exciting ideas for light-bulb packaging that transforms into interesting lighting features & structures.

5. Use this space to jot down all your ideas, notes and sketches
1st dice roll notes: idea is quite safe, all box like construction
2nd dice roll notes: simple, easy to construct, solid & strong box
3rd dice roll notes: special design, heavier materials so the design doesn’t float off too far
4th dice roll notes: could be bigger, could store more than 1 bulb
6th dice roll notes: Yes & No. To function it would require light fittings to also be included.

(Each step is illustrated by sketches, measures and commentaries. The model which is crossed over is accompanied by the commentary “won’t work” and an explanation why.)

6-9 The following four photos show features and structure of the model

10. What do you think of your ideas so far?
Thumbs up: The modelling has been good for development, it makes it easier even though it’s more time consuming.
Thumbs down: Quit make an accurate hexagon so models do not fit flushly.
11. What does your first partner think of your ideas so far?
Thumbs up: *I think it’s an interesting shape, the light is kept safe and the feature component is attractive + should give a good effect.*
Thumbs down: *It’s quite small, and I don’t know if the light will be that well protected, the structure may not be strong enough.*

12. What does your second partner think of your ideas so far?
(Illegible handwriting)

13. What will you do next?
*Final measurements. Decide on materials.*

14. Stick your post-it notes here
Wackiest: *(Sketch)* Lots of dangly bits & pieces like a fountain.
Name: *My best idea is the one I have developed, the hexagonal box which has a lid that opens up into another box which acts as a shade.*
Problems: *The bulb is very tightly fitted into the box, might prove to be a safety hazard if the bulb gets too hot, may begin to melt alt. catch fire!*
Next: *Finalise idea, measurements. Decide on suitable materials.*

15-18. The following three photos show features and structure of the product

19. Partner 1 final thoughts on your ideas
*The shapes and materials are original and good. It’s very compact. I don’t really understand how the top bit works, but I’m quite stupid.*

20. Partner 2 final thoughts on your ideas
*I like the interesting shape, and the use of storage for the bulb, but also using it as a feature. It’s very compact, which adds safety. I’m not sure how effective the feature would be, but it certainly offers protection to the bulb, and is aesthetically pleasing.*
21. What are the good things about your idea?
The idea is small and compact so you could take it on holiday easily. The base is very strong and sturdy. The idea is original.

What would you change if you had the time?
The way the top unfolded, the sizes of the top net and the material used.

22. What do you need to know or find out about to take your ideas further?
How much do current light bulbs cost? How much of the price is the packaging, how much the bulb? How much would it cost for my design to be manufactured? Is there a market for the idea?
Light Fantastic

A light bulb company wants to minimise packaging waste and extend the product range they offer.

The company decides to develop a new range of light bulb packaging that is not just thrown away when the bulb is taken out and used. They want the package to build into interesting lighting features & structures.

- Bulbs come in different shapes and sizes
- Bulb packaging needs to contain protective display
- The assembled feature can be reused to enhance the surroundings of any context: a nursery, a garage, a waiting room, a party, a garden, a bike, a garage, a restaurant.
- The cost of the packaging needs to be in realistic proportion to the cost of the bulb.
- Everything needed (apart from e.g. adhesive and tools) for building the feature must be included in the packaging.
- A possible option would be to encourage buying sets of bulbs or lots of bulbs. In this case lighting feature elements might be part of a collectable set of features or parts of one feature.

At the end of the project (6 hrs) you must have at least:

- A light bulb package that works as a package and contains everything needed to the lighting feature.
- An assembled lighting feature.
- A persuasive argument about why your product would attract the purchasers of your light bulb.

School:
Name: S.J.C. Smith
Date: 27/10/03
Pupil No: 5
Group: 1
On a national and international level, technology education is considered to be part of general education. This paper highlights causes and effects, and presents the concepts that are available today for teaching technical subjects. Also discussed is a comprehensive, open approach which covers the essential invariant characteristics of technology education.

Technological change has become an increasingly dynamic and complex process. As a result, a fresh look has to be taken at technology education, which is one of the major aspects of this paper. Only if technology education adequately considers the invariants of technology as well as up-to-date standards of science and technology, can students be enabled to solve technical problems that are of immediate relevance for life.

**Technological development**

Developments in technology cannot be illustrated without taking a closer look at what is understood by technology. A distinction can be made into the following aspects:

- Technical systems (artefacts and processes)
- Technical action for the generation, use, and dissolution of technical systems
- Knowledge/awareness of the origins, use, and dissolution of technical systems.

Technology and its development are directed at satisfying needs of individuals and society. This implies that humans, with their individual needs and their needs as society, are the origin as well as the aim of technological development.

The very first beginnings of technology are closely related to the evolution of mankind. Man has taken technology from the first primitive stone tools through all its stages to today’s high level of sophistication. In view of the complexity of the issue, the question as to what has changed and what has remained the same deserves a closer analysis.

**Changes in needs**

Let us take a first look at the needs that have to be satisfied. Today, as in the past, technology is expected to satisfy the basic needs of humans, which
include lodging, clothing, food, health, etc. However, new and different needs were created as human societies developed, and these needs may by far go beyond the satisfaction of basic needs.

*Changes in technical action*

The basic principles of technical action (becoming aware of needs; defining tasks; developing ideas; manufacturing, using, and disposing of products), which aims at satisfying needs, has not changed. Technical action involves such activities as innovating, creating, designing/calculating, optimising, producing, analysing, using, experimenting, recycling (Liao 1994, 2002).

Now as before, all technical activities are always complete activities that have to cover the stages informing, planning, implementing and analysing.

Technical action is the tool by means of which humans have successively appropriated nature in the form of technical artefacts. In this way, they have always influenced and changed both nature and the society they lived in, and this has in turn acted back on humankind itself.

What has changed is the intensity of the effects of technical action. Today, humankind is in the position to effect not only long-term changes, but also changes that may reach menacing proportions. The tools humans use for their actions have changed, too, and the division of labour has reduced the extent to which individuals participate in these actions to selective sub-actions, as a consequence of which the individuals involved have to be brought together within networks.

*Changes in technical processes*

When subjecting technical processes to a closer analysis, one will find that the basic structure has again remained unchanged. Operands are transformed in sub-processes/operations from state A to state B through the action of operators. This is true irrespective of whether matter, energy and/or information is transformed. The operators may be machines and humans performing functions or tasks that have been defined for the process in question.

What has changed is the degree of involvement and the role humans play in technical processes. Mechanisation and automation has allowed humans to assign an ever increasing number of tasks to machines, leaving supervising and monitoring functions to themselves. Machines have made it possible to network technical processes that used to be separated and integrate them to highly complex units (e.g. data transfer in the world-wide web). Although closely related to all things that are technical, humans have at the same time moved away from the technical processes, sub-processes and operations as such.
The physical, chemical or biological principles of action determining technical processes have not changed. But today human beings have the ability to avail themselves of an increasing number of natural laws for closely defined purposes, as, for instance, biosensors or laser technology.

**Changes in technical artefacts**

The pace at which technical artefacts are changing is evident for everybody. This change affects the shape of artefacts, the size (miniaturization: nanotechnology), and the efficiency. For instance, cars and computers that are in common use today differ in a number of ways from earlier generations, while the basic functions are still the same. A fork or a knife have not seen any change in their basic functions, nor has the basic function of a car, which is to transport an object from A to B, experienced any change. Only new functions have been added to the list.

Changes that have taken place concern the degree of cross linking and complexity of technical artefacts. An example that can be mentioned in this context is the intelligent house. The way in which technical artefacts are produced have undergone changes, too. The use of heavy-duty materials, the quality of the products, and the automation of the manufacturing process, which allows large quantities to be produced at a constant quality, are indicators of the high level of sophistication.

**Changes in knowledge**

The half-life of technical knowledge is decreasing in the same manner as this is experienced for other disciplines. Technical know-how is exploding as intervals between inventions, discoveries and developments are becoming shorter and shorter. During the early stages of technical development, knowledge was normally generated from experience and was handed down to the next generation as empirical knowledge. This was also true for the handicraft/practical phases of the Middle Ages.

The scientification of technical methods is a relatively recent phenomenon, which employs mathematics as well as the natural sciences as methods to generate scientific insights. The process of scientification eventually produced such specific disciplines as information and communication technology, as well as biotechnology and genetic engineering, environmental technology, energy technology, material technology, aviation and space technology, traffic engineering, micro technology, laser and plasma technology, medical engineering and building engineering, which may affect the reality of life of each individual. It is worth noting at this point that there is an increasingly higher level of interconnection, both between the different technical sciences, and between the technical sciences and the natural sci-
ences and mathematics (e.g. mechatronics, biotechnology). Information technology, in addition, plays an important role as a basic technology for all technical sciences.

But also the way of how knowledge (or rather information) is passed on has undergone substantial change, as oral tradition, and later hand-written and printed documentation, was replaced until information technology became the major instrument for passing on knowledge. This technology is now providing almost global access to information, irrespective of place and time.

**Changes in responsibility**

In the course of its development, technology has allowed both people and peoples to move closer together and to overcome dimensions and distances. At the same time, mankind is now in a position to put its livelihood at risk. Even without waging war, which would certainly be tantamount to absolute destruction, we can do a lot of damage to our basis for living, merely as a result of technical action – if it takes place without being aware of, or considering, the principles of interaction.

It follows from the above that for today’s humankind it is important to understand the implications of technology. This will allow us to develop, and make use of, new technical systems in a way that reduces consequences and risks to a manageable level. Only those who understand how technology affects all walks of life, and that, by using technology, human beings act back on themselves, can translate knowledge into responsible action.

**Technology education**

*Significance of technology education*

According to Schlaffke, general education should be seen as a foundation which “is ready to support a complex building of education – with an increasing number of storeys and corridors”. General education should provide global knowledge, and the ability to think along structural, procedural, or systematic lines, but also standards of value, which are all combined to form one complete concept (Schlaffke 1997).

Education is more than knowledge, which, on the face of it, can be utilized as a key to the job market and a means of social balance. Education has to prepare for a “life in freedom and self-determination”. It has to enable individuals to cope in an “open and highly complex world offering new kinds of freedom”, without allowing themselves to be drowned in a “maze of facts and events”. Education must not remain limited to imparting knowledge and functional abilities. To allow human beings to develop their per-
sonality, education also means imparting values and social competences. On the other hand, school education must not remain separate from the realities of life. Schools have to arouse and encourage interest and inclination, no matter whether this means developing practical or theoretical talents. They have to counteract premature specialisation, offer a wide range of subjects, and thus impart a broad basic knowledge, without heeding later professional carriers (Herzog 1997).

If we endorse the conception according to which school education should enable individuals to cope in a highly complex world and to understand the significance of technology for the reality of life of individuals, as well as its significance as a cultural heritage, technology education undoubtedly has to be seen as being part of general education.

Education comprises three basic components. These are the process of imparting knowledge as an informational component, the process of learning to learn as a didactical component, and the process of arousing interest as a motivational component. Against the background of a rapidly changing technical world, the question is what technical knowledge should be imparted, what share should the informational component of technology education have.

“As technical systems are becoming more complex [...] and as we are abandoning the utopian idea of understanding technology, the didactical and motivational components of technology education are gaining significance. Today, education is, therefore, above all the ability of learning how to learn. It is not the product-, object-, or formula-based learning which gives access to understanding, but the process- and phenomena-related learning, and the ability to apply the acquired knowledge and translate it to other fields” (Pfenning 2002).

If “understanding technology” was referred to as utopian above, this primarily means the impossibility to understand technology as a complex phenomenon with all its facets. Technology education should rather aim at presenting technology within a context by relating to examples, and thus illustrate underlying structures and functions. The insights thus gained can then be raised to a meta level which offers the possibility of transferring acquired knowledge. Ideal tools for his purpose are system theoretical models (Hubka 1973, Wolffgramm 1994, Ropohl 1999, Luhmann 2002).

The intention of technology education is to develop a competence to act in every student, irrespective of any later professional carriers or any personal inclinations or preferences. This competence is seen as the disposition of the individual to successfully solve problems in a given technical situation.
Technology education should aim at enabling students to
• be part of a process in which a world undergoing technical change has to be given shape
• be capable of responsible technical action, which gives due regard to the interrelationship between humans, nature, technology and society
• cope with technical/practical requirements encountered in our daily lives and on the job
• understand the principles of technical systems
• be able to use their basic technical understanding to decide in favour of a technical profession.

Development of technology education

Developments that have taken place in technological fields have also had their effects on technology education, but other factors have also plaid their role. These include the economic and political situation, the pedagogical mainstreams, and the significance that is attached to education. Some of the main concepts of technology education, which may still be of relevance today, are outlined below (cf. Graube, Theuerkauf 2002).

Manual skills

Manual skills with their practical orientation started to be taught as a school subject in Finland, Sweden and Denmark at the end of the 19th and beginning of the 20th century. But the Vienna World Fair in 1873 and the Philadelphia Centennial Exhibition in 1876 made it quite clear that the quality standard of industrially produced consumer durables was poor, which was attributed to inadequate practical handicraft skills in handling machinery and tools.

Manual skills as a subject not only aimed at improving the skill as such, but also at supplementing the purely theoretical subjects and thus striking a balance between physical work and mental activities as one means of encouraging the full development of the student, which was one of the basic pedagogical requirements. The skills taught concentrated on traditional manufacturing methods and the systematic development of the ability to handle such materials as paper, cardboard, timber, and metal. The subject was widely introduced in many countries, including the US, Russia, Romania, France, England, Hungary, Austria, and Belgium.

Polytechnics

The polytechnical approach dates back to the first polytechnical schools in Paris in 1794, which was the time of industrial schools. Marx started from the ideas and principles of this école polytechnique to develop a concept of
education, in which brainwork, physical work, and a polytechnical education combined to form one unit. With this concept, the polytechnical part covered the general scientific principles of all production processes and also the practical use and handling of the elementary instruments needed to perform the production process. The concept implied a fundamental expansion of earlier practical handicraft approaches to arrive at a technical and economic education, which combines theoretical as well as practical elements of work.

This educational concept could not be implemented until after the first socialist countries came into being, i.e. after the fundamental changes had taken place in the 20th century in production and ownership structures. Politically, the polytechnical approach aimed at the education of socialist personalities. What its proponents had in mind was a technical and economic education that was to encourage people to take their share and responsibility in shaping society.

The curricular programme of polytechnical education concentrated on production processes and engineering sciences. A special feature of these schools was that, starting with the primary to the school leaving levels, the subjects were based on each other, that a shift took place from school as a place of learning to a more practical environment (workshops, polytechnical cabinets, industrial workshops, production departments, development departments). This was accompanied by a change from supervised practical activities to practical scientific work.

Despite its distinct political orientation, the significance of polytechnical education has to be seen in the close links between education and the technical/work environment, in the uniform technical education it offered, in the fact that it provided a defined transition to vocational training or university education, as well as in a consistently developed and coordinated concept and teaching materials.

**Work orientation**

Work orientation means to focus on the actual work environment and the interrelationship between humans, work, technology and economy. Needs are assumed to be a starting point, and work is seen as a tool that can be used to satisfy these needs. From this follows that technology is always viewed in its relationship to work and its influence on humans. The aim of this approach is to convey insights into work processes, to develop a positive attitude to work/technology, and to help prepare for an active professional life (Oberliesen 2002).

In curricular respects, the approach starts from the model of the business process and integrates the fields work/profession, home economics, tech-
nology and economy. The work orientation can be seen as a more advanced level of manual skills teaching, with its development from a handicraft to an industrial approach.

In countries, which do not know the German dual vocational training model, e.g. China and the United States, this concept is of special significance. This approach is also where the German “Arbeitslehre” would have to be located.

**General technology – systems theory**

System theoretical considerations relate to thinking in terms of systems, which is typical of humans and takes us back to the ancient world. This way of thinking means to comprehend things within global contexts. More specifically it means that all technical systems are regarded from the point of view of material, energy and information and their modifications. Originally, this approach was a fairly strict technical approach relating to the processes and artefacts involved. It has now been expanded to include socio-technical aspects.

The significance of this approach, i.e. thinking in terms of systems, has to be seen in the fact that it helps to think in terms of models and thus has a propaedeutical scientific element. It aims at conveying engineering subjects and methods and is to prepare for engineering courses at university. In the US, and also at the secondary school level (Sekundarstufe II) in the federal states of Brandenburg and North Rhine-Westphalia, this approach has, for instance, been integrated into the curriculum.¹

**Science and technology**

This approach is rooted in the natural sciences and the engineering sciences, as well as their specific methods. Solutions may be sought in either scientific or technical options. The underlying aim is to develop cognitive skills (thinking in terms of systems), to develop research and planning skills (planning of experiments and processes), and to develop practical skills (performing measurements, producing electric circuits). This approach is valid for elementary schools, as well as for junior high schools or senior high schools. In teaching the subject, scientific and technical elements are linked. This approach is actually used as part of the subject Science and Technology in the United States and in Israel. But in Germany, too, similar methods are used for illustrating phenomena in the natural sciences, with concrete technical applications.

¹ Technical aspects are linked with mathematical and scientific elements, as well as elements of a mathematical-scientific-technical nature
Design and technology

When technology education focuses on design as part of its teachings, this is because needs and desires are at the bottom of any development, and for developments to take place, there have to be inventions. For this reason, this approach is directed at developing innovative skills and creativity, or in other words, at turning students into creative inventors and problem solvers (Kimbell 2002).

The curricular programme concentrates on inventing, producing and evaluating products. Central elements are the processes of invention and design, while production is of lesser significance. This approach is implemented in England as well as Australia as part of the subject Design and Technology.

Implementing Technology Education at schools

The concepts for technology education as outlined above incorporate different kinds of technical action, which may also vary as to its emphasis. Concepts for technology education have changed along with developments that have taken place in the technical sector and along with what were seen to be educational requirements.

When considering the complexity of today’s technical systems, technical action may serve as a key that gives access to technology with its basic structures and functions, and the aspects linking it to humans, nature and society. This relationship for technical action is also found in international concepts, where reference may be made to such fields as building and accommodation, work and production, supply and disposal, information and communication, food and health, clothing, playing and learning, which relate to the students’ immediate life experience.

In dealing with the above fields of action, the attention should be directed at such guiding principles as the preservation of the environment, careful use of resources, and protection of the human dignity and the cultural heritage (Klafki 1995). Depending on the cultural, political or economic situation, in which action has to be taken, different fields of action may be attributed special importance.

As a general conclusion, technology education can be said to be integrated into school curricula in the following way:

• Primary level: phenomenon-based work
• Secondary level I: theoretical and practical work
• Secondary level II: propaedeutical scientific work
For technology teaching at what are seen to be open schools, external partners are increasingly integrated into the programme. These may be partners in industry, handicraft businesses, the service industry, or (educational) institutions, who may have the function of initiating tasks or offering room for action, or they may provide experts or equipment, as well as the necessary professional orientation. At the first level of secondary school education, suitable partners would, for instance, be the production sector of small- or medium-sized businesses or handicraft businesses, while for the advanced secondary school level this could be planning and research in industry or at universities. Positive experience with this kind of cooperation has already been made (MINT, TheoPrax, Step-In, etc.).

**Conclusion**

Interest in technical matters can be aroused when the subject is introduced in a playful manner at an early stage, and this interest can be consolidated when technology forms part of the curriculum from the primary level to the school leaving age. Technical tasks that combine theory and practice can, in addition, be motivating and have a reinforcing function, because the result of the learning process is a real and concrete result. Developments in the technological field require everybody to be permanently involved in the subject, so that the function of technology education is to prepare for lifelong learning.

**References**


Also in Germany the results of international comparisons of educational levels have lead to intense discussions. A consequence of this is the fixing of educational standards for the different school subjects. For mathematics and German as a mother-tongue first results have been achieved and the other subjects will follow. So the Technological Education in Germany has to deal with the problem, too.

The international situation of Technological Education has to be considered in this reference. On one hand it is marked by the various approaches to access of Technological Education. So in an international set you will find e.g. approaches that will be orientated towards work, different perspectives, creativity, engineering or systems. On the other hand standards for Technological Education are already existing in some countries like Canada, USA or England.

Another special criteria that has to be considered is the varying implementation of Technological Education into the subject range and into the various school grades. Therefore the standards for the Technological Education have to be developed in a way which enables us to use them for different school and subject purposes as well as for different didactical approaches.

The educational standards which have to be defined have to include the basic idea of gaining competence in a subject or in a combination of subjects and also to describe their educational mission. This should grow into a model of competence which defines subject related competencies in various levels of development on a relatively high level of abstraction. These assignments of competence will be realized by giving exemplary tasks as a basis for examination.

So, for Technological Education the following tasks have to be fulfilled:
- defining an educational mission
- creating a model of competence
- achieving exemplary tasks

---

1 Graube, Theuerkauf 2003a
2 Dugger 2003 and Hill 2003
3 according to the standards set by the Federal Minister of Education of Germany, see expertise of BMBF 2003
Educational Mission for Technology

The educational mission for the field of Technology can be derived from the general mission\(^4\) of school. School has to contribute to:

- development of an individual personality
- gaining of cultural and scientific traditions
- dealing with practical problems in every day life and in working life
- an active taking part in social life

Technology, e.g. Technological Education can play an essential role in the picture of school as a “house of learning”\(^5\) as it contributes important parts to these general tasks.

Technological Education includes either a side of cognition and action which complement each other. Cognition can be derived from action in the same way as action is based on cognitive knowledge. The act of cognition is based on the understanding of technology. This includes that technology has to be comprehended as an element of our culture and that of foreign ones and that the development of technology represents an agent of social changes, which are connected to technological action. The understanding of technology also includes the understanding of the effects and interaction between technical acting and nature, technology and also man. Moreover, this part of cognition is based on the grasping of technical systems, technical processes and technical action as well as the systematic and process-orientated way of thinking.

Technological Education, however, has got one part of action which is undoubtedly of special importance for learning. Learning in the process of action is based on technological action itself.

Technological action always links theoretical and practically active parts with affective elements so that learning in the process of technological action is always learning with all your senses. Moreover, the cognitive parts in the different stages of technological action allow the differentiating of the levels of assessment in the process of learning. Another potential can be found in the experience of complete actions which have a special importance not only for the future job.

Learning in the process of technological action is centered around the joy of creative feeling and re-invention, of creating and realizing of one’s own ideas and the joy of one’s own achievement. At the same time learning in the process of technological action includes also a potential for the deve-

\(^4\) compare: Klafki 1985 and Oberliesen 2002
\(^5\) compare Meyer-Dohm 2002
lopment of team competence, which plays a considerable role in personality development. Team work allows you to experience how everyone can contribute their own ability and creativeness in problem solving and later the appreciating of their achievement. On the other hand they experience in technological action the finality of technology and the variable solutions and ways of problem solving.

We have to note, however, that learning in the process of technological action is limited just by technological action itself. Apart from a few exceptions the stages of technological action can be completely fulfilled by the students themselves. This is true for cognitive parts as well as for psychomotorical parts of technological action.

In productive-practical fields these abilities can only be developed by the students in a limited way. This cannot and should not be the target of Technological Education. Additionally we have to take into consideration that the technical equipment of the school workshops very rarely allows a decent quality of the products to be manufactured. Thus, the production-relevant transfer of solutions is limited although its educationally defined function should not be underestimated. Because of the limits of technological action at school case studies reach a special relevance for many areas of Technological Education

Consequently, the educational mission of technology can be described as follows. Students should be enabled to:

• create and co-create a world which is changing through technology
• act technologically responsible considering the interaction between man, nature, technology and society
• cope with practical technological life tasks in everyday life and working life
• realize basic technological structures
• decide for technological professions using a basic technological understanding

These abilities can be summed up in the term competence of technological action. Competence of technological action has to be understood as the ability of solving problems successfully in certain technological situations.

**Model of Competence**

**Basis**

In the following I would like to suggest an explanation how the model of competence of Technological Education can be structured. In order to get a basis for the development of competence of technological action an operationalization in a model of competence has to be made. The most important
cognitive processes and actions in the field of technology have to be determined, to be divided into partial dimensions and to be matched with levels of competence. Figure 1 shows a general model of competence for this.

![Diagram of Competence Model]

*Figure 1: General model of competence*

Man acts in areas of personal life, working life and society. These areas are more and more penetrated by technology and they represent the technologically determined situations in which problems have to be solved. This includes the use, creation and assessment of technology always starting from a complete action.

Certain basic and cognitive processes and actions can hereby be found in all fields of action:

- Recognizing and describing of problems and needs in technologically determined situations
- Analysis of technological systems and processes in the vicinity of these problems and needs recognized
- Strategies for problem solving
- Creativity and innovative abilities for the development of solutions
- Transfer of the created technological solution
- Assessment of the created technological solutions under various aspects (e.g. economy, ecology, society)
- Appropriate use of technology
So the following part dimensions can be derived (fig. 2): Technological action, Technological systems and Relations between man, nature, technology and society.

![Figure 2: Part dimensions in Technology Education](image)

In this process man with his technological action represents the link between technological systems on the one hand and the interactions between nature, man, technology and society on the other. Technological action solves technological processes and requires the use of technological systems. At the same time technological action has effects on nature, technology, man and society. Consequently the part dimensions of technological systems, technological action and the relations to nature, man, technology and society are related to each other. Starting from one partial dimension the others can be opened. In the following these part dimensions are dealt with more closely.

**Part Dimension: Technological Action**

Technological action covers the total sum of actions in the developing process of a technical product (Fig. 3). Technological actions are the result of part actions and elements of action. For instance in the developing of ideas and solutions actions like innovating, creating, but also constructing, calculating and documenting can be found. When producing, testing and improving, students have to experiment and optimize. The dealing of the products includes the use, maintenance and repair of technological systems. All technological actions and part actions have to be based on the proceeding scheme of general action (informing, planning, executing and assessing).
Part Dimension: Technological Systems

Technological action is based on technological systems. Technological systems can be understood as systems of subjects and technological processes. This model is based on General Technology\(^6\).

In this model, the categories material, energy, and information are considered (fig.4). They describe the condition of an operand at a certain moment of time. Technological processes transform the operand from a starting state into a final state. In that case, a technological process is composed of a defined number of part processes and operations. Thereby, the operations represent the transformations of state which cannot be divided any further.

---

Effective operators are subject systems which have to fulfil certain func-
tions in the technical process, as well as man with his actions and partial
actions. The technological systems can also be divided into partial systems
with partial functions and elements with special functions that are given in
a certain structure. Here too, the elements are the structure components
which cannot be divided any further.

The importance of this model lies in the fact that on the one hand simple
as well as complex and complicated technological subject systems and pro-
cesses can be shown. On the other hand, however, it is also possible to
describe complex and complicated systems in varying stages of detail. This
means that the same technological systems can be described on an upper
level in a very simple way and at the same time on different level in a very
detailed way up to the single operations and elements.

**Part dimension: Relation between man, nature, technology and society**

Technological action is a link to the next dimension – the relations between
man, nature, technology and society, man being the center of everything
(fig. 5). With its lithosphere, hydrosphere, atmosphere and biosphere natu-
re is the vital basis for man and other creatures. Society represents man’s
way of living. This means: social relationships among each other, but also
politics, economy, culture, religion and science.

As an element of culture technology has got a special importance in this
context. Technology means the sum of user-orientated, artificial settings
(subject systems), the sum of actions and technological processes for the
creation and use of these subject systems as well as the knowledge of crea-
tion and use of these subject systems.

---

7 compare Graube/Theuerkauf 2003b, p.102
In this process, technological action has to be understood as a step by step acquisition of nature in order to satisfy social and personality needs. At the same time, by his Technological Acting and the hereby created subject systems man changes nature itself and causes an effect on his own life. Technological development also causes social changes in the same way as society has an influence on the development of technology. Consequently by his Technological Action, man changes nature, technology and society and finally himself. From this construction of relations basic goals can be derived, e.g. protection of resources and environmentally friendly action.

**Competence Model of Technological Education**

The competence model of Technological Education is based on the partial dimensions shown (fig. 6). The competence steps could be matched according to the sections of education (primary/ junior high school/ senior high school). There can also be more subdivisions or nursery school could also be included. The competence steps should be based on each other, so that connective knowledge can be guaranteed. But the single levels in the different partial divisions have to be defined and described. For this, further research is necessary which should among others include the representatives of the schools.
Figure 6: Competence model of Technology Education

In the following I suggest how such levels can be defined clearly. For the part dimension technological system the degree of absorption rises with every step, the technological system however is always considered in its entity. In the partial dimension of technological action, it has to be executed as complete action in every competence level of technological action. But the differences can be found in the degree of complexity and complicity of technological action. This is also true for the competence steps of the part dimension of interaction. Tables 1 to 3 show the competence demands which are related to each other vertically as well as horizontally.

**Table 1: Competence demands in Technological Action**

<table>
<thead>
<tr>
<th>Step</th>
<th>No</th>
<th>The student is able to …</th>
</tr>
</thead>
<tbody>
<tr>
<td>1: Primary School</td>
<td>Technolog. Systems</td>
<td>Process of Baking</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Baking device</td>
</tr>
<tr>
<td>2: Junior Highschool</td>
<td>Technolog. Action</td>
<td>to Bake a Bread</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Staple Food, Genetics,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Agriculture</td>
</tr>
<tr>
<td>3: Senior Highschool</td>
<td>Nature-Man-Technology-Society</td>
<td>Complexity and Complicity</td>
</tr>
</tbody>
</table>

1 TA 1.1 … read most simple technological documentations for technological systems from the closest areas of experience and can produce simple technological sketches
2 TA 1.2 … read simple technological documentations for technological systems from the areas of experience, can produce simple technological drawings and can communicate via technological information and communication technologies
3 TA 1.3 … read and value technological documentations for technological systems from the areas of experience

1 TA 2.1 … describe most simple familiar technological partial activities from the areas of experience in his / her own words
2 TA 2.2 … analyze and describe technological activities / partial activities from the areas of experience
3 TA 2.3 … analyze, describe and value technological activities from areas of experience

1 TA 3.1 … completely execute most simple technological activities
2 TA 3.2 … completely execute simple technological activities which are focussed on subject practical activities
3 TA 3.3 … completely execute technological activities / partial activities of medium complexity and complicity which are focussed on cognitive processes

<table>
<thead>
<tr>
<th>Step</th>
<th>No</th>
<th>The student is able to …</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td>TA 1.1 … describe in his / her own words familiar technological subject systems from close areas of experience in their basic structure and basic function</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>TA 1.2 … analyze and describe in a simplified way technological subject systems from the close area of experience in their basic function and structure</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>TA 1.3 … analyze, describe and value technological systems and their partial systems from his / her area of experience with reference to their structure, function, hierarchy</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td>TS 1.1 … describe in his / her own words in a strongly simplified way familiar technological processes from the close area of experience in their basic proceeding</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>TS 1.2 … describe and analyze in a simplified way technological processes with reference to their partial processes</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>TS 1.3 … analyze, describe and value technological processes from the area of experience with reference to their included partial processes with their operands, operators, efficient places and principles</td>
</tr>
</tbody>
</table>

**Table 2: Competence demands in the part dimension Technological Systems**

**Table 3: Competence demands in the part dimension nature, man, technology and society**
Step No The student is able to …
1 WW 1.1 … realize that man changes his environment with his technological action and that technology changes itself
2 WW 1.2 … realize, describe and value in a simple case the influence of technological action on man, nature, society or technology
3 WW 1.3 … realize, describe and value in a simple, single case the influence of technological action on the frame of reference of nature, man, technology and society
1 WW 2.1 … understand that technological action depends on environment
2 WW 2.2 … realize and describe effects and influence of environment on technology
3 WW 2.3 … realize and describe effects and influence of nature, man, technology and society on technology
1 WW 3.1 … realize that he/she changes the direct environment and is responsible for this
2 WW 3.2 … realize the responsibility of the individual and draw conclusions on own technological action
3 WW 3.3 … realize the responsibility of the individual and society and draw conclusions on own technological action

**Examples**

The competence requirements from the competence model have to be made more concrete by use of pattern tasks. This is done by various tasks and problems to be solved from the action fields Technology (building and dwelling, working and producing, informing and communicating, transport, supply and disposal, nutrition and health) (fig. 7). Concerning the inner connection of the competence requirements the tasks can be posed in a way which allows one solution but also several ones. In the following, examples for tasks from the action fields Building and Dwelling (primary section), Working and Producing (junior high school) as well as Informing and Communicating (senior high school) are described. These examples are suitable for developing the competence requirements.

The task from the action field Building and Dwelling for the primary school is highly orientated to the life reality of the students. The students have to solve the following task: what does your room look like and what is your idea of your ideal room. The task is focussed on the development of technological action as a complete action. Special attention is given to the ability of realizing and formulating own needs, to use and develop your own imagination and to transfer them in a model like way.

---

8 a subdivision into partial tasks because of the complexity of the problems seems to be appropriate
The task for the junior high school is matched with the action field Working and Producing. The students have to design and create a lamp made of metal (table 5). The solution of this complex problem requires a variety of competencies from the field of Technological Action. This can be focussed by the creative process of development of ideas as well as the transfer into a technological solution. The manufacturing of the lamp is of minor importance.

In the senior high school the task is settled in the acting field information and communication. The students have to develop a control and an adjustment for a greenhouse (table 6). This task is focussed on technological action, too. The main importance lies in the cognitive processes which are required for the solution of this task.

---

This task is also fit for learning arrangements using an Elab for the remote control of adjustment of technological models. This Elab has been developed at the TU Braunschweig by the Department for Technological Education and Information Technology.
Table 4: Competence requirements in an example for primary

<table>
<thead>
<tr>
<th>No</th>
<th>Task: What does your room look like and what is your idea of your ideal room?</th>
</tr>
</thead>
<tbody>
<tr>
<td>TS 1.1</td>
<td>Analysis of the room (size, furniture, function etc.)</td>
</tr>
<tr>
<td>TH 1.1</td>
<td>Development of size notion (original and on the paper) 3d and 2d – illustration of simple solids (e.g. furniture)</td>
</tr>
<tr>
<td>TH 2.1</td>
<td>Formulation of wishes as to furnishing. Planning of the ideal room. Illustration of the own room in drawing or models. Valuation of the result</td>
</tr>
</tbody>
</table>

Table 5: Competence demands in an example for the junior high school

<table>
<thead>
<tr>
<th>No</th>
<th>Task: Design and manufacture a lamp made of metal</th>
</tr>
</thead>
<tbody>
<tr>
<td>TH 1.2</td>
<td>Drawing of sketches and drawing of a model plan</td>
</tr>
<tr>
<td>TH 2.2</td>
<td>Analyzing of the actions and partial actions from the idea to the product</td>
</tr>
<tr>
<td>TH 3.2</td>
<td>Formulating of the task and the qualities of the lamp. Developing of ideas and solutions (material, shape, construction) Constructing of a model, improvement Making of production plans. Construction (metal work as an order, fitting as own work) Valuation</td>
</tr>
</tbody>
</table>

Table 6: Competence demands in an example for the senior high school

<table>
<thead>
<tr>
<th>No</th>
<th>Task: programming of a control and an adjustment for a model greenhouse</th>
</tr>
</thead>
<tbody>
<tr>
<td>WW 2.3</td>
<td>Analysis of the parameters that influence the growth. Determination of the technological greenhouse parameters (temperature, light, humidity)</td>
</tr>
<tr>
<td>TS 1.3</td>
<td>Technical analysis of the greenhouse (sensors, actors)</td>
</tr>
<tr>
<td>TH 3.3</td>
<td>Matching plan of the sensors and actors for the input and output modules of the PLC-Controller. Planning of the latter diagram process Programming. Testing of the latter diagram as to running qualities and correction of faults. Evaluation and possible optimization</td>
</tr>
</tbody>
</table>

Conclusion

The competence model for Technological Education which was presented here seems to be fit for the development of technological action competence on a basic level and for the achievement of general educational targets. It is related to the center of Technology and Technological Education by basing on technological systems, technological action and the relations between man, nature, technology and society. The center of all this is man with his acting in technologically determined situations.

The competence model of Technological Education shown here has common characteristics with other subjects and makes it possible to teach on a subject interacting level (mathematics, natural science, computer science, social sciences, work, economy, textile work, and domestic economy).

The sketched competence steps within the competence model represent first thoughts and have to be further specified and coordinated.
The special importance of the competence model lies in the fact that it allows a varying focus in the part dimensions, in the action fields of technology and in the stages of Technological Action. This allows different approaches of Technological Education as well as the development of specified curricula. In this sense it has to be understood as an open concept.

**Sources**


4. Novice or Expert?  
Conceptions of Competence in Metalwork

The aim of this study is to articulate implicit criteria used by teacher educators in craft and design (sloyd) and professional artisans to assess competence in metalwork. The research questions are: a) How do expert teacher educators and artisans assess portfolios in metalwork consisting of finished products, sketches, and interviews about the working procedure? b) In the view of these assessors, what distinguishes novices from experts (including professional craftspeople) with regard to how they address their tasks and succeed in them? c) To what degree do different professions (educators, artisans) agree in the assessment of what constitutes competence?

Criteria were formulated by means of a *bottom-up* procedure (inductively), in contrast to a *top-down* approach (deductively) whereby criteria are formulated on the basis of previous research and the professional discourse expressed in professional journals and other forums.¹ To arrive at criteria that correspond to the prevailing practice and opinions of experts in the field, a method called *repertory grids* was applied. The method is basically phenomenological and originates from George Kelly’s (1955) psychology of *personal constructs*, a theoretical framework for studying how human beings make sense of their experiences of the world. As regards its openness to different descriptions of reality, it resembles the methodology used to study “conceptions of the world around us” developed by Ference Marton (1981) and his co-workers. The strength of the repertory grid technique is that this openness is combined with a sensitivity to the subtleties of the interviewee’s personal constructs, that opinions are consistently anchored in authentic cases (examples) and that underlying patterns for each individual can be discerned with the aid of statistical methods.

¹ The latter method of formulating criteria has been tested in a project funded by the National Agency for Education: “Portfolio Assessment of Student Performances in the Visual Arts” (Lindström, Ulriksson & Elsner, 1999).
Theoretical background

Articulating tacit knowing

This study tries to articulate what is also known as tacit knowing (Polanyi, 1966) in a profession. Words and terms draw our attention to qualities in craft and design that we might otherwise overlook. They allow us to describe learning processes in a way that makes these qualities observable. Others may look around for themselves, examine our interpretations, and form a judgement of their own. Value judgements, including assessments as to where a person is situated on the continuum from novice to expert, thus become open to intersubjective testing; they become something that can bear and deserve discussion. Language gives the learners tools with which to reflect on and communicate about their own learning processes.

Tacit knowing is often conveyed in a “master–apprentice” relation-ship. To articulate this experience-based knowledge, we must give the language we use a foundation in “examples” or “cases”, according to Donald Schön (1983). A skilled practitioner does not primarily rely on explicit rules and principles but rather on analogies with the aid of which he “sees [a new situation] as something already present in his repertoire” (ibid., p. 172). The repertory grid is a technique for charting individuals’ constructs of phenomena in the world around them, based on a set of “examples” or elements. It has been applied in a wide range of fields, for instance in studies of the assessment of musical performances (Köllerström, 1999). In recent years it has been increasingly used in educational research (Alban-Metcalf, 1997; Cohen, Manion & Morrison, 2000). In this study the repertory grid technique was applied to investigate conceptions of competence in metalwork among teacher educators and artisans.

The focus was not only on the assessment of the products completed by student teachers in their metalwork classes; another purpose was to articulate the criteria that were used for assessing the working process. Previous research (Lindström, Ulriksson & Elsner, 1999) has shown that students can very well develop their abilities to use materials and techniques and to apply basic principles of colour, form, and composition. However, this proficiency does not imply that they have acquired a high degree of independence, a readiness to be inspired by others, or the habit of assessing their own work and setting higher-order goals for themselves. Such dispositions are vital if one is to develop one’s creative capacity outside the school context as well.

Portfolios are tools that have been developed in order to convey a rich picture of students’ performance, a picture that considers both products (final results) and processes (working habits). It is assumed that portfolios
will offer a valuable basis for the present attempt to articulate criteria of competence used in the training of craft-and-design teachers.

**A novice–expert paradigm**

There are different ways to understand learning in the aesthetic domain. In the past, aesthetic activities were primarily regarded as a spontaneous flow originating from the unique personality and subjective imagination of the creative person. Today we are aware that the creative process is shaped by conventions in a particular culture and that it takes a long period of schooling to be able to use these conventions in a flexible way, that is, in a way that corresponds to the creative person’s intentions. In every domain of knowing, one can describe a progression from “novice” (apprentice) to “expert” (master). What distinguishes an expert or master is not primarily that he or she can master more techniques, materials, facts, etc. in a purely quantitative sense. The most important characteristic of an expert is that he/she has the judgement required to determine when a particular technique or material is appropriate and can adapt its application to the immediate need. A similar characteristic is that he/she can apply knowledge and skills in new situations. This is often expressed in terms of the individual having attained qualities of knowing such as **familiarity** and **understanding**\(^2\) within a domain.

Assessment criteria govern the direction of education. In inquiries into curricula and grading, the emphasis in recent years has been on familiarity, understanding, and various higher-order qualities of knowing (e.g. creative and communicative abilities) rather than merely knowledge and skills in a quantitative sense. Attention has been paid as to how experts in different domains of knowing ask questions and solve problems. That is, focus is no longer merely on the conclusions in a field of inquiry but on the inquiry itself. This perspective is not new; in the international discussion it can be traced back to the conference at Woods Hole, Massachusetts, in 1959 and Jerome Bruner’s (1960) seminal book *The Process of Education*, in which he argues that the scientific way of thinking can also be taught to school-children, albeit in its elementary forms.

Bruner also considers the artistic way of thinking, a theme subsequently elaborated by Manuel Barkan (1962; Henry, 2002) and others who advocate that art education should introduce contents and modes of inquiry found in the art world, that is, in the art studio, in art criticism, in art history, and aesthetics. In today’s discussion about the teaching of the arts, this broader perspective on learning occupies a central position (e.g. DBAE, Discipline-
Based Art Education. See: Wilson, 1998; Smith, 2000). The perspective is sometimes referred to as the novice–expert paradigm (Koroscik, 1990). This perspective is adopted in the present study of qualities of knowing in craft and design. One consequence is that the focus is not only on competence in a school context; also explored is how this relates to high-quality work by experts within the field, that is, by those who represent elaborate thinking and advanced practice in craft and design.

Hubert and Stuart Dreyfus (1986) have described the development of competence from novice to expert in five steps. Each step shows a growing ability to adapt knowledge to the current situation, that is, to see it as a useful tool in a particular context and in specific circumstances. The beginner follows the rules he has learnt, regardless of the particular circumstances. The advanced beginner has moreover learnt through experience what usually works in practice and takes this into consideration. A competent performer has a purpose in mind and can justify his or her behaviour on the basis of that purpose. A proficient performer rapidly adapts his or her behaviour to a new situation by recalling from memory how it resembles or differs from similar situations, while an expert performs these deliberations without thinking about what he is doing. The competence has been automatised; it has become part of the individual’s familiarity or tacit knowing.

Method

Portfolios and repertory grids

In this project external experts have been engaged alongside the craft-and-design experts in teacher training. Three craftspeople, acknowledged to be highly skilled in the field of metalwork were recruited. Two of these (Metal Designer D, Silversmith E) acted as role models and were asked to document elements in the process leading from an idea to a finished product. It was a matter of preserving journal notes, sketches, and drafts and of being attentive to sources of inspiration (one’s own previous works, works by colleagues, works which are part of the cultural heritage, etc.). The two craftspeople participated in in-depth interviews, with questions intended to provide a picture of their working process and how a craftsperson evaluates his or her own work. Five trainee craft teachers (Students F–J), recruited by asking the participants in a metalwork course who would volunteer for the study, presented their portfolios in a similar way and were interviewed about the qualities of their own craft work.

Metal Designer D and Silversmith E were assigned a free design task in metal which took ten weeks or more. Students F–J were assigned the task of interpreting the concept of a chandelier; they had five weeks, three of
these weeks full-time and one week in a workshop. In comparison with the expert craftspeople engaged, the trainee metalwork teachers were regarded as novices, that is, they were solving problems in a domain which they did not yet master. The study nevertheless showed that even within the group of students there were considerable differences as to where the participants were deemed to belong on a continuum from novice to expert.

The interviews with the two craftspeople and the five students were conducted by the author, by two craft-and-design experts from the teacher training college (Educators A and B), and by a third crafts-person (Artisan C), who was engaged as an external co-assessor. These portfolio interviews lasted about an hour each and were held in a room where all the portfolios were exhibited. At the beginning of the interview a number of preset questions were asked by the author; the educators and the artisan were then allowed to include questions of their own. The three expert assessors were instructed not to confer with each other at any point during the interviews or afterwards.

In the next stage, the teacher educators and the external co-assessor were interviewed by the author, clarifying the qualities of knowing that they perceived in works of craft and design. All the portfolios were available in the interview room for closer scrutiny if necessary. The subjects’ implicit criteria of competence were explored by using the repertory grid technique, which gives a picture of the categories used by different assessors to describe similarities and differences between portfolios. The method is based on an insight formulated by Donald Schön in *Educating the Reflective Practitioner* (1987): “not only in artistic judgement but in all our ordinary judgements of the qualities of things, we recognise and describe deviations from a norm very much more clearly than we can describe the norm itself.” (pp. 23-24)

The interviews were conducted using RepGrid (Shaw & McKnight, 1992), a Macintosh program, with the interviewee placed in front of the computer screen. The program presented the portfolios three at a time, in randomly chosen combinations. The interviewee was asked to say how two of the portfolios – any two – resembled each other and differed from the third one. The similarities and differences made up two poles seen as the extremes on a continuous scale. In RepGrid the scale runs from one to nine. The interviewees were asked to click on the symbol for one portfolio at a time and move it to the point on the scale where the portfolio was believed to belong. The ratings of all the portfolios on the scale resulted in a repertory grid for each interviewee, with bipolar constructs in the rows and portfolios in the columns.
The procedure was repeated twice for the entire set of seven portfolios (two craftspeople, five students). The first time the focus was on the product, while the second time it was on the process. A total of 33 bipolar constructs were elicited in this way. In addition to the constructs generated by means of the repertory grid technique, the pairs of “novice–expert” and “bad–good” were included. The former pair was intended as an objective assessment of the individual’s performance; the latter pair was a wholly subjective judgement. This addition may be perceived as a departure from the inductive approach otherwise used. However, there need not be any absolute contradiction between assessment criteria generated in one or the other way. “There seems to be no need to be pedantic” in the choice between constructs which are “elicited” and those which are “provided”, according to Fransella and Bannister (1977, p. 19).

Immediately after the interviewee had elicited a construct and placed the portfolios on the scale between the similarity pole (X) and the contrasting pole (Y), the interviewer asked questions intended to “generalise” and “anchor” the meaning of the construct. This technique is called *laddering*, a metaphor referring to climbing up or down a few rungs in the interviewee’s meaning system, which is assumed to be hierarchically structured. Laddering can be done by asking the interviewee which pole of the pair he or she prefers and then posing the question: “Why do you prefer X to Y?” (*laddering up* to a more abstract or general level). Or one can take the opposite course and ask: “Looking at each individual portfolio, how did you know where to place it on the scale between X and Y” (*laddering down* to a more concrete or specific level).

According to Solas (1991, p. 159), a repertory grid interview lasts “until either triads or respondents have been exhausted”. The laddering technique generated fewer constructs (five to six) than conventional repertory grid interviews. In an unpublished study of competence in the domains of textiles and wood, a repertory grid interview generated up to nine bipolar constructs, besides the two supplied by the interviewer (novice–expert, bad–good). On the other hand, the laddering technique applied in the present study yielded a rich harvest of qualitative data. Each interview, both parts (product, process) included, lasted about three hours. Half of this time was devoted to laddering. This part of the interview was tape-recorded. Later on, the tapes were transcribed and analysed by three trainee craft teachers (Madeleine Mittag, Magnus Ollén, and Tomas Olsson) under the supervision of the author.
Through further analysis of the repertory grids, it is possible to reveal the degree of agreement between bipolar constructs and between elements (here: portfolios) in terms of 100% to 0% overlap. This can be done with the aid of hierarchical cluster analysis, whereby the original grid is re-arranged so that bipolar constructs as well as elements (portfolios) that show a high degree of similarity are arranged close to each other. Figure 1 shows the result of a cluster analysis, performed with the aid of RepGrid, of Artisan C’s original grid concerning product qualities. Of particular interest in this study are the eight bipolar constructs shown at the top of the grid. In the continued analysis of the repertory grid interviews (including laddering), only bipolar constructs that show 80% or more agreement with the novice-expert dimension are discussed. Other bipolar constructs are generally more descriptive and are therefore not likely to increase our understanding of how the interviewee construes the differences between a novice and an expert.

In Figure 1 the following bipolar constructs show great agreement with the novice–expert dimension: inferior craftsmanship/great craftsmanship, less successful execution of idea/successful execution of idea, bad/good, making utility goods/artistic exploration. The following bipolar constructs — as Artisan C interprets their meaning — show less agreement with the novice–expert dimension; they have therefore not been included in the continued analysis of the repertory grid interview: experiment/fixity of purpose.
se, free/strict interpretation of task, thought/no thought given to place or function. A closer scrutiny of the novice–expert cluster shows, moreover, that it can be divided into two sub-clusters (at roughly the 95% and the 85% level respectively): one concerns an objective evaluation in which expertise includes craftsmanship and the accomplishment of an idea; the other is more an expression of personal taste (the dimension bad-good), where artistic quality is valued more highly than function and utility.

**Qualitative processing of interview data**

The qualitative processing of interview data followed a phenomenological approach. The analysis started with the acquisition of an intuitive all-round view of the material, with the aim of understanding what was said from the point of view of the interviewee and searching for the crucial message behind the bipolar constructs elicited in the study. Then units of meaning, core meanings and thematic categories were extracted. These were linked into a hierarchical structure with headings and subheadings, first for each interview, finally for all interviews together, divided into “process” and “product”. The aim was to find the best approximation of the novice–expert dimension. At this stage it was possible to use the properties of the repertory grids; after cluster analysis they yielded percentages that describe how much each bipolar construct agrees with the novice–expert dimension. The higher the agreement, the more equivalent the meaning is and the more central the position will be in the overall hierarchical structure.

**The interviewees**

Below is a brief presentation of the two subject experts from the teacher training college and the professional artisan in the field of metalwork who were interviewed in order to clarify the criteria used for assessing portfolios.

**Educator A:** Male, aged 58. Teaches trainee craft teachers. Has worked as a craft teacher since 1967; ten years in comprehensive schools and 23 years at the Stockholm Institute of Education (SIE). Has completed a four-year course in cabinetmaking and has had one year’s practice working with a silversmith in order to become a craft teacher. After his teacher training, he enrolled at the University College of Arts, Crafts and Design in 1969. He spent the first two years in the silver programme and then two years in the industrial design programme. After six months in a design office, he wanted to return to school and to the challenge of working with special needs students. He is trained as a special needs teacher. In 1977 he began working at SIE, where he has worked full-time in the training of craft teachers since 1995.

**Educator B:** Male, aged 58. Teaches trainee craft teachers. Qualified
with the craft teacher training college in 1967. Before that he trained as a cabinetmaker for four years. Has worked for two years in an architect’s office designing interiors, and for one year he worked with a silversmith. Has worked for ten years as a craft teacher in comprehensive schools, at all levels. Has studied the history and theory of art, education, ethnology, and drama at the university. Trained as a special teacher. Started working at SIE in 1975, and since 1985 he has done most of his service there in the training of recreation instructors. Gives occasional lessons to trainee preschool teachers and comprehensive school teachers.

Artisan C: Male, aged 36. Silversmith. Attended a Waldorf school for twelve years. He then worked as an apprentice to a silversmith for three years and has had his own workshop since then. He has supplemented his knowing with jewel cutting and goldsmithing. He does custom orders for shops and also produces some of their stock goods, and he makes works of his own that he sells through a gallery. In the last seven or eight years he has had apprentices for varying durations of time. These are students from the University College of Arts, Crafts and Design gaining practical experience and pupils from the Crafts Association in Stockholm, which trains people for unusual craft professions.

The craft portfolios

Educator A, Educator B, and Artisan C studied craft portfolios produced by Metal Designer D, Silversmith E, and Students F–J. The two craftspeople (1 male, 1 female) and the five students (3 male, 2 female) explain below in their own words their goals and how they set about to achieve these. The process descriptions, which are extremely abbreviated in this presentation, are supplemented with photographs of the finished products.

Metal Designer D (male): “Ancient Mariner is a design job executed with public space in mind. The design study is based on a poem written by Samuel Taylor Coleridge in 1798. /.../ My wrought-iron individuals visualise a part of the poem where the ancient mariner has a vision in a delirium, when he sees the whole sea crawling with slimy creatures. /.../ A long sketching phase means that I can streamline the product before I do the first three-dimensional trials. After the sketching and experimentation in the forge I enter the third phase of the work, whereby I become a craftsperson who solves practical problems instead of an artist or designer who feels his way forward. /.../ In the course of the work I have been led down many side-tracks which were sometimes more interesting than the main track. However, I think that one should, if possible, fulfil the intention of the work, even if one’s personal development has almost always gone further, before the thing is completed.”
Silversmith E (female): “Ever since my time at the University College of Arts, Crafts and Design I have been interested in forging and ‘moving’ the material in thick silver plate. … After my year of study in Mexico I began to work with copper inlays. … For my exhibition in 1998 at Contemporary Swedish Silver I made hand-worked neck rings with inlays of gold and iron – inlays as lines, and neck rings where half of the surface was of iron and half of silver, where the two metals meet along a smooth line. During my work with these neck rings I got the idea of making a neck ring of thick silver and thick sheet iron, where the meeting of the metals has a wavy movement. The light-grey surface of the iron stands out very beautifully against the bright silver. Time and time again I work from almost the same basic form but with nuances and balances in the decoration in order to find a harmonious whole. This neck ring of silver and iron, with a ‘wavy’ meeting, is something I chose to do as my ‘portfolio work’.”
Student F (male): “The aim for me was to try the relatively new material. … The impulse that got me started was a little piece that someone had made in school and left in the coffee room. It looked roughly like one of the two butt-solders in my ’creation’. When I was finished with the first butt-solder and had cut out ’flames’, there was plenty of time left for me to work. After thinking for a while without being able to develop the first butt-solder, I decided to make a ’sibling’, that is, a similar butt-solder, but with different ’flames’. … Student I suggested that I elevate [the two units] at the same time as I put them together. This also gave me an opportunity to hard-solder bar material, which I hadn’t tried before. I look on my work as a tentative and random experiment in the new material.”

Student G (female): “’You have to make a chandelier,’ said the teacher. … I immediately thought of the prisms I found in my building’s waste room fifteen years ago. Now I had a use for them. I had wanted for a long time to have a light to hang on an existing hook in our living room. These two aspects were the starting point. I looked at chandeliers in shop windows. … I went home and did some simple sketches. The children were involved and doing sketches too. I soon left behind the appearance of the traditional chandelier in favour of cloth or paper as the material.”
Student I (male): “I interpreted the task as meaning that I could associate freely on the basis of the term ‘chandelier’ and end up in principle anywhere. … I felt time-pressured, and I limited my work by using techniques that to a large extent I already knew. I didn’t want to risk losing control of the final expression. … Things went rather sluggishly at the beginning, in the sketching, and it was rather late when I realised that sketching with cardboard and on the computer [with

Student H (male): “I am going to make a chandelier. At the same time I want to try forging. I am vaguely sketching a design that appeals to me and that I think is feasible. I envisage that I can use a chandelier in the kitchen, above our kitchen island. I have chosen to work more with the material than with sketches, I am testing my way forward to the design I want. I find it difficult to shape the metal, it doesn’t do what I want it to. I force it where I want it with rivets, which spoils the impression a bit – but what can I do? I give the candle holders a form I have tested before.

These turned out much worse, frail and crooked. The attachment is difficult, the solution I use is poor, it’s not tight and goes lopsided. I was in too much of a hurry. I have it hanging from the ceiling while waiting for the kitchen to be finished. It probably won’t be used, it’s a failure.”
image processing software] was insufficient. I wanted to start with the metal. My way of working was testing; I tried out different bits of metal, cutting off and putting on. ’Does it fit? No. Well, maybe if I bend it’ and so on. I was searching for the ’key combination’ with the right metal, the right form and distance, the right amount of air and light between, and the right *everything*, which would be in sync and give, for me, some kind of maximum or optimal expression.”

Student J (female): “… I wanted a personal interpretation. A chandelier but not a traditional one. The important elements ended up being a metal framework and light of some kind, and I wanted the metal to reflect the light. It could well be moving, an eyecatcher, maybe a mobile. In addition, I wanted to decorate it, with some kind of crystals and other things. That far into the process I had a grasp of an idea, a feeling of what I wanted to convey and how. But when I compared that with the fact that I only had a week to do it, I felt I didn’t have enough time.

… I wanted to be proud of my product. That meant that I had to start searching for another solution, I made the project smaller and what was left were the elements of the framework, light and crystals, and simpler treatment of the metal. In that way I mostly used knowledge that I already had. The object is intended to hang in a window so that the sunlight will be reflected in the crystals.”

**Results and discussion**

The combination of quantitative processing of data (hierarchical cluster analysis of repertory grids) and qualitative methods (the laddering technique and the phenomenological approach to the analysis of interview data) made it possible to answer the research questions on which the study focussed. The first two questions concerned how expert teacher educators and artisans assess craft portfolios and how they distinguish between a novice and an expert in the field of metalwork. It was found that the assessment criteria used by the interviewees may be categorised in five themes. Three of these distinguish the expert from the novice based on properties in the
working process (Table 1); the other two constitute an evaluation of the qualities of the finished product (Table 2).

**Process criteria**

<table>
<thead>
<tr>
<th>Expert</th>
<th>Novice</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Idea and design</strong></td>
<td></td>
</tr>
<tr>
<td>The expert has a goal or an idea in mind. He has a clear view of what he is going to do, what he has done, and the consequences of his actions. He controls the result by being “in the process”, that is, he is not controlled or distracted by external factors.</td>
<td>The novice enters the process fumbling. He has no clear idea of what he is looking for or how to get there; he is forced to resort to makeshift solutions in the course of the work, since the material causes problems.</td>
</tr>
<tr>
<td><strong>Realisation</strong></td>
<td></td>
</tr>
<tr>
<td>The expert has worked through the process before starting, often by doing detailed sketches. He is aware of the problems that may arise and has considered how to address these.</td>
<td>The novice embarks on the work unprepared; he is forced to search for solutions to technical and design problems whilst working with the material. He does not control the process; instead he is controlled by the material and its properties.</td>
</tr>
<tr>
<td><strong>Evaluation</strong></td>
<td></td>
</tr>
<tr>
<td>The expert is involved and close to his product. He is absorbed by the process and can describe it in words to other people. He is active, distinct, and detailed in his presentation. He takes responsibility for his work.</td>
<td>The novice describes the working process in an impersonal and detached way. He is passive and uninvolved in relation to the product. He finds it difficult to comment upon his work, to express himself.</td>
</tr>
</tbody>
</table>

Table 1. *Novice-expert matrix for metalwork: process criteria*

The process criteria are contained under three thematic headings, which coincide with the different phases of the craft process which are found in the most recent Swedish curriculum for comprehensive schools, Lpo 94 (Skolverket, 1996). The main categories that emerged from the qualitative analysis correspond to the different stages in “the craft process” as described in the current curriculum. Similar categorisations of the working process, from idea to finished product, have been presented ever since the preparatory outlines of the 1969 curriculum for comprehensive schools, Lgr 69 (Skolverket, 1969), were given. In the follow-up of Lgr 69, it was stated that pupils “have hitherto devoted themselves too much to the production, while the teacher has devoted himself to the first two steps [idea, design]” (after Borg, 2001, p. 121). In the last thirty years the planning
phase has been the subject of intense discussion among craft teachers (ibid., p. 138). It is therefore not surprising that our interviewees attach great importance to the formulation of goals, sketching, and other preparations. More remarkable is the emphasis placed on the significance of students being able to describe and evaluate their working process and the finished product. The latter ability has hitherto received less attention in the discussion of craft education.

Two observations are conspicuous. The first one concerns the way in which the interviewees describe the interaction between idea, design and realisation. The expert, they say, “has a goal or an idea in mind”. He or she “has worked through the process before starting, often by doing detailed sketches. He is aware of the problems that may arise and has considered how to address these”. As a consequence, he recognises problems as they appear and is able to solve them “in the process.” The novice, on the other hand, “has no clear idea of what he is looking for” and “embarks on the work unprepared.” Thus he or she is “forced to search for solutions to technical and design problems whilst working with the material”. Since he does not master the process, he will be “controlled by the material and its properties.”

This description of expertise in the domain of craft and design is strikingly similar to Donald Schön’s (1983) portrait of the reflective practitioner. The latter not only recognises situations and is able to reflect upon how these are similar to and different from those that he has already encountered. He has also built up a repertoire of alternatives of action, from which he can select the one that is most appropriate to the current situation. The selection is facilitated by use of the sketchpad and other aids, which will allow the practitioner to experiment with qualities and relations in manners that are not possible whilst working with the authentic materials. Furthermore, the interviewees’ expression of solving problems “in the process” aptly describes the brothers Dreyfus’ (1986) expert performer as compared to “the detached, deliberative, and sometimes agonising selection among alternatives” (p. 28), which characterises the novice.

The other observation concerns the way in which the interviewees describe the expert’s approach to evaluation. There is an obvious difference between the criteria of excellence that were generated by this study and those checklists that are often found in textbooks. The latter list those components that must be present in a product or performance, while the interviewees in this study instead tried to define a set of more general dispositions or key competences. The items on the checklist are, at best, indicators of such “habits of mind”. The process criteria, in particular, describe a culture of learning rather than specific skills. The image of the expert, drawn
by the interviewees is projected as an involved craftsperson who is able to
tell about his or her work in a distinct and detailed manner, a person who is
proud of what he or she has achieved. This image drastically differs from
the traditional one of an anonymous craftsperson whose knowing is “si-
lent” and inaccessible. In the present study, the expert craftsperson’s attitu-
de to his work instead resembles that of experts in any other profession.

Product criteria

<table>
<thead>
<tr>
<th>Expert</th>
<th>Novice</th>
</tr>
</thead>
</table>
| Craft  | The expert does not compromi-
|        | se quality. He is able to success-
|        | fully predict how the material
|        | will behave when shaped by for-
|        | ging, bending, planishing, etc. He
|        | possesses the know-how enabling
|        | him to get the desired form
|        | and expression. |
| Form   | The expert is attentive to the
|        | properties of the material and
|        | consciously chooses the mate-
|        | rial that will provide the desi-
|        | red function and expression. He
|        | also possesses the required craft
|        | skill. |
| Function | The novice allows himself to be
|         | controlled by the material. Uncer-
|         | tainly in the treatment of the ma-
|         | terial obstructs his potential to ex-
|         | press what he wants to. |
| Utility | The novice does not know which
|         | material would be the most appro-
|         | priate in terms of form. He may
|         | perhaps unconsciously mix two
|         | idioms that counteract each other.
|         | He has little feeling for how dif-
|         | ferent parts of the product interact
|         | through weight, balance, etc. |

Table 2. Novice-expert matrix for metalwork: product criteria

The product criteria can be summarised under the headings craft and form. Craft criteria such as “craftsmanship” (Educator A), “conscious treatment
of the material” (Educator B) and “good craft” (Artisan C) showed 95% or
more agreement with the placing of products along the novice-expert di-
mension. It was also clear from the interviews that it is a person’s crafts-
manship that allows a connoisseur to see whether someone is an expert or
not. Importance is also ascribed to good form, but this criterion takes se-
cond place. When asked why craftsmanship is so important, Educator B
answers that this is what conveys the artistic expression. Craftsmanship
makes it possible to achieve the form to which one aspires, in the opinion of
Educator A. Without good craftsmanship, an appealing form rarely arises,
according to the interviewees in this study.
The interviewees’ respect for the craft also emerges under the headings of idea, design and realisation in Table 1. The educators and artisan all agree that a person who lacks knowledge of the craft has little potential for monitoring “the craft process”. He does not grasp the opportunities hidden in the material; he searches, fumbling, and is controlled by the material and its properties instead of controlling the work process himself. To sum up, the craft teachers and the artisan have not fallen victim to the devaluation of practical skills that is common in the art world. They seem rather to share design theorist Peter Dormer’s (1994, p. 9) view that craft is “the crucial, the only link between intention and expression”.

The central place occupied by good craft among the assessment criteria gives the subject of craft and design (sloyd) its special character. Another feature that used to distinguish craft from other visual arts is the importance attached to the function and utility of the object. Craftspeople produced utility objects, i.e. things that can be used and that fulfil specific – not just aesthetic – functions in an envisaged or predetermined context. Functional aspects were mentioned repeatedly during the interviews, but it is worth noticing that they did not coincide with the assessment in terms of novice-expert. There may be several explanations for this; one is surely the fact that students had been given a rather free design assignment, in which evidently the utility of the product was given secondary importance.

However, the kind of assignment given as well as the hesitation to include function and utility in the definition of expertise, probably also reflect the profound change in the meanings of craft objects that has taken place during the last century. Today, we respect or even envy the craftsperson primarily for his or her ability to direct the whole of the work process as well as the design of the artefact. We admire the skilful process and the unique design, even if we do not want the craft objects for use in our everyday life (Dormer, 1990). Thus it would be unfair to apply the standards of lighting design to a lamp project in metal work.

The low priority attached to the utility of objects may also be associated with the traditions of craft as a school subject. Otto Salomon’s famous series of exercises in woodwork was aimed to get boys to make simple, practically useful objects with an increasing degree of difficulty, for instance from flower sticks and rounders bats, via nesting boxes and bootjacks, to toolboxes and cupboards. Up to and including the introduction of the 1962 curriculum for comprehensive schools, Lgr 62 (Skolöverstyrelsen, 1960), this progression was ensured by having pupils in each year make certain prescribed objects. In the mid-1960s, however, the focus shifted from the object to the process.

Kajsa Borg (2001), a researcher in craft education, indicates that this
degrading of the product in favour of the process may also have brought about certain undesired consequences. In her study of craft teachers and former pupils she found that, whereas the teachers emphasised “the craft process”, the pupils tended to remember the objects. The work was pleasurable if the pupils understood the purpose and thought that they had some use for the finished product. It is probably still important to emphasise the **utility values** (associated with the **functions** of objects) and reflect upon these in craft teaching, if pupils are to feel that the subject is meaningful. In a student degree project, a craft teacher was quoted saying that “you could just as well tinker with mopeds to achieve the goals”. Such an extreme focus on the process would probably undermine the legitimacy of the subject of craft and design and erode the support for it among the general public.

### Learning cultures

The term **learning culture** denotes the assumptions that are made and the attitudes that prevail in an environment where learning takes place. In this study I have been particularly interested in the relationship between the learning culture of school and that of working life. The first two research questions focused on those who were assessed. This group included both students training to become craft teachers and professional craftspeople. The criteria used to distinguish the expert (the master) from the novice (the beginner) were explored in this study. The third research question focused on those who made the assessments. The differences and similarities between different professions (teachers, craftspeople) in the assessment of what constitutes competence in crafts were investigated.

The main impression is that there were large, recurrent similarities in the way that teachers and the artisan assessed craft portfolios. However, a difference in the way the two groups viewed the working process also emerged. The craftsman was found to be more productoriented, while the teachers were more processoriented. For Artisan C it was important and a sign of expertise that “**one can achieve the desired result without mishaps in a short time**”. He often worked under time pressure himself. If the product was not finished in time or became too expensive, there was a risk that the customer would not be willing to pay for it. The customer then went to another crafts- person instead, who could offer a lower price or faster delivery. As a professional practitioner, the craftsman has the basic need of making a living. It is then safest to rely on what one has already mastered.

At the same time, Artisan C admits that he would be glad to devote more time to experimenting during the work process. If the aim is to acquire new experience and knowledge, he said, “**the experiments and mistakes can also be a good working process**”. For the craftsman – a person who “himself
is responsible for the idea/sketch for his products” (Ziemelis, 1984, p. 16) – it is essential to find the right balance between utilitarian production and personal development. Without utilitarian production he has no income; without personal development he risks running out of ideas or suffering burnout. The former jeopardises his income in the short term, the latter in the long term. This can also be formulated as a balance between tradition and innovation. In silversmithing, for example, there is a solid craft tradition on which to draw; on the other hand Silversmith E’s process description (cited above in condensed form) shows that a successful practitioner must constantly renew herself. This mainly takes place by means of “experiments and mistakes”.

The conflict between social utility and personal development has a long history in the school subject of craft and design as well. In the early days of craft teaching, from 1877 onwards, the main justification for the subject was from an economic point of view. It was mainly a matter of early vocational training in crafts such as carpentry, ironworking, tinsmithing, bookbinding, basket making, brush making, turning, and coachbuilding (Luhr et al., 1887). A tour of the more famous craft schools in 1882 showed that in several of them the pupil “makes things to sell for a profit, confines himself to such articles as can most easily be sold, and lets the work be governed by the demand. Sometimes the boy makes a multitude of things which are well below his level of development, while sometimes he is busy with things that are equally far above it, in which case, as they say, he ’does as much as he can’ and lets the teacher do the rest” (after Berg, 1932). “Under such conditions,” as Hjalmar Berg (ibid.) comments in retrospect, “craft must essentially lose its educational influence; the economic planning makes pedagogical planning impossible”.

Otto Salomon, who eventually made Swedish craft education well-known internationally, did not content himself with criticising this encouragement of “jacks of all crafts”. He adapted craft teaching to the child’s own potential by designing a series of exercises and suggesting a set of models ordered by increasing degree of difficulty. The standard method that he designed at Nääs Craft School (later a training college for craft teachers) was to serve as a model for the rest of the country. To borrow the pithy wording of Salomon (1882), it had the effect that “the attempts to use school as a means for the training of craftspeople gave way to the efforts to use crafts as a means to educate human beings”.

Salomon’s methodology simultaneously helped to separate learning from production. But because Salomon stuck to the principle that craft objects should have a utility value, there was still a connection to the original and more primary activities of which craftwork was once a part. The introduc-
tion in the 1960’s of “the craft process” as the core of the subject resulted in the utility value of the craft object taking a secondary place. The product did not necessarily have to be finished, either in a functional or an aesthetic sense. The aim could have been achieved anyway, as long as the students had entered a learning process. Educator A is the interviewee who most clearly expresses this view of the subject when he discusses the students’ work in terms of involvement in the “metalwork process”, “drawing the bow”, “going the whole way”.

The development of the subject of crafts is a good illustration of the decontextualisation that characterises pedagogical activities, from a sociocultural point of view (Säljö, 2000). Learning is freed from more everyday practices and becomes the very goal of the activities. There is a great difference, for example, between making utility objects for sale and making a bootjack according to Salomon’s model, as an exercise in various craft techniques such as sawing, planing, filing, and so on. The distance to the social practice from which the assignments were once taken, becomes even greater when the purpose is no longer to make a useful object but to enter a “craft process” (Borg, 2001, pp. 117 ff.).

The separation between the learning cultures of the school and of the practising craft involves both potentials and risks. One of the potentials is manifested by the increasing scope in schools for self-generated creating, experimenting, and risk taking. These are valuable abilities in a society in constant change. The same applies to the ability to design, realise, and evaluate one’s own chosen work. The risks include the possibility that the school’s learning culture distances itself too far from other social practices and learning cultures. Teaching can then be considered irrelevant, antiquated, and divorced from reality. The result can be an anachronistic “school craft” that is said to rear human beings, but is lacking a clear connection to the more developed craft cultures that exist outside school. One way to prevent a development of this kind is to do what has been tried in this study: to examine and discuss what distinguishes the expert from the novice, with a view to achieving greater clarity about what is needed to attain higher levels of competence.

**Conclusion**

Repertory grids proved to be a useful tool for making tacit knowing explicit and articulating implicit assumptions in a professional activity. However, they do not eliminate the need for detailed descriptions and more traditional forms of qualitative analysis. The method allows the interviewee to reflect on a complex reality, but it does not show what meaning interviewees ascribe to their personal constructs. This study used an interview technique which
involved “laddering up” constructs to a more general level and “laddering down” by asking the interviewee to apply them to the individual craft portfolios in the study. This method provided a wealth of information which could be processed by a phenomenological approach, which meant gradually discerning units of meaning, core meanings, personal thematic categories and more general thematic categories.

The repertory grids made it possible to distinguish between descriptive and evaluative categories. The latter showed a high agreement with the expert–novice dimension “provided” and therefore served as a foundation for the qualitative analysis. The purely descriptive categories were not explored in great detail in this study. A cluster analysis of the repertory grids illustrated how crucial a bipolar construct was in the interviewees’ hierarchy of values, i.e. how closely it agreed with the expert–novice dimension. Without repertory grids, it would have been difficult to extract, from the large quantity of information, what criteria the interviewees actually used in their evaluation of craft portfolios.

It was found that the teacher educators and the artisan in this study, evaluated craft portfolios by criteria that are very reminiscent of Donald Schön’s portrait of the reflective practitioner. This practitioner not only has a rich repertoire of alternative solutions to a problem. He or she also tends to invent a virtual world, often by using the sketchpad, where various solutions may be tested before they are applied to the actual situation of his or her practice. Thus expertise, as construed by the interviewees, is related to a particular culture of learning and practice, including a disposition to use experience, knowledge and skills in certain ways.

This general approach to problem solving, however, is not in opposition to the need for sound knowledge of the craft, as one would sometimes be inclined to think listening to advocates of the “process” versus the “craft”. On the contrary. No other trait of the craft portfolios agreed more with the interviewees’ conception of expertise than the demonstration of good craftsmanship. Sound knowledge of the craft, according to the teacher educators and the artisan, is a necessary prerequisite of a good working process. The expert, who is attentive to the properties of the material, solves problems “in the process”, in contrast to the novice, who is controlled or distracted by external factors which force him or her to makeshift solutions.

Finally, there were great similarities in the way that the teacher educators and the artisan assessed craft portfolios. However, the artisan did not allow himself as much leeway for trial and error as the educators did. The difference can be explained by the circumstances in which the two professions work. This discrepancy is important to keep in mind in debating the relationship between craft education or school at large and society. Ambi-
tions to make schoolwork more “authentic” or “real”, if carried too far, can reduce the freedom to fail and tolerance for failures that are required in order to foster thoughtful learning.

References


CURRICULUM DEVELOPMENT TODAY
5. Perspectives on Technology Education in Germany and the situation today

Educational legislation and administration in Germany are the responsibility of the different federal states. Therefore the educational landscape presents a very heterogeneous picture. This is especially true for technology education, which appears in different forms and school subjects.

This presentation intends to give a general idea of the situation, to describe different concepts of technology education and to identify current trends involving the evaluation and quality standards of technology education in Germany.

The German School System

Looking at the German educational system, foreigners are often astonished by how diverse and heterogeneous the situation is in the different states of the Federal Republic of Germany. Educational legislation and administration are primarily the responsibility of the 'Länder' ("sovereignty of culture" of the federal states). That means there are 16 different school laws in Germany and 16 ministries of education and 16 different school landscapes in all; there are some 2,000 different curricula and syllabuses (cf. Tillmann 1997, p. 587). It is not only from a foreign standpoint that this is difficult to imagine.

There are comprehensive schools in all the federal states, but they are attended by only about 9% of pupils (whereas 18% of pupils are in secondary general schools ('Hauptschule'), 21% in intermediate schools ('Realschule') and 37% in grammar schools/high schools ('Gymnasium').
Technology Education in Germany: Differences

The patchwork structure of the German educational system is reflected in the diversity of technology education. We find it in different forms of subjects under different names: 'Technik', 'Technikunterricht', 'Arbeitslehre' (work studies), 'Werkunterricht', 'Werken', 'Natur und Technik', 'Sachunterricht', 'Werken/Technik', 'Wirtschaft/Technik' etc.

Looking at the table below (Höpken 2000), a naive optimist could happily point out that technology education is part of school curricula in every federal state in Germany, but the problem lies in the fact that school technology usually does not possess the status of compulsory subject for every student at any grade level and that (with only a few exceptions) no technology lessons are found in the high schools ('Gymnasium'). Taking into account the fact that nearly 40% of all pupils attend this type of school today, this is really alarming. The 'Gymnasium', in the German tradition the locus of true 'Bildung', still ignores technology education to a great extent. Recognising and acknowledging technology predominantly as applied natural science, it misses the core of the subject matter: its human and social dimensions.

<table>
<thead>
<tr>
<th>Primary School</th>
<th>Secondary Schools</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

![Image showing the structure of the German educational system with different levels and subjects marked as compulsory, optional, or integrated.](image-url)
As far as I know, there are only three states (Nordrhein-Westfalen, Brandenburg and Sachsen-Anhalt) in which technology is a subject at the senior level of the Gymnasium. So our Gymnasium has not really opened up to technology education yet. Hopefully, international development will help to change this situation.

If we now take a closer look at what technology education in Germany is like in terms of its theoretical aspects, we can roughly say that it appears in two conceptions.

Firstly, it appears as part of a curricular complex, in which different fields of study and different subjects (like economics, technology, household management, work, industry, production etc.) are integrated. Such an integrated approach, embracing the full extension of work and production in a wide sense, is realised in the concepts of what are called ‘Arbeitslehre’ (work studies), which can be found in city-states like Berlin or Hamburg and in Brandenburg or Hessen.

Secondly, although it may be closely linked to other subjects like economic education or home economics, technology is found as a school subject on its own, called for example ‘Technik’ or ‘Technikunterricht’. This is true, for instance, for Baden-Württemberg (my home-state), Nordrhein-Westfalen, Sachsen and Schleswig-Holstein.

In the following section, I will refer to this concept as ‘genuine’ technology education, because only here do we find technology taken as a content domain, in which specific theoretical and practical competences have to be acquired.

**Didactic concept: The “Multiperspective Approach”**

– Idea, Objectives, fields of Content

One didactic model most frequently referred to is called “the multi-perspective approach” (‘mehrperspektivischer Ansatz der Technikdidaktik’).

Underlying this model is a specific understanding and definition of ‘Technik’, which is not seen solely as a set and quantity of technical products and processes (to be differentiated from objects of arts, nature and thinking/language by three criteria: artificial, useful, concrete) (cf. Ropohl 1999, p. 31). It is also viewed as comprising specific forms of human thinking and doing, such as know-how and as creative problem-solving in action, with reference to the complete life-cycle of technical products: construction, production, distribution, consumption, removal from operation/recycling.

Although technology makes use of nature, of energy and material resources, of causal effects, it – like all other spheres of human culture – cannot adequately be described with the instruments and categories of (natural) science alone.
This is so because technology transforms causal relations into goal-means relations, which are situated within a societal context and in which human desires and needs, conflicting interests, values, normative attitudes and ethical orientations are reflected. We can therefore speak of social and human dimensions of technology.

Technical literacy, according to this theoretical approach, is seen as part of general education (‘Allgemeinbildung’), which can be specified as:
– education for all citizens (egalitarian aspect)
– education related to all human capabilities (human potential aspect)
– education related to common problems of living, in the sense that they are relevant to all of us (content aspect) (cf. Klafki 1993, p. 53).

Aims and objectives

The idea of ’Technische Bildung’ (an expression which can be translated as “technical literacy” or “general technology education”), in the tradition of the German ’Bildungstheorie’ (“theory of (self-)forming”), is characterised by a specific relationship of personal and cultural components and aspects, especially the active acquisition of cultural content and – in doing this – by the forming of one’s self.

General technology education targets different basic competences:
1. The ability to know and understand technical systems and processes (seen under a multitude of aspects: structural, functional, societal, historical, ecological, economic, esthetic etc. (cognitive perspective).
2. The ability to “manage” technical systems (in a broad sense, including all forms of operations: design, production, use, management, removal from operation, recycling technical systems) (pragmatic perspective).
3. The ability to assess and evaluate the social, human and environmental impact of technical products, systems and processes (evaluative perspective).
4. The ability to orient oneself in vocational fields (pre-vocational perspective).

These are the highly interdependent perspectives that technology education should aim at. The multi-perspective approach to technical education received its name as a reflection of these perspectives.

Content

Keeping in mind the multi-perspectivity and interdependence of the aims listed above as well as the fact that technology is an important part of culture intricately interwoven with all spheres of life, it is evident that the con-
tent of technology education cannot simply be derived from the structures of engineering sciences or from theoretical concepts of general technology (for example, following the material, energy and information flow structure).

Instead, the content of technology education is oriented towards “socio-technical fields”, i.e. fields in which technology appears to be important and meaningful for life and the living conditions of people, fields in which people are challenged to act and react in relation to technical systems and developments.

These fields are usually specified as:
1) Labour and production
2) Transportation and traffic
3) Construction and the built environment
4) Supply and waste disposal
5) Information and communication

Possible extensions of this structure are discussed below.

**Current trends involving the evaluation and quality standards of technology education**

When the results of the PISA 2000 study were distributed in Germany, they caused a kind of shock amongst the German public. The cover of the German weekly *Der Spiegel* asked “Are German students stupid?”.

The PISA shock generated a level of public interest and attention to educational matters that presumably had never been experienced before.

This led to nationwide efforts to reform the German educational system. Sarcastically, this could be called a kind of ’productive misunderstanding’ because if one analyses the PISA results in a more nuanced way than the mass media usually do, it becomes clear that the outcome is not generally poor. The situation is complex and there is not simply one factor influencing results. But we can clearly state that we have severe problems in two specific fields: firstly, the states of eastern Germany and, secondly, students with an immigration background.

Whatever interpretation is given to the PISA results, one thing is certain: There is a consensus about the need for fundamental reforms, which could also help advance the case for technology education.

At present, reforms are being promoted on two different levels:
1) On the one hand, the ministries of education in the different ‘Länder’ are restructuring their curricula and syllabuses.

The following may give some idea of curriculum development and the discussion going on in my home-state of Baden-Württemberg at the moment. The ministry of education there has initiated and is organising a reform to
be officially put into action in 2004, the core of which will be educational standards and “contingent plans” (lesson pools, e.g. 12 hours for ‘Technik’/Realschule grades 7-10). Individual schools are free to arrange these hours differently according to their specific situation and requirements.

While in the existing/“old” syllabus, the aims and content of ‘Technik’/Realschule were precisely determined the “new” syllabus does not give detailed content prescriptions or methodical guidelines anymore. In general, it no longer prescribes the “inputs” of teaching but rather the “outcomes”; it defines what a student should know and what he/she should be able to do at certain levels.

This new ‘Technik’ curriculum is structured as follows: On the one hand, it is based on the didactic concept I have outlined above: the multiperspective approach. On the other, it refers to the “key qualification competence model”, which originates in vocational education concepts (such as key qualifications/competences: factual, methodical, social and personal competence).

The content is structured based on the “sociotechnical fields” listed above.

**Curriculum Reform 2004 Baden-Württemberg**

**Example:**

**Transportation and Traffic**

*Pragmatic perspective*

Example:
Students have gained experience in handling objects and models from the transportation and traffic sector.

*Cognitive Perspective*

Examples:
- Students know the functional principles of combustion engines.
- Students know the importance of mobility (in our society) and its ecological effects.

*Evaluative Perspective*

Example:
Students are able to assess the effects and impacts; that arise from the fabrication, use and dismantling of motor vehicles.

*Perspective of pre-vocational orientation*

Example:
Students have gained experience in vocations in the field of Transportation and Traffic and are thus able to pre-estimate their own vocational interests and preferences. (cf. Kultusministerium 2003)

2) On the other hand, there are extensive reforms being advanced on the national level (e.g. development of national educational standards, intro-
duction of new institutions like a national evaluation agency to monitor national education standards etc.

The Federal Ministry of Education and Research and the Standing Conference of the Ministers of Education and Cultural Affairs of the ‘Länder’ in the Federal Republic of Germany (Kultusministerkonferenz (KMK)) have decided to push forward reforms, especially in developing and evaluating national educational standards.

The VDI (Verein Deutscher Ingenieure e.V. – Association of German Engineers), Europe’s largest body for technological concerns, has long supported technology education and in 2003 convened a board of some 15 people, who have been commissioned to develop German national standards for technological literacy. As a member of this group, I will try to describe some basic ideas and concepts of our project. It is important to understand that the work has just started and that there are no detailed results at hand yet.

**Educational standards, educational goals, learning targets – some fundamental considerations**

Looking at the standards discussion, one could ask: “What’s so new about it?” Education is and always has been intentional. Educational processes and actions are always goal-oriented.

For the purpose of teaching and education, a broad bandwidth of different goals, aims, objectives, targets is necessary.

First of all, we need educational goals of superior status and general prevalence. In the German tradition, these are called ‘Bildungsziele’ (such as self-determination, responsibility, emancipation, independence).

Goals of this general type can serve as guidelines. They are needed to make possible the specification of more concrete and precise objectives. They are formulated in somewhat open and vague terms. Because of this, they do not allow the monitoring and evaluation of goal attainment. Reality feedback in the form of behaviour observation and operational assessment is not possible on this basis. Without any output control, however, these goals do not really seem to influence what is actually going on in the classroom.

At this point, the importance of educational standards can be identified, in terms of determinations and formulations – what kind of domain-specific competences students should have acquired at certain levels of their school career.

Competences, as understood here, are educational aims of a middle hierarchical level which, on the one hand, are precise and concrete enough to allow output control and, on the other hand, are open enough to be compa-
tible with different pedagogical and didactic concepts and approaches as well as administrative parameters, institutional conditions and local situations.

Competence descriptions contain two components: For illustration I will take one of the benchmark topics from the US – Standards for Technological Literacy “Students should learn [activity component] that materials have many different properties [content component]” (standard 2; benchmark topic J, Standards for Technological Literacy (ITEA 2000).

Therefore, to establish reliable content-based grounds for designing competence formulations, one first needs clear ideas of the nature of the subject itself, of its core concepts, principles and facts, and of its contributions to general educational goals.

Secondly, a competence model is required that allows for the description of the activity component of the competences in a way that can be monitored.

The structure of the Baden-Württemberg standard model surely seems to be quite useful. But it refers to a “key qualification competence model”, which leads to problems: It is difficult or even impossible to give precise operational definitions for social, personal and partly methodical competences. Examples taken from the Baden-Württemberg technology standards include: Personal competence: “Being able to reflect gender-specific role expectations”; social competence: “Being able to take over responsibility in a group”. Even if one succeeded in creating an operational definition for those aims, it would be very difficult, if not impossible, to reach general consensus about it.

Psychological research has taught us that the learning process starts within domains (as specific content fields). Consequently, the German Institute for International Pedagogical Research (DIPF) explicitly rejects the “key qualification competence model” and supports a domain-specific approach instead. In their opinion, competences can only be built up in specific fields of content and experience (DIPF 2003, p. 112), which are represented by the domains.

**Development of National Standards for Technology Education – The current state**

The commission has discussed, identified and described the tasks and aims of technology education and its contribution to general educational goals.

At the moment, the work of the members of the VDI commission is structured along a simple matrix combining content components with activity components.

I have added two fields to the usual classification of “sociotechnical fields”. They are printed in italics.
1. I am convinced, that general education should not just focus on specific technical and sociotechnical systems and processes, but also include the whole horizon of technology with its anthropological, societal and cultural implications in its perspective.

Important topics and questions (What does the term “technology” mean? What are the fundamental dimensions (natural, social, human) of technology? Are there general characteristics of the historical development of technology?) are easily ignored if one simply focuses on specific technical fields. However I want to emphasise that this does not at all mean that learners confront topics of higher abstraction levels without an opportunity for technical acting, for learning-by-doing, for hands-on experiments and problem-oriented learning.

So adding general aspects to the structure does not predetermine the methods the individual school or teacher must use but serves as a classificatory frame for this field of content, as a list of requirements, so that curriculum development devotes attention to this important aspect.

2. If we aim at technological literacy for all citizens, not only and not specifically for future professional technicians, we should take into account that technology predominantly appears to all of us in everyday-life contexts, in situations that people are regularly confronted with, everywhere and in relatively homogeneous ways.

For this reason, the field “everyday life and leisure” was added. The technology used in households, for entertainment, for sports and leisure-time activities should be included in our view as well.

Outlook

Much more work will be needed in this matter. The basic structure for competences will have to be filled in with competence descriptions in the different fields. Different competence levels will have to be elaborated. Learning outcomes will have to be defined.
Realising there is a great difference between what has been accomplished and what work remains to be done, we must acknowledge our limitations. This is true especially in relation to the American standards project, which is resourced with personnel and finances far beyond what we have at our disposal in Germany at the moment.

**Some concluding reflections**

Educational standards in my view surely can not work miracles.

They can be helpful in improving teaching only if their function is not restricted to output control alone, and if they help to find and establish a broad consensus on self-concept and fundamental ideas of technology education on a national and international scale.

This is presumably even more important for technology education than for other school subjects because it seems to be highly endangered by misinterpretation and misunderstanding (for instance, being understood as applied natural science or as manual work).

Therefore the development of standards for technological literacy could also have important strategic and propagandist functions for advancing our case.

Furthermore, we have to pay attention to the fact that “subject matter standards” cannot claim to embrace the pedagogical field in total. They are necessarily focused on a small fragment of the total spectrum of educational goals to aim for, goals in which successful socialisation, enculturation and personalisation are manifest.

**References**


6. Updating Technology in the Comprehensive Schools of Ukraine

Technology is included as a subject in the National Curriculum of the Comprehensive Schools of Ukraine. The area consists mainly of the educational subjects of Craft, Design & Technology and Technical Drawing.

In order to promote public progress, there is an urgent need to reconsider traditional approaches to the teaching of technology in comprehensive schools and to update its content and general orientation. It is important that such a reform should not be reduced to hasty, insignificant, superficial changes, and it would not be wise to simply copy the experience of others (which has already occurred in some spheres of educational activity).

The changing content of how pupils are prepared for the working world needs to be acknowledged. However, it is important to avoid mistakes because one can already see attempts to replace the material-based work of pupils with information technology. Nevertheless, it is necessary to remember that such enthusiasm will result in replacing the real world of productive activity for 10-15 year-olds with the virtual one. This will naturally distort the representation of the working world.

The current system of labour training was established in the last century. It is difficult to deny the fact that it was affected by the processes that occurred in that society. The majority of scholars who have studied this period agree that school education was guided by the need for construction in an industrial society where the demand for industrial manufacturing trades was unlimited. In Ukraine, there was a sharp increase in the 1920-30s in the demand for qualified workers. Machine operators, mechanics, joiners, seamstresses etc. were needed, and pupils in comprehensive schools were prepared for such occupations. Therefore, the content of labour training in 5th-9th class was traditionally linked to the material sphere of manufacturing. This also was true in the 1950-80s, when there was significant demand in the national economy for industrial manufacturing trades.

However, it is crucial to remember that, relative to this, the maintenance of household needs was almost ignored. That is why the services sector was always undeveloped. It was also generally believed that every individual should acquire such abilities on his or her own, like the skill of building a house, constructing or repairing, sewing, gathering, cooking or storing products. One must also remember how much time women spent in the prepa-
ration of meals and household tasks, while also working at these enterprises, in fields or in factories. Currently the service sector continues to expand across the world, affecting the industrial balance, freeing up time for rest or hobbies. In highly developed countries, material manufacturing will account for no more than 20% of the working population in the near future. The rest will be found in personal services, information, management and other kinds of service activities. In this situation, the question arises: Why is it necessary to teach labour skills which will barely be used by the majority of pupils once they have left school?

These circumstances lead one to consider the content and conformity, as well as the name, of what is called service work. The realities of life attest that the service sphere is not simply reduced to sewing or cookery.

It must be remembered that, because of recent financial difficulties in Ukraine, school educational workshops could hardly replenish educational equipment, tools and materials. There is thus no appropriate material base for conducting traditional labour training in Ukraine. It would be unrealistic to hope that during the coming decades school workshops will be filled with new machinery and other necessary equipment. One sometimes hears it said that people have prevented the modernisation of study material for labour training. Yet why is it not realised that nothing is eternal? Neither the natural and physical processes of ageing nor the process of wear and tear is reversible.

At those schools where the material base of labour training was poor (especially in distant regions and villages), the lessons simply familiarised pupils with an activity that had nothing to do with basic training. The function of such lessons for the pupils’ development became doubtful. If the director of an educational institution did not pay attention to this problem, the teacher had to conduct lessons in some other way. However, if under such circumstances the headmaster of the school did not include labour training lessons in the general educational plan, the teacher immediately tried to bring attention to the fact that there was an infringement. This could not last for long, however, because nobody should have to deceive both themselves and society, in addition to undermining their dignity and adversely affecting children’s minds. Most likely, such circumstances caused labour training to be considered a second-rate school subject. However, labour training is a general educational subject on par with all the others.

It is important to acknowledge one more circumstance here. The opposition between what is traditionally incorporated in the normal content of labour training at school and what pupils see around them arose a long time ago. In labour training lessons, pupils are forced to saw, hew and plane, but where is that used in manufacturing nowadays? Even in the most traditional
factories there are lathes with digitally managed programmes, automated production lines, machinery centres, robots, progressive technologies and many other advanced technological devices. The same situation is also relevant in household activities. Modern tools, materials and technologies are becoming accessible in domestic situations, but they are still unavailable in schools. Therefore one can see that the level of technical preparation of pupils outside school is surpassing what is proposed for them in educational workshops.

There is also a moral aspect to this problem. There is no point in making pupils change their minds about the social importance of mechanics, joiners and other trades, when the material basis on which teachers try to acquaint them with the content of these trades generates disgust rather than interest.

One more fact speaks against the benefit of traditional labour training. The complicated demographic situation suggests yet another problem: the small number of pupils. It has become quite common to teach 15-20 pupils in one class. The small number of pupils in a class does not give an opportunity to separate the sexes for the purpose of labour training. In this situation, keeping the traditional content of labour training seems senseless. Thus the need to update this sphere of education is obvious.

What solution is there to the problem outlined? Clearly, it will be necessary to create an essentially new techno-cultural educational subject for the 5th-9th grades in the comprehensive school. This subject is required to ensure that pupils have an opportunity to gain knowledge about how the environment is transformed and teach them to apply the knowledge they receive whilst studying other general educational subjects. Therefore, the new subject should focus on representations and knowledge of the transforming activity of a human being, which penetrates every area of the modern condition: everyday life, recreation, studies, the industrial sphere and management. Technology, thus conceived, defines a place for the individual in nature and society and provides a framework for understanding his or her intervention in the natural processes. The central place in knowledge about such transforming activity should be occupied by engineering as a generally cultured paradigm, which provides a unity of material and spiritual culture as well as an interaction of all aspects of culture (labour, law, ethics, art etc.).
Proceeding from this, the new content should ensure the formation of:

1) representations of a variety of activities, of their consequences for an individual, culture, nature and society, of the evolution of the technological environment;

2) skills to estimate the condition of the technological environment, to be able to orient oneself in it, to understand the need to prevent negative consequences of technological activities for the individual, nature and society;

3) knowledge of engineering as a result of integrated cognitive and transforming interaction between humankind and nature. The result should be an understanding of technology as a means of knowing and influencing vital aspects of the human environment;

4) knowledge about general scientific laws applied in technical objects and processes around us. Such knowledge should help students to understand the structure of a technical object or the opportunities of process, to explain the principle of its actions and to offer opportunities for improvement;

5) skills to predict and to project processes, objects and means of transforming activity, according to the given conditions of their functioning;

6) skills to plan individual technical activity, to adhere to norms and rules of technical culture and work culture.

The knowledge outlined above will become the foundation for a polytechnical orientation and formation of the labour capability of pupils. This will be necessary for mastering the elected profile of labour training in the upper secondary schools. The updated content of labour training will provide the formation of a technical culture and a work culture that are necessary for each person in his or her daily life and educational and labour activity.

The new orientation of labour training should overcome the now widespread technological way of thinking. The spontaneous character of technical development should be changed so that the priority becomes ecological and humanitarian. First of all, it will concern those who develop and introduce new technical means of transforming activity.

The given reasons have found their embodiment and realisation in the Project of State Standards of Basic and Complete Secondary Education. As it became clear from the results of a public discussion of the standards project, the scientific-pedagogical public of Ukraine completely approved of the approaches offered for updating the content of labour training ideas in the comprehensive school.

The main purpose of the educational branch called “technology” consists in technical formation: making people technologically and computer
competent; preparing them for life, active labour, human values and transforming activity under the conditions of a modern, highly technological and informed society; inculcating the requisite knowledge, skills and abilities for maintaining home facilities and a family economy; providing basic components of pupils’ informational culture and thus maintaining conditions for their professional self-determination; promoting skills of creative activity, education of a work culture, and realisation of pre-professional and professional training according to the pupils’ desires and individual opportunities.

Through the content of this educational sphere of "technology", the following are provided:

- formation in pupils of a technical outlook and an appropriate educational level, fixing in practice the knowledge and skills of transforming activity based on the laws of nature, society, manufacturing and human development;
- pupils’ acquaintance with the place and role of information and communication technologies in modern manufacturing, science and daily life, and preparation for the rational use of computers in solving various tasks connected to information processing, such as searching, ordering, storing, submission and transmission;
- pupils’ acquaintance and familiarisation with different kinds of subject-transforming activities, formation of requisite knowledge and skills, and the teaching of ways to manipulate with different tools;
- creation of conditions for the pupils’ professional self-determination, preparing them for the choice of a profession by taking into account individual abilities and interests;
- formation in pupils of the work culture, skills for maintaining their home economy, a culture of life, responsibility for the results of their own activity, complex personal qualities necessary for humans as the subject of modern manufacturing and the cultural development of society;
- education for an active position, professional adaptation, readiness for continuous professional education, competitive struggle in the marketplace, preparedness for the system of new economic relations and enterprise activity;
- creation of conditions for the realisation of what is called a personal-focused approach to the training, education and development of the individual as a whole.

The given functions should be made concrete by keeping in mind the pupils’ age and development, the content and availability of educational material and its connections with other educational branches.

The structure of basic knowledge, skills and abilities should focus on:
1) an individual in the technical environment;
2) the technological activity of an individual;
3) the social and professional orientation of an individual in the job market;
4) the graphic culture of the individual;
5) the individual’s information activity (elements of informology, bases of technological information, basic algorithms and programming);
6) projecting activity of the individual in the sphere of material culture.

Every study programme is very important for the realisation of technological content at the junior and senior school. They are based on a principle of progression from infant to elementary and secondary schools to higher educational establishments.

The basis of realisation of all these items for the content of labour training is project-technological and information activity, which integrates all kinds of an individual’s modern activity: from the emergence of a creative idea to the realisation of a finished product. The project-technological approach will allow variation in the content of labour training, i.e. to avoid the strict regulation of the content of education activities. The new educational subject will enable its content in technology to be displayed not only as a means of practical transformation of nature, society and public relations, but also as a way of forming the world of human culture. That will make possible the presentation of technology as a purposefully organised process of transforming natural objects into the material culture of the society.

The issues mentioned above are complex. Hopefully, they will spark broad scientific discussions and new directions in research. This in turn will ensure that the essentially updated educational area of Technology has an opportunity to confidently occupy an appropriate place in the general structure of the National Curriculum of the Comprehensive Schools of Ukraine.
Towards a Philosophy of Technology Education Based on Heidegger and Dewey

Since I first began, some 30 years ago, to work with education in compulsory schools, technology as a school subject has undergone a change in character. To some extent, this change may be regarded as a reflection of the technological advances in our society as a whole: whereas technology during the 1960s and 1970s was more or less identical to factory practice, in the 1980s it became a kind of applied natural science, and as such a compulsory subject. However, it was only with the current curriculum, Lpo 94, that the subject was given a course of study of its own. But the difficulties still remain concerning the identity, content and method of the subject. Reports from the field also show that in the schools today, one teaches technology only to a limited extent (see CETIS enkätundersökning 1998/1999, Skolinspektörernas halvårsrapport 2001: grundskolan 2002). A personal conviction has gradually emerged of the need to situate the elaboration of technology as a school subject within a theoretical and philosophical framework, which also takes into account the guidelines that are provided by the curriculum. When a new subject is introduced, a process is initiated, whose direction must be marked out so as to supply teachers with the tools they need in order to develop the subject in question. Merely providing them with a course of study and concrete examples is not enough; to this must be added systematic reflection on technology, to which teachers can look for support in their own pedagogical practice.

In other words, there is a definite need for a philosophy of education, which can assume the task of articulating a theoretical framework for education in technology; otherwise this education runs the risk of remaining purely empirical and practical, and thereby of lacking a solid foundation as far as its content, method and purpose are concerned. This article is intended as a contribution to such a philosophy of education. Apart from the above-mentioned questions concerning the identity, method and purpose of technology as a school subject, the aim is to formulate certain basic concepts, which could work as cornerstones in technology education and in this way give teachers a hint as to what is central in their practice.

According to John Williams (Williams 1994), philosophy should form the starting-point for every kind of technology education, and it will determine both the content of the subject and the way in which this content is
communicated. For this reason, he argues that a philosophy of education might be derived from both a philosophy of technology and a philosophy concerning educational issues. This has also been my starting-point. In this article, I will elaborate on some ideas related to technology education via a discussion of Martin Heidegger and John Dewey, with the former contributing a philosophy of technology to which the latter adds a philosophy of teaching and learning. These thinkers are treated with a view to framing a notion of education in technology as “technology re-presentation”, as I have chosen to call it.

The overall aim of technology re-presentation is to help pupils to have a kind of visualisation or representation of artefacts and systems of artefacts in order to understand them. Technology re-presentation is a process that generates knowledge, and in this process, theory and practice are interwoven. It is reminiscent of the modelling or designing operation employed by the engineer, the industrial designer, and above all the architect. Unlike them, however, the pupils will not invent or develop technical products but instead, with the help of models and simulations, seek to understand the genesis and function of technology, as well as its effects on humans, nature and our society. As we shall see, this means that even though technology re-presentation takes its point of departure from the classical, ancient view of technology as creation and production, it does not remain at this level of intelligibility, but eventually proceeds to analysing this view on the basis of a broader, social perspective. In this connection, the idea is that there are many ways in which to interpret and describe the “technical” phenomena of our environment. In the end, the aim of technology re-presentation is to make our reality or world comprehensible, such as is described by Heidegger and Dewey.

In this paper, I will explain the different aspects of and stages involved in technology re-presentation by addressing in turn the questions of purpose, method and content in connection with technology education.

1. Why? The purpose of technology education

Let us begin by noting how the overall purpose of technology as a school subject is stated in the curriculum for technology:

… the education in the subject of technology develops a familiarity with the essence of technology. The aim is to enhance our understanding of how conditions of production, the society, the physical environment, and therewith also the conditions of life are changed. (Kurssplanen i teknik, p. 1)
Another aim is “to make everyday technology as comprehensible and conspicuous as possible”, another “that everyone in education is granted the opportunity of a focused and comprehensive pursuit of knowledge” (ibid.). From these quotations, two basic aims may be discerned: to make pupils familiar with the way in which technology itself works, i.e. its machines, systems, processes, etc., and to give them the opportunity to reflect on technology on the basis of a broader perspective, in which technology is no longer regarded as something exclusively technical, so to speak, but as a social phenomenon, which has bearings upon the human condition as a whole.

Both of these aspects have been dealt with by Heidegger, who has probably discussed the question of the essence of technology in a more penetrating fashion than anyone else. His thoughts on technology are not only helpful with regard to the rather difficult question of what technology really is supposed to be about, but they also contain some ideas which are worth considering in connection with the question of what kind of knowledge or ability education in technology should have as its goal. For apart from presenting different views of technology, Heidegger has tried to show why it is necessary to look beyond that one-sidedly technical outlook on the world which in his view governs public consciousness today, for the benefit of critical reflection on the presuppositions and social role of technology.

Dewey might also be said to encompass these two perspectives in his philosophy of education insofar as he thinks that, apart from the obvious, more narrow educational goal of making pupils familiar with different specialised disciplines such as geography, mathematics, etc., the schools must also – and indeed above all – regard their pupils as citizens to be educated for democratic and civic purposes. In *Democracy and Education* (1959a), Dewey argues that teaching and learning make up the primary instruments of socialisation available to society, as they are the processes through which our culture is reconstructed from one generation to the next:

Society exists through a process of transmission quite as much as biological life. This transmission occurs by means of communication of habits of doing, thinking, and feeling from the older to the younger. Without this communication of ideals, hopes, expectations, standards, opinions, from those members of society who are passing out of the group life to those who are coming into it, social life could not survive.

(Dewey 1959a, pp. 3-4)

Education should thus not be regarded as an isolated occurrence but as a social phenomenon, as an integral part of society. As is clear from the quotation above, Dewey emphasises the transmission of basic values and opi-
nions between the members of the society as an important feature of social life. When our school system is also regarded from such a social perspective, this process of transmission becomes an important starting-point for education. That is to say, life itself becomes the primary object of teaching.

With this brief survey of the purposes of education, we have also received some indications regarding the content of technology education, namely that it should not be restricted to providing pupils with distinctively technical knowledge, but also make them capable of reflecting on technology as a social and public phenomenon. Before penetrating deeper into the question of content, however, I will discuss the question of method, such as this has been dealt with by Dewey. This arrangement might perhaps seem a bit odd, but as the question of method to Dewey by and large is a question of the proper beginning or starting-point in teaching, it seems to me best to take up the question of method already at the outset.

2. How? Educational methods

It should perhaps be pointed out already at the start that, in his discussion of method, Dewey does not give us any definite model which should be followed step by step. In his view, this is on the contrary detrimental to the teaching process, for it leads to stereotypical routines, which do not leave any room for that element of creativity which is a necessary prerequisite for all genuine teaching and learning. Teachers have a tendency to cling to methods as if they were settled once and for all, partly because of the way they have been brought up in their turn, and also because of the belief that methods will generate quick and correct results. It would be better, however, if flexibility and personal initiative were to govern the teaching process. Still, Dewey emphasises the importance of making an effort as a teacher to generate good habits of thinking and writes that thinking is “the method of an educative experience” or “the method of thought”, as he calls it on one occasion (op. cit. p. 192). In order to improve the methods for teaching, we have to take into account what benefits and challenges thought, what can set thought in motion by encouraging it (op. cit. pp. 179ff). This view of method has to do with Dewey’s conviction that in order for genuine learning to come about, the school must let its pupils take active part in formulating and solving problems, instead of treating them as passive recipients of a sum of knowledge already acquired. For by his account, the very process or the “how” of learning is just as important as its content. Hence, by “method”, Dewey means “a statement of the way the subject matter of an experience develops most effectively and fruitfully” (op. cit. p. 211). The purpose of method is to bring forth the most productive or insightful experience possible by making possible what Dewey calls “reflective thin-
king”, which will be treated below. In this way, a method also includes the subject matter of education, not only the way in which this is taught.

Now, how might teachers bring about the productive insight identified above by means of their methods? That is to say, how can our educational system help its pupils to become responsible and reflective agents, instead of passive receivers? A claim made by Dewey at the beginning of the last century was that the world of children and youths is becoming more and more invisible and that it is the task of the school to make it visible anew. This claim is even more to the point now, considering the almost incredible technological advances witnessed in the last century, which have resulted in a great sum of acquired knowledge. A consequence of this sudden increase in obtained knowledge is that today, the amount of information is too large to be grasped by a single individual. Dewey, who made his diagnosis in the first half of the last century, was already aware at that time of the enormous amount of knowledge which almost overpowers pupils at school, and which is not connected to the pupils’ own experiences or abilities. The danger of this predicament is that pupils at school are confronted with an alien world, which is distinct from their own, the one they are personally acquainted with. As a consequence, the task of the pupils becomes that of learning for school purposes, that is, for the sake of tests, recitations and degrees, which Dewey calls the “constituent parts” of this world (op. cit. p. 220). One thus runs the risk of reducing knowledge to a sum of facts or truths established by others, instead of something that every pupil partakes in forming. Dewey wants to reorganise education in such a way as to be based on experience and creative with it – in order to make an otherwise foreign and distant world comprehensible to pupils.

In *Democracy and Education*, Dewey tries to show that the goal of teaching must be to let children learn about the world such as it is experienced by us. Both theory and practice are components in that process. The aim of learning is not merely to attain the right answers to stated problems but to grant to pupils the possibility of understanding and using their experiences. This becomes possible when the pupils are allowed to develop their power of reflective thinking, with which they can scrutinise their experiences. Through reflection, experiences undergone in the past may be generalised and used in new situations.

In every experience, interest is the driving force; the subject matter of education must awaken curiosity and dedication:

I believe that interests are the signs and symptoms of growing power. I believe that they represent dawning capacities. Accordingly the constant and careful observation of interests is of the utmost importance
for the educator. I believe that these interests are to be observed as showing the state of development which the child has reached.

(Dewey 1959b, p. 29)

True learning presupposes that pupils are able to actively respond to education as participants, instead of merely being observers of facts. They must feel that schoolwork, including its consequences, is relevant to their own reality or life. For this reason, Dewey thinks that in order to awaken interest in pupils, the problems and questions raised by the learning material must be tied to the children’s actual capacities and concrete situations. For different settings will generate different experiences, and it is the responsibility of the educator not only to be attentive to the fact that the environment generally is of importance in this connection, but also concretely to recognise what kind of environment will let the pupils make progress. This is related to Dewey’s idea that knowledge cannot be communicated except in an indirect way, by means of an influence on the surroundings. The task of the teacher is therefore to bring about the possibility of learning precisely by communicating a beneficial milieu, but the knowledge as such has to be brought about by the pupil him- or herself, through active participation (Dewey 1959a, pp. 14ff).

An obvious aspect of the environment or the surroundings is interaction with other people. What is crucial here is the relation between the social environment and the individual, in such a way that their interplay affects the pupil’s thinking, at the same time as the pupil in turn affects the situation or environment he or she is in. In this way, the very process of living together is educative. Or, as Dewey puts it, “. . . all communication (and hence all genuine social life) is educative. To be a recipient of communication is to have an enlarged and changed experience” (op. cit. p. 6).

The idea that the educational process must take into account the situation and background of the pupils may also be motivated by reference to Heidegger and his conception of understanding as a process essentially determined by its situation; thus, if one neglects the situation of the person who is to be educated, one does in fact neglect the very basis of learning and understanding. Obviously, with this perspective, the concept of spatiality, or rather the notion of the specifically human way of occupying space, takes on a new meaning; it can no longer be understood in scientific, mathematical terms as some kind of coordinate system. Against this “quantitative” notion of space, we thus have to introduce a “qualitative” notion, as Heidegger has argued by means of his discussion of the “location” (Ort) of human thinking and action in the essay “Building Dwelling Thinking” (Heidegger 1977a, esp. pp. 333-334). This idea means that the spatiality of man
consists in the fact that he necessarily relates to his environment by way of understanding it, so that the things he encounters always concern him in one way or other. Being in a place as a human means being in a concrete situation, where certain circumstances and presuppositions are given which govern our understanding and our way of relating to the environment. In Heidegger’s view, it is our comportment towards the things which surround us that leads to the institution of a place and thereby also of space. When we relate to things, we are subjected to certain limitations as far as our understanding and our actions are concerned, since what can be done with some things and in some situations is impossible in other circumstances. This does not mean, however, that limitation is something negative, something that obstructs our thoughts and actions. On the contrary, it makes these activities possible by granting them a definite direction (op. cit. p. 332).

But the situation or locality that is to be acknowledged in education not only concerns the pupils’ understanding and their presuppositions. As Heidegger has shown, the situation also belongs to the thing itself, so to speak, that is, to the technical machines and tools encountered by pupils in learning technology. This is to say that we cannot understand what a thing is, nor consequently the nature of technical devices either, if we regard it as an isolated object. The thing in fact upholds an entire world, in that it points beyond itself, towards a context or a life world, where it has its place and function. Thus, when engaged in engineering or production of different kinds, the pupil partakes in the institution of his or her situation and thereby in the creation of the world or society we live in as well.

As these reflections show, technology constitutes a rich and multifaceted landscape of learning. It is against the background of this landscape that the pupils may become familiar with technical, economic and social questions. On the basis of Heidegger and Dewey, it is possible to claim that technology education should take place in interaction with the world both in school and outside it. In order to make clear the change from classroom to society, the concept of place is introduced as indicative of the arena of learning. “Place” is a concrete word for our environment or surroundings. According to customary language, actions and events “take place”. One cannot imagine an event without reference to a locality. Place is obviously an integral part of our existence. Belonging to a place means having an existential footing in a concrete sense. In this way, the concept of place such as it will be used in connection with the notion of technology representation preserves some aspects of Heidegger’s idea of the “locality” of human understanding. However, it also takes into account Dewey’s conviction that learning has to begin with pupils’ concrete experiences and background situation. The place is the pupil’s environment, home, school, other
people, infrastructure, social organisations, culture, politics, leisure, and systems in our society. The place with its technical milieu, consisting of systems and artefacts, is the existential footing for the pupil, his or her means of navigating in reality. Place becomes both the content and object of technology as a school subject. If pupils are to understand the processes that form the genesis, development and use of technology in our society, they must be able to relate to this place, namely by realising, among other things, that technology cannot be identified with individual artefacts, but must be regarded as parts of a complex system. Jane Summerton (1998) claims that all technical systems are essentially socio-technical, that is, consisting of both technical and social (political, economic, organisational, cultural) components that are interwoven in a complex interplay. For this reason, different kinds of knowledge and artefacts should be combined in education without any consideration for supposedly strict boundaries between subjects.

When place is given a central role in school, the learning process becomes similar to that of fitting together pieces of a puzzle; and as more and more pieces are made to fit in, the pupil understands in a more sophisticated way larger and larger parts of that complex puzzle which is given to us in the form of the technical landscape. For this reason, technology representation begins in such a way that a problem is developed that stimulates thinking – an assignment. The pupils are to come to grips with a defined assignment or fulfil a certain need; it may concern improvements of existing systems or products, innovations, the creation of original ideas, or simply the development of some kind of technology or other. In connection with education, it is common to use the word “problem”. I prefer “assignment” since problems are connected with difficulties and troubles. Problem solving may also give rise to the idea that there is only one solution. By contrast, an assignment is a formulation that indicates one way or one direction of action, which allows different kinds of solutions.

This notion is in line with Dewey’s idea that the initial phase of education begins when the pupil has a “genuine situation of experience” (op. cit. p. 192). This situation must be such that the pupil is interested in it for its own sake, out of which a problem can emerge that stimulates the pupil’s thinking. The art of teaching consists very much in raising problems which are difficult enough to challenge thought, without, however, the pupil losing his or her own point of departure, what he or she is familiar with (op. cit. p. 184). Traditional education often begins with facts and truths that are outside the pupils’ own sphere of experience. That is why the pupils often find it difficult to incorporate these facts into their own world of experience.

I believe that we violate the child’s nature and render difficult the best
ethical results, by introducing the child too abruptly to a number of special studies, of reading, writing, geography, etc., out of relation to this social life. I believe, therefore, that the true center of correlation on the school subjects is not science, nor literature, nor geography, but the child’s own social activities. (Dewey 1897/1959, p. 25)

Thus, the process of technology re-presentation takes its point of departure from the world of the pupils, their environment and background. And as was already stated, this is the reason why the concept of place is accorded a central role in education, both in the sense of the pupil’s concrete situation, such as was explained above, as well as in the narrower sense of technical systems and artefacts as objects of studies.

3. What? The content of education
If the first stage of technology re-presentation, that of formulating an assignment, is intimately connected to the question of method, the next stage, which consists of analysis, brings us closer to the question of content. When an assignment has been chosen, the task of the pupils is to analyse existing technical systems so as to make clear the presuppositions for fulfilling the assignment. In this connection, we come across the question of the very meaning of “technology” and “technical”. As noted at the outset, the notion of technology re-presentation begins with the Greek concept of technology, based on the assumption that the ancient idea of what is characteristic of technical comportment to a great extent is still valid. For this reason, it may give us a hint as to what should be included in that part of teaching that concerns specifically technical knowledge. Aristotle, who is the first to have carefully elaborated on the concept of technology, techne, thinks that this is a form of knowing or skill that governs poiesis, production or making. Techne is marked by its insight into how a given end may be attained. The end is always something that is to be made or produced, e.g. a house, and so technical knowing consists in grasping the means with which the end in question can be realised (Aristotle 1966, Book IV, Ch. 4). This description of technical skills in terms of means and ends represents what one could call an “instrumental” view of technology. With its focus on the relation between means and ends, it gives us an insight into the basic structure and essential components of the technical process, which no doubt is decisive for an understanding of how technology works. However, this perspective obviously does not convey anything about the social role of technology or its effects on man and nature. But before turning to that issue, it is important to be clear about what it really means to understand technology such as it was described above, that is, what the object of inquiry should be when
technology is communicated by teacher to pupils. On this point Dewey may be of help, primarily in virtue of his notion of “reflective thinking”.

As Dewey sees it, the educational process centres on *experience*, which may be divided into primary and secondary experiences, where the former are supposed to be our sense perceptions, i.e. our relatively immediate sensual experience of reality. These experiences do not really involve any knowledge in themselves, although they make up the point of departure for secondary experiences by providing them with material or objects. For whereas the former are confined to an understanding that things are or function in a certain way, e.g. that a house is used for living, the latter involve an insight into *how* or *why* this is the case, e.g. how a house must be designed in order to function (Dewey 1959a, pp. 169-170). Thus, the secondary experiences are marked by their reflective character, where the purpose of reflection is to organise and explain the primary experiences. In this way, they let us understand our sense perceptions at a higher, reflected and conceptualised level.

Experience involves both a passive and an active element, which are combined. The active part consists in doing something, trying and testing, whereas the passive part concerns our being subjected to or undergoing the consequences of the active phase. The value of experience depends upon the connection between these two phases:

When an activity is continued into the undergoing of consequences, when the change made by action is reflected back into a change made in us, the mere flux is loaded with significance. We learn something. (op. cit. p. 163)

Hence, learning cannot be understood purely in terms of experiments, but it is only when the passive phase is added, when we are exposed to the consequences of an experiment, that a genuine experience comes about. The value of experience is to be found in the knowledge of connections and relations it leads to, that is, when it lets us see not only that something happens as a result of something else, but also why it happens. Dewey calls this activity of deliberately trying to understand the connection between actions and their results “reflection” or “reflective thinking” (op. cit. pp. 169ff). This is one of the most central ideas in Dewey’s philosophy of education.

As stated above, this aspect of education, and more precisely of education as technology re-presentation, could be called the phase of “analysis”, which is directed towards an understanding of existing technical systems and artefacts in order finally to be able to cope with the problem or to take on the assignment from which one originally set out. This becomes possible once the pupils understand why different systems and artefacts work
as they do, why they have some effects on the environment but not others, etc. Dewey sees this second phase of learning as being concerned with seeking knowledge and making observations in order to be able to handle and solve problems. One has to have material in order to think effectively. More specifically, Dewey writes that effective thinking requires access to other experiences, which can constitute a resource for coping with the problem one is facing (op. cit. p. 184). And as the line of reasoning above indicates, the principal aim of the analysis is to understand the relation between cause and effect, or between one’s actions and their consequences, with regard to whatever technical system or device one is analysing at the moment. In this way, one is able to survey the different effects the system has, e.g. on its immediate surroundings as well as on our environment in a broader sense. In this connection, the teacher obviously has an important role as a supervisor in the pursuit and treatment of data originating from different sources with different kinds of means.

But insofar as learning is not static but a changeable process, it cannot consist in analysing existing material alone; we also have to acknowledge a creative phase as well. This insight made Dewey define education as a “constant reorganizing or reconstructing of experience” (op. cit. p. 89). This process is in principle without end. It is not possible to become fully educated since learning as reconstruction of experience does not belong exclusively to education in a narrow sense, but makes up an essential part of life itself. This was of course implied already in connection with the introduction of Dewey’s social perspective on education. In simple terms, one could say that he wants educational pedagogy to follow life’s own way of learning, and thus to preserve the kind of experience situation that is already present there, instead of forcing an artificial way of learning upon pupils. For this reason, learning should not be regarded as merely a means to an external, future end; it is an end in itself. Or, as Dewey himself puts it: “the object and reward of learning is continued capacity for growth” (op. cit. p. 117). Education is thus not really a preparation for the future but rather concerned with something already going on.

All thinking in this sense takes its departure from something that is en route to something and which has not yet been finished. This means that thinking always concerns something unsettled and problematic. The goal of thinking is then to attain a – hypothetical – conclusion by setting out from something already known. Dewey writes:

… thoughts just as thoughts are incomplete. At best they are tentative; they are suggestions, indications. They are standpoints and methods for dealing with situations of experience. Till they are applied in these situations they lack full point and reality. Only application tests
Developing knowledge is actively seeking clarity on the basis of the discovery that there is something one does not understand. The world we live in is not static but changeable, that is why the individual has to learn how to deal with future situations and to be able to solve hitherto unknown problems. Against this background, presenting a subject matter as some kind of finished totality, which is common in schools today, reduces thinking to some kind of registering activity, but thinking in the true sense is pondering the signification of events for what is about to happen but has not yet occurred (op. cit. pp. 171-172).

Thus, according to Dewey, the third phase of education is an uncertain phase. Drawing conclusions means making a leap from what is known to something unknown. Here, innovation and creativity must be added. The information one already has certainly gives implications as to what the connection between a certain kind of problem and its solution looks like, but in order for pupils to be able to solve the particular problem they are facing, they have to move beyond experiences undergone in the past. This leap into the new and unknown is thus the truly creative element in thinking, since it requires inventiveness (op. cit. pp. 186-187). Pupils thus test their ideas by using them practically. Given the opportunity to test and apply their newly gained experiences, the pupils discover the value of these experiences by themselves. One may compare this to the inventor who, by using accepted knowledge in new ways or in a new context, creates new artefacts. This phase, which thus follows upon the phase of analysis, is called here “visualisation or construction”.

So far, technology re-presentation has been presented as beginning with the formulation of an assignment, proceeding then to analysis, which by means of the reflective thinking advocated by Dewey enables pupils to discern the relation between actions and their consequences that is contained in all kinds of technical operation and production. The phase of analysis was then said to be followed by a creative stage, the visualisation or construction, in which past experiences are used in order to envisage new solutions to a stated problem or assignment. However, as has been noted several times now, it is important that the pupils are given the opportunity throughout the process of technology re-presentation to situate their own constructing or visualising activity within a social and cultural context. The pupils must thus be given time and opportunity to take a break, leave work, to reflect and ask questions. Reflection may also be performed in writing or through different kinds of discussion, and it does not necessarily have to
conclude the design process but can be allowed to interrupt it at every stage, for example in connection with the analysis.

Dewey’s notion of reflective thinking is also helpful in this connection, since one way to investigate the consequences, for instance, of different kinds of technical systems is to spell out their social impact. But as regards this question, that is, of what is involved in reflecting upon the effects of technology on man and his society, we may also get some help from Heidegger and his discussion of the essence of technology.

One of Heidegger’s most basic ideas in this regard is that the essence of technology is not itself of a technological nature, and thus cannot be explained by reference to the handcraft or apparatuses used by technology. This means that technical knowledge in the strict sense does not involve any understanding of the nature of technology, for that pertains to philosophical reflection alone. Another consequence of this view is that Heidegger is critical of the instrumental view of technology, according to which technology can be seen as a human device, the aim of which is to fulfil human needs. In his view, this perspective is far too one-sided (Heidegger 1977a, pp. 287-289). As Heidegger sees it, an understanding of the essence of technology can be reached only when we come to see what kind of world-view modern technology not only conveys but also is based upon. In this way, the question concerning the essence of technology is really a question concerning the nature and presuppositions of human understanding, based on the assumption that the now prevailing view of technology as applied science is untenable. In Heidegger’s view, it is actually the other way round, for the attitude towards the environment that makes technology possible is also the basis of the advances of natural science (op. cit. pp. 302-305). To Heidegger, “technology” is in the end simply a name of the world-view of modern man. With this change in meaning, he not only adds another perspective, in addition to the instrumental or “interdisciplinary” view of technology, but he also argues why such a perspective is absolutely necessary. And this is why Heidegger’s ideas are relevant to questions related to technology education; in his view, learning technology is in fact – whether we know it or not – an introduction to the basic conditions of human life!

In order to apply this broader perspective on modern technology we must, or so at least Heidegger claims, go back to the ancient concept of technology, in order to see what kind of notion of reality it implies, a task that he takes on in the essay “The question concerning technology”. In accordance with the above-mentioned change in perspective, it is not technical manipulation as such that is central in Heidegger’s discussion of techne. Instead, he focuses on the element of understanding inherent in techne, and in particular on its anticipation of the goal of production. The goal that the techni-
cally skilled person has to grasp in advance does not consist in a product pure and simple, but it is rather the look or form (Gr. *eidos*) of the product that has to be given in advance in order for the process of production to get going. This form, which to the Greeks is eternal and unchangeable, and which therefore strictly speaking is outside the sphere of human will and action, is in other words what is responsible for the nature and the special features of the produced object.

This description shows, Heidegger argues, that what is essential in *techne* and *poiesis* is not really production as such but rather its element of understanding, or as he also calls it, its “uncovering” (*Entbergen*) of the look of the finished object (op. cit. pp. 293-294). One could also say that technical production is no longer seen so much as an instance of creation but rather as a way of making something *present*. In the technical process, an object is made present by being produced, since this means that the reality of the object changes from being merely thought to being furnished with concrete physical shape, and what makes this transition possible is something that in a way was already present, i.e. already existed, namely the uncreated appearance of the object, for this was given at the outset as a starting-point. As far as I can see, this is, for Heidegger, the reason why one should say that the thing is brought to presence rather than created, for in this way, one captures the fact that in a way it already existed before it was actually created, namely, as an idea or form. Heidegger may thus draw the preliminary conclusion that the essence of technology consists in a kind of happening of truth (Gr. *aletheuein*), whereby something is revealed or made accessible to man:

*Techne* is a mode of *aletheuein*. It reveals whatever does not bring itself forth and does not yet lie here before us, whatever can look and turn out now one way and now another. … Thus what is decisive in *techne* does not lie at all in making or manipulating nor in the using of means, but rather in the revealing mentioned before. It is as revealing, and not as manufacturing, that techne is a bringing-forth. (op. cit., p. 295)

But, Heidegger remarks, when it comes to the task of understanding modern technology, the ancient concept of *techne* is not enough, although it provides us with an initial and necessary step. The reason is that the ancient world-view, and more precisely its understanding of presence, differs significantly from ours. What is characteristic of modern technology is that it is based upon an experience of the world as a kind of “standing reserve” or resource, something that exists for the benefit of man (and in this way is
constantly present to him), so that he is free to exploit it for his purposes and in accordance with his needs. This is different from experiencing the world with respect to its appearance, which was the basic trait of the ancient perspective, for that requires the world or nature to be experienced at a certain “distance” and in this way to be essentially distinct from man, based on the idea that the forms of things are eternal and thus not created by man. But this kind of distance is lost when nature is regarded as a standing reserve, for this implies that it is no longer really understood as an essentially autonomous reality, albeit given to man to examine in different ways, but rather as a resource which does not have any independent existence, irrespective of human needs. One could say that in the ancient perspective there is a greater respect for the uniqueness of nature and its being outside human control which has been lost in modern times.

Instead of – like techne – investigating a nature independent of human manipulation with regard to its appearance, modern technology challenges (herausfordert) nature, that is, forces it to give in to the demands of technical manipulation, without inquiring into what nature is really like (op. cit. p. 296). Modern technology is not concerned with this, having no interest in what nature might be like in itself, apart from its usability and exploitability. In this way, Heidegger wants to get at the fact that the technical comportment is marked by its “framing” of nature with a view to making it correspond to the technical demands of exploitability.

With this diagnosis of the essence of technology, Heidegger has, as we have seen, also tried to highlight the necessity of a critical reflection on technology. In this way, he leads us to consider the proper relation to technology and the proper way to think about it. As Heidegger sees it, it is just as meaningless to naively welcome the development of modern technology as it is to discard it as something horrible, for both of these attitudes presuppose the instrumental view of technology. This view is predominant today, but in Heidegger’s view it is nonetheless faulty. For challenging nature as a standing reserve, which is thus a presupposition for the manipulation and treatment that are characteristic of modern technology, is not within human control. That is to say, technology is actually not in the service of man as a means, given to him to use or to dispense with. On the contrary, it is more correct to say that we are a means for technology: the prevalent technical world-view makes use of or controls us, for if technology is to function successfully we must understand ourselves and our world in a way that sustains it. That is to say, technology “challenges” us to look not only upon nature but also upon ourselves as resources to be used for determinate purposes (op. cit. pp. 305ff).

Hence, we have to accept that we live within a technological outlook on
the world, through which we experience everything as a means to human ends. This is the modern version of aletheuein, that is, our way of revealing or understanding the nature of reality, which constitutes the necessary background to each and every kind of human activity. What we can and must do is reflect precisely upon this predicament. The danger of modern technology is above all that it threatens to reduce our perspectives on the world, so that in the end, the variety of perspectives that after all exists is ultimately outdone by the distinctively technical view. And as has already been implied, technology also brings with it a faulty self-interpretation on the part of man: it tempts us to believe, as Protagoras once said, that we are the measure of everything, that we are the masters of the world and ourselves, whereas we in fact are slaves to the powers of technology. But there is a truth worth considering which is embedded in what seems to be a rather dark predicament: that technology makes use of us in order to rule. For it implies that our essence is to be that “place” where reality is received and given meaning. Even if we cannot govern the current world-view, there would not be any such thing at all without our cooperation, since reality, including technology, has to be interpreted and concretised in order to have meaning and to affect us (op. cit. pp. 313-315).

It is thus of the utmost importance to understand the relation between man and technology, and for this purpose, a new kind of thinking is needed, which does not naively hold itself within the confines of the technical worldview, but is capable of reflecting upon the essence of technology. In his essay “Science and reflection”, Heidegger characterises technical and scientific thought in general in terms of “cultivation” (Bildung). With this terminological choice, he aims to get at the productive or “cultivating” character of technology, that it sets out from an ideal (Vor-bild), a given goal that is to be realised. In the end, this ideal is the technological paradigm which scientific thought does not call into question, since – on the contrary – it is a presupposition for scientific progress and the production of results and new hypotheses. This kind of thinking thus excludes critical questioning, precisely by determining in advance where it will end (Heidegger 1977b, pp. 180-181).

Of course, this outlook of the world is not without its merits, but it has to be completed by a critical mode of thinking, which is capable of reflecting on the place of man in the modern technological era, and which can show that man is now experiencing nature as stock etc. Heidegger calls this thinking “reflection” (Besinnung). Reflection is not productive; it does not set out from some “image” of anything that is to be realised, but it takes a step back, so to speak, as it reflects upon something already given. As a result, reflection has the form of self-understanding: it is about seeing what one
already was (the slave of technology and thereby also the interpreter of reality), rather than bringing forth something new. Since Heidegger thinks that we cannot control the essence of technology, he often describes the attempt to understand it as a kind of preparation or waiting. We cannot just decide to analyse technology and then perform this task. For what it means to be human in the epoch of technology does not have a single, definite answer, since it is historically changeable (what the comparison of the ancient and the modern world-view has already implied). Thus, our understanding is still on the way to a grasp of technology. For this reason, reflection is ambiguous: it cannot posit and work from determinate goals and ideas, but directs itself towards an uncertain future:

Through reflection so understood we actually arrive at the place where, without having experienced it and without having seen penetratingly into it, we have long been sojourning. In reflection we gain access to a place from out of which there first opens the space traversed at any given time by all our doing and leaving undone. (op. cit. p. 180)

Heidegger may thus be of assistance in the attempt to understand what technology is and what it could mean to reflect upon it as a phenomenon characteristic of our culture. In virtue of his discussion of the interrelation of two basic perspectives on technology, he gives us a proposal as to what could be contained in technology as a school subject. Even though Heidegger has not referred to education in his discussion, there is something fruitful from an educational perspective in his thinking, since a central goal there is that pupils should precisely develop their power of critically scrutinising facts and relations and realising consequences of different alternatives. By helping pupils to surveys and analyses in this way, the school can make them capable of orienting themselves in the complex reality of today, with its fast pace of change.

As I see it, the philosophy of Heidegger and Dewey clearly supports the idea that education in technology should be directed towards understanding and reflection. It is not about training pupils to become technicians but making them able to understand and evaluate technology, to reach an insight into the tradition and development of our technical culture, to assess the consequences of the impact of technology on man and his environment. One could perhaps say that it is education about technology instead of in technology. On the basis of Heidegger, the difference between the two perspectives becomes particularly clear: it is one thing to educate pupils in a technical handicraft, another to give them the power to reflect on the role and function of technology in our society. For pupils, the latter involves parta-
king in the formation of knowledge and attitudes in order to be able to live a rich, active and responsible life. In this way, they become individuals with an ability to appreciate and critically scrutinise whatever kind of technology they may happen to encounter.

It is stated in the curriculum that the aim and task of compulsory schools is that they “should prepare [pupils] for everyday and social life, give civic all-round education and a basis for further studies” (Lpo 94). As far as the subject of technology is concerned, this means, as I see it, that one should provide pupils with such technical general knowledge that can educate them to become individuals capable of a free and reflective partaking in our democratic society.

As was already mentioned, Heidegger is critical of the notion of education as Bildung or cultivation, since he associates this with the idea of an ideal (Bild), according to which man cultivates himself, in this way adhering to something that has been settled in advance. As shown earlier, he contrasts this kind of knowing with reflection (Besinnung):

Reflection is of a different essence from the making conscious and the knowing that belong to science; it is of a different essence also from intellectual cultivation. …Cultivating the intellect requires a guiding image rendered secure in advance, as well as a standing-ground fortified on all sides. The putting forward of a common ideal culture and the rule of that ideal presuppose a situation and bearing of man that is not in question and that is secured in every direction. (Heidegger 1977b, p. 180)

As far as I can see, Heidegger’s point is that we should not look for universal, absolutely valid knowledge available to everyone, for the nature of critical reflection varies with experience, context and time. What is crucial is understanding the actual and concrete phenomena in the ordinary world we live in. Now Heidegger emphasises that reflection is not a cultivating or productive way of thinking. However, one could use his notion of reflection in order to develop a concept of education as intellectual cultivation, which takes into account that sense of creation and formation that is embedded in the verb “cultivate”. Such a concept of cultivation captures the notion of education as a process in which the pupils precisely create or form a world-view through a constant reshaping of their experiences. Dewey writes about the importance of taking the point of departure from the child’s experiences in this process:
An ounce of experience is better than a ton of theory simply because it is only in experience that any theory has vital and verifiable significance. An experience, a very humble experience, is capable of generating and carrying any amount of theory (or intellectual content), but a theory apart from an experience cannot be definitely grasped even as theory. (Dewey 1959a, p. 169)

By consequently working with the method of cultivating experience, pupils develop their capacity for working with problem solving, that is, identifying, interpreting and solving authentic problems individually as well as in groups. But what parts of the complex technical landscape pupils will come to know and understand in a more sophisticated way will vary according to experience and context. The experiences developed by the pupils will broaden their understanding of the technical reality they live in.

In this way, it is thus possible to combine the classical perspective on technology, which gives us insight into the structure of technology, its different systems, artefacts etc., with a reflection on the presuppositions and social role of technology. The notion of technology education as technology re-presentation is intended to capture this kind of multifaceted thinking. As implied by the discussion above, the re-presentation process is thought to consist of four stages: formulation of the assignment, analysis, visualisation or construction, evaluation and reflection. The method, with its different stages, is intended to make teaching easier and to given certain directives to the teacher, but it is the personality of the teacher, his or her own way of dealing with situations, that together with the pupils will determine the precise method and content of education. Thus, the teaching process varies with teacher, the pupils and the society that constitutes the environment of education. And in this process, the pupils are required to have an attitude of “intellectual thoroughness”, as Dewey calls it (op. cit. p. 210), that is, an ambition to learn, an eye for the possibilities of the situation and a responsibility for their activities. Here one can clearly see a change from a situation in which the teacher transmits already finished material, to that of active participation on his or her part. Dewey writes that in such activity, the teacher is a pupil and the pupil is a teacher at one and the same time (op. cit. p. 188).

One could summarise the phases involved in technology re-presentation as follows:

In the first stage, that of formulating the assignment, one sets out from the place, that is, the pupils’ reality, where past experiences and interests constitute the point of departure for the choice of artefact or technical system, for instance, one which has to do with living in a house.
Every assignment requires a penetrating *analysis* of the development, function and constitution of the product or the system, together with an analysis of the advantages and disadvantages as regards its effects on nature, society and the life conditions of the individual. The analysis often involves a comprehensive work of research, which perhaps is the heaviest and most time-consuming part of an assignment. At this stage, the pupils are thus trying to acquire knowledge about the current technical system, e.g. the history of the house, different systems in the house, the construction of the house etc. Moreover, they could also seek knowledge directly tied to the designing process, e.g. a sketch or drawing or a model.

The third phase is *visualisation* or *construction* of understanding, communication with the help of sketches, descriptions, models and simulations, which convey the pupils’ understanding. This phase involves, from the teacher, an organisation of activities that gradually will develop the pupils’ understanding and, from the pupils, working on their understanding and showing that they have acquired it. Below, I give a list of examples of tools which pupils may use in order to create as well as to display their understanding of the technology being used at the moment:

**Sketch:** helps pupils to specify the problem; it can also form a kind of preliminary material used in discussions about problem solving.

**Modelling:** the model is a very useful device in the re-presentation process. It “materialises” thought; it is about thinking in action. A simple model made of paper is easier to understand than any advanced two-dimensional illustration, and it immediately reveals what does not work in practice. Being able to build models quickly and with simple means is, in other words, a useful method for considerations regarding our three-dimensional reality. As such, it has a definite pedagogical value. Building models requires some knowledge of material, construction and tools (Rosell, 1990).

**Simulation:** the last decade has witnessed increased use of the computer for the purpose of working in so-called micro-worlds. Users can work in an imaginary world and perform their actions as simulations.

**Technical principles:** these should function in several technical constructions. Some of the technical principles are scientific laws and rules, others are mathematical, still others are mechanisms, structures, automatic etc. David Layton (1993) compares the laws and rules of natural science with tools in a factory’s stock. The objects are well ordered and structured, although intended for practical purposes and uses outside the environment in which they were originally created. One should use them as instruments in order to attain certain desirable ends, which are outside the subject field to which they belong. The central aim is thus to find in this kind of “stock of knowledge” what is usable and valuable in connection with the task at hand. The choice of technical principles depends upon what kind problem the
pupil is supposed to solve, and it is important that the teacher is familiar with the kind of thinking on technology that Heidegger has introduced and realises that education in technology does not have as its goal to educate technicians but to give the pupil certain insights into the nature of technology from a broader perspective. Technical principles may thus be used in the creation of models in order to attain desirable effects, but also as a means to understand the technology of our environment.

Documentation: documentation also belongs to the work of problem solving and has several functions: it gives us opportunity to develop our thinking in different ways and to practice our powers of expression, both linguistically and pictorially.

Both during and after the work, pupils are given an opportunity for reflection and evaluation. In order for the process of teaching to move forward, it is important that the pupils’ thoughts in connection with the re-presentation process are made visible in different ways. Technology re-presentation is characterised by the use of real images in connection with the creation of models. Such images could be the technology they find at home or in their neighbourhood, or in pictures, movies, books, etc. It could also be sketches and models made by schoolmates. By observing models made by others, the pupils may discover new connections between different ideas of construction and acquire an enhanced understanding of how their own construction could be developed. But the aim of reflection in the form of analysis is not only to develop one’s own shaping technique; it is just as much to understand the technology of our society. Thus, reflection could be performed before, during and after the re-presentation process. Finally, the experiences from the completed assignment are preserved for the sake of future assignments.

Understanding takes time to develop and requires the opportunity to perform a variety of different acts of understanding. By continuously working with technology re-presentation, pupil may well develop an understanding of the technology that surrounds us.
When the place is situated within the context of technology re-presentation as a whole, a model could look like this:

![Diagram of technology re-presentation model]

**References**


Technology re-presentation

Designing houses – a practical example

One example from Grade 6, Högalid School in Stockholm, shows how a change in the environment that is of interest to students is used as a task. A new skyscraper, was to be built and would have an impact on the school’s surroundings. The press was full of relevant articles, describing among other things, the appearance and construction of the new skyscraper. Below is a description of the different stages of the project:

Formulation of assignment

The task is designed with the help of students concerning a question (assignment): design your own vision of a new skyscraper.

Analysis

We started with a visit to study the construction, function and shortcomings of the buildings that is currently there. Students also watched a movie showing the history of buildings construction. The movie was supplemented with a tour of Stockholm’s buildings led by staff from the Swedish Museum of Architecture.
Ideas, sketches
The groups began drawing different proposals for solutions before eventually choosing the most suitable solution.

Construction - visualization
The models were constructed according to earlier sketches. While the work was being done, students discovered new opportunities for working out the construction of the skyscraper in a different way.

Documentation
Each student had to document all the work involved in the task by producing a technical report.

Reflection and evaluation
Reflection was performed during and after the re-presentation process. The groups also gave oral presentations of their solutions to the class and a demonstration of the models they made.

The models were exhibited at the school together with the technical reports. Students demonstrated their own models and their visions and ideas to other students in the school, as well as to teachers and parents.
8. Technology and Innovation as an Attractive and Crucial Discipline for Tomorrow

Technology is a crucial part of the culture of human beings – for our survival and development. It is of vital importance to know what technology is today: to understand the many forms it takes and to know how it interacts with other fields of culture, such as science, religion, economics, languages, legislation etc. Many of us would agree with these two statements. It might also be said that such basic understanding will give the generations of tomorrow a valuable platform of knowledge from which better choices can be made. This, however, is not the way technology is generally considered, and there are difficulties in many countries in promoting a better understanding of and general interest in technology in the school systems and in other parts of society.

This article presents a picture of how technology can be introduced as a multidisciplinary and attractive subject in education. It is also argued that an excellent way to present technology is to use the past – the history of technology and innovation – as a powerful method for attracting students with different backgrounds, ages, sexes and choices of educational programmes. By letting history show how men, women and children through the ages have lived and interacted with technology, interest can be stimulated and sustained. Furthermore, history provides us with the practical means to understand modern technology and complicated systems such as the Internet. The method has no time limits because even the latest developments in technology and science will be history tomorrow.

By combining various media with artefacts and stories of the lives of individuals who are easily recognisable to students, a new multidisciplinary model of teaching technology and innovation is created. Using the holistic approach taken in this model – creativity, design, ethics, material resources, sustainable development, environmental aspects, gender etc. – perspectives are included that all have their natural place here. Science, ideas, inventions, innovations, products, processes, marketing etc. are brought to the students’ attention by teasing their intellects with stories of the contributions of women and men like Marie Curie, Henry Ford, Isaac Newton, Andreas Vesalius, Hildegard of Bingen, Christopher Polhem and many others. The aim of this article is to provide a set of didactic guidelines for teachers and others working with technology education.
The Concept of Technology

We all have our own concept of technology, which is developed by formal learning and our experiences of life. Our individual interest in this subject may also vary significantly. But this interest and our view of modern technology are often limited by the fact that the historical dimension is unknown. Let me give you an example. Generally, most people would define the computer as modern or new technology. They might add that it is the result of developments that took place during the latter part of the 20th century. In most cases this is what is known. The PC and Macintoshes that we have on our desks can be described from technological and scientific points of view, from social and economic standpoints etc. But as long as we regard the computer as a “new” technology we lose several dimensions of information which are not only valuable, but crucial for the processes of understanding and learning.

The computer is, of course, not a new technology, in the sense that it just came out of nowhere to establish its strong position in modern society. All technologies have their history. Technology is a cumulative phenomenon. I believe that the modern computer should be connected to the long chain of developments it really belongs to. The oldest historical roots of the computer are to be found in the development of calculating – calculating aids such as our fingers, the abacus and calculating machines – and document reproduction and printing.

The initial idea, to make a program-operated machine with a printer, was born in Germany in 1784. This special calculating machine represents the first step towards the modern computer, although it was intended to operate mechanically and was made of brass and steel. During the early 19th century, costly attempts were made by Charles Babbage (1791-1871) in London to build a single large steam-driven machine of this type. One machine was considered to be enough for the whole world. The first successful, completely programme-operated calculating machine with a printer was made by young Edvard Scheutz (1821-1881) in Stockholm, Sweden, in 1843. He arrived at this cutting edge of technology at the age of fifteen. With the invention of electronics at the beginning of the following century, mechanical solutions were abandoned, and electronics formed the basis for the first computers. In 1945, a very large computer – ENIAC (Electronic Numerical Integrator and Calculator) – was completed for the American army. It was built for the armed forces to make ballistic tables and to print them. Again, one machine was considered to be sufficient for the whole world. All our modern computers are derived from that machine.

The point made here is that, by adding in the historical dimension of the
modern computer (in this case), the size of the matrix of available knowledge and the number of angles of understanding vastly increase. The computer on your desk is connected to a long series of events – events that might attract your attention and interest. The first electronic computers, including ENIAC, were calculating machines – the computer has a military World War II background – and the birth of the first idea can be traced to as early as 1784.

If we like, we can trace the history of the computer all the way back to the oldest known mathematical and astronomical tables, those made in Babylon in Mesopotamia 3,800 years ago.

Below, I will describe for you some of my experiences from teaching students with various backgrounds and choices of educational programmes. I will also show you what components the history method and the multidisciplinary model of teaching may include and why I believe this combination is a powerful and successful way to approach the subject of technology and innovation.

**Technology as a School Subject in the Swedish School System**

Since 1994, technology has been, or should be, a compulsory part of the Swedish school system, from 1st to 9th grade. The National Curriculum in Technology (Lpo 94) gives quite detailed lines to follow regarding what goals pupils should have attained at various levels of their education. In short, one aspect is that they should be able to understand and create constructions and use common technology in a very practical way. The other is more theoretical: they should be able to describe some areas of technology, their development and importance, the driving forces behind this development, the consequences for humanity, society and nature, etc. In this aspect, the focus is on both the past and the present. The ultimate goals to strive for in the teaching of technology, according to the National Curriculum in Technology, should be to ensure that pupils:

– develop their insights into the traditions of knowledge and the development of the culture of technology and how technology in the past and the present influences people, society and nature.

– develop a familiarity in the home and workplace with commonplace devices and working methods of different kinds, as well as knowledge of the technology that is a part of our surroundings.

– develop the ability to reflect on, assess and evaluate the consequences of different technological choices.
– develop the ability to incorporate their technical knowledge into their own personal views of the world and practical actions.
– develop an interest in technology and their ability and judgement in handling technical issues.

**The problem**

However, the school inspectors of Stockholm informed us in their report for Spring 2001 that, with a few exceptions, technology is being ignored in the 1st to 9th grades of the Swedish school system (Fabricius et al. 2002:1). They considered the situation to be “alarming”. In a later report, they noted that technology, despite its great importance to everyone, is considered to play a minor part when the natural sciences are taught (Fabricius et al. 2002:5). All this has happened despite the clear guidelines the National Curriculum in Technology (Lpo 94) gives on the subject of technology. The inspectors conclude that the foremost reason for this is the lack of competent teachers in the area. The situation is the same for the whole country. For several years now, a number of new, well-planned courses on technology have been offered by Teknikum (founded in 2000) at the Stockholm Institute of Education to remedy this severe problem. Other groups in Sweden have long played important roles in trying to remedy this problem, like CETIS, the Centre for School Technology Education, founded in 1993. Important activities include national and regional conferences and research. It has to be stressed that there are talented, devoted technology teachers out there who are doing a very good job. But much more needs to be done to make the necessary changes in Sweden on a national scale.

**The general view**

With this in minds, I would like to give some examples of how students have reacted to the subject of technology that I have come across in my role as a teacher. Since 1995, I have had about 1,400 students in my classes at Halmstad University. Approximately 1,000 of these have completed courses from 5 to 20 credits (in the Swedish system approximately equivalent to the number of weeks of study) or 7.5 to 30 ECTS credits. These courses were compulsory for 70% of the total 1,400 students. They have been given to all categories of students, ranging from engineering students to those studying languages and arts. In addition to this, I have met another 1,500 students at lectures I have given at other universities and elsewhere, where the students were required to attend the lecture. My conclusion from this experience is that the majority of the more than 2,400 students who had to attend the lectures take two opposing views on the general subject of technology.
The first view is taken before the lesson starts; the other surfaces after a few hours of lectures.

- The first view is that technology and innovation are not interesting to students and that it is not important to the students to learn more.
- The second view is that technology and innovation are very interesting and that it is important to the students to learn more.

I would like to stress that these are not the views of a few students, but of the majority of the students who have experienced and expressed this, orally or in the written assessment of the courses.

It is interesting and alarming to learn that this prejudice – that it is neither interesting nor valuable to them to learn more about technology – is so widespread.

However, it should be noted that there is always a group of students who do have a genuine interest in technology, often because they find it valuable from the beginning. They choose to apply and attend out of personal interest, although many of them are not really certain if they are interested enough to pursue a whole programme.

**Experience at the Stockholm Institute of Education**

In the autumn of 2002, I had two 6-hour lectures, on two different days, on technology and innovation at the Stockholm Institute of Education. (The reason for the large number of consecutive teaching hours was travel and the need to use the time for lecturing at the Institute efficiently.) These students, who are to become teachers, had not chosen technology, but were “forced” by my presence to confront the subject – a close encounter.

I asked these students to write a short paper of 1-2 pages afterwards on what they thought about the subject of technology, which I presented by using examples from the history of technology.

About 80 students were present. It was surprising to learn that all of the 57 teacher students who submitted papers had had the same experience, which can be summarised using their words:

- That they had never been interested in technology.
- That they were very sceptical about being forced to attend lectures about it.
- That technology to them was “hard things like computers, things with a motor etc.” and that they never thought that technology was really related to anything else.
- That technology in the compulsory school at most had been soldering together pieces of metal, connecting batteries to lamps, or gluing ice-cream sticks into the form of a sun.
But during these lectures they understood – to many of them as a great surprise – that technology was not only interesting, but fascinating; it was not only valuable to understand it, but very important.

In the following section, I would now like to show you how the subject of technology was presented to them, by giving the structure of the course and some examples. It is technology as it is, and as I believe it should be presented to all students – a result of the activity of men, women and children in nature and society throughout the ages.

**Understanding Technology**

In order to continue, it is useful to ask three questions.

1. What is our concept of technology?
2. What does innovation mean?
3. How do we use technology and innovation?

First, what is technology? Some might start by asking “why should we care?”. For one thing because technology is not just “hard things like computers, things with a motor”. My ambition is to make students understand that technology is all around us. It forms everyday life. It is present in the clothes we are wearing, our shoes, socks, rings, our dental fillings and pacemakers. The Romans said “The room is a machine”, as did much later the architect Le Corbusier (1887-1965). With its ventilation, walls, windows, blinds, electricity, lights, heating and the furniture inside, the room is a machine. I would argue that we have technology on and in our bodies. When we are not in nature, we are inside machines, inside technology.

Technology is not easily defined. We know that it is something that engineers do, often connected to industry and handicraft. Definitions seem to vary from one country to another. One way to approach technology is to say that it can be described in the following way:

Technology is a result of human activity, created in interaction with nature, and realised in the form of artefacts, methods and theories.

For example, the artefact is a hammer; the method is using it, to hammer. In the form of theory, technology is the science behind it for example “strength of materials” is a technology.

Of course other technologies, methods like forging steel, are used to make the hammer. When a technology is new, we call it an invention. After that, we generally refer to it as technology. Sometimes technology is organised into systems, in which artefacts cooperate, thus forming the system and its function. The Roman aqueducts of Antiquity are one example of a technological system. The railroads constitute another one, where the locomotive and stations can be regarded as artefacts in the system. Examples of modern
systems are television, mobile telephone systems and GPS (Global Position System).

To understand technology, we do not need to understand all the hard engineering details of something like a machine – a bit about the basics of a machine and more about its role in society constitute a useful blend. Let me give you an example. In Fig. 1 you can see a piece of technology. It is like a box with cut-off pieces electrical cables and a long rod with a little handle (total length 60 centimetres). Students do not know what it is when it is first shown to them. That is no surprise. Most of them have never seen something like this before. If they are allowed to guess, their guesses range from clock or radio to mousetrap. They do not know by simply looking at the device, and it is of no help if they are told that they all have it in their homes, or at least had it until recently (when it was replaced by computer technology). The fact that they even use it quite often is beyond comprehension. But when the handle is turned, it produces a sound, which sometimes makes a few of them “see”.

Fig. 1. A piece of everyday technology – so familiar, yet still unknown.

The technology in question is the electromechanical device which you find in washing machines and dishwashing machines. But what you see is the handle – the rest is inside the cabinet of the machine. When you use it, you turn the handle and set it on “wool”, for instance, if it is a washing machine. It is natural not to know what the device in question is. What is inside a washing machine is of little interest to the person who uses it. The function, the fact that this machine cleans our clothes, is what is interesting. It is a routine to load the machine with clothes and detergent, turn the programme
handle and let it do the job. The sound of this device is familiar to some, but not its existence inside the machine or its mode of operation.

In the field of economics, it has long been a tradition to regard technology as a “black box”. It is generally believed that there is little to be gained from understanding the harder facts about technology, like how the gear wheels in a gear box in a car operate. What is inside the transmission system is of little or no interest. Instead, the function on a larger scale, in this case that the car is moved by the addition of fuel, is perhaps more valuable knowledge to economists. Something comes into the “black box” and something comes out. It is a matter of input and output. In our example of the washing machine, it is dirty clothes in, clean clothes out. To conclude, technology as a “black box” conception is not only a trademark of economists, but a general view of technology in society that is widespread. This creates a problem when the subject of technology in education is approached.

We cannot deal with the subject of technology without including culture and the connections between technology and culture. Spontaneously, students tend to believe that culture is art, architecture, music, food etc. They often say that “technology is technology” and not culture. Without having a clear picture of what culture actually is, many are certain that technology is something different from culture. But technology is culture, just as art and fashion are. Technology is part of every culture. Just as the language and all other forms of culture are transferred to the following generations, so is technology. Thus, as we live, technology lives and is developed by us, and with us.

Technology is not simply culture. It is interlinked with all forms of culture, with architecture, food, fashion etc. Technology is a form of culture which is actually more necessary to us than things such as music. It would be terrible to live in a world without music, but we could do it. But we cannot survive for long without technology. We also know that we are very dependent on technology to make music, unless we just sing, whistle or clap our hands. Humanity has become entirely dependent on technology for its existence. From that perspective, technology is perhaps the most important part of human culture.

Our habit of taking technology for granted is deeply rooted in us as individuals and in our culture. Not only can the absence of small household artefacts cause problems, like a lost corkscrew or a can opener. Modern humans tend to build larger interconnected technological systems, which are vulnerable. With the advent of large-scale technological system breakdowns, like the electrical failures experienced in the US, Canada and Italy in 2003, this has been made quite clear. When millions of people lose their telephone, light, heating and air condition and the function of institutions
like hospitals is threatened, our dependence on technology and our way of handling these situations are being subjected to hard tests.

On the other hand, technology, this crucial form of human culture, is also the only aspect of it that can do serious harm to Earth and even end or change most of what is living here. Pollution, global warming etc. are terms that are intimately connected to technology.

This struggle between Technology and Nature is as old as the creative human being.

**Understanding Innovation**

Secondly, now that we have a notion of what technology is, what is innovation? A generally accepted definition is that: *Innovation is a technology that has reached the market and has been spread and used there.*

In contrast to this, a technology does not necessarily reach the market. There are millions of ideas of technology that got to the stage of presentation as an invention, in the form of drawings, models, working prototypes etc., but which never got to the market or were spread there. Just to give one example, **Fig. 2** shows a man on a bicycle pedal-operated mechanism with a propeller and sail. This technology was invented in the 19th century to help sailors survive in the event of an accident but was never produced in quantity for the public and does not qualify as an innovation. I would argue that we should make this pedagogically useful distinction between technology and innovation.

*Fig. 2. Late 19th century technology.*
Innovations have effects; they make changes and they can be found across the ages. The stone axe of the Stone Age is an example of an innovation which is now, in the form of an axe or a hammer, still spread and used by billions of people. Some innovations never die. They just change a bit, as generations pass. Another innovation is nylon, a synthetic fibre with excellent qualities for mass production. One of the first ways nylon was marketed, in the 1940’s, was in the form of stockings for women, soon called “nylons”. The demand grew rapidly and women stood in lines waiting hours to get a pair. Of course, the invention of synthetic fibre affected the production of ancient natural fibres like wool and cotton. Markets changed and reacted worldwide. Some innovations are born in one place and developed and spread in another. The car is one example, a technology invented in Europe and later mass-produced in the US by Ford, Chevrolet, Buick and other companies. Then Europe followed, and the innovation was adopted and spread here too.

**Irrational Humanity**

The third question concerns how technology and innovation are used. It is easy to come up with an almost infinite number of examples of why and how men and women through the ages have invented new technologies and transformed them into innovations. Although it is very important and interesting to discuss the driving forces behind technology and innovation this is beyond the scope of this article. Let me just give two examples of somewhat unexpected actions in this respect.

One of the first machine guns was invented by Richard J. Gatlin (1818-1903) in the US in the early 1860’s. It was a reliable hand-cranked gun which could produce a high rate of automatic fire – 150 times a minute. Such guns were ordered to be used in the American Civil War but were not delivered in time. By 1879, the capacity had increased to 600 rounds per minute. Other inventors followed who developed and improved the idea further. The capacity of the fastest machine guns now is over 6,000 rounds a minute, but guns that can shoot 1 million rounds a minute are being developed. Gatlin had studied medicine and received a diploma as a physician from the Ohio Medical College. His reasons for inventing this machine are unknown. However, there is an old notion that resurfaces now and then in history which says that a terrible enough weapon can stop war. Up until today, the atomic bomb has been demonstrated to be the most powerful weapon, albeit unreliable, in this respect.

The next example is related to environmental problems. When the automobile was to be introduced to the general public in the US, men like Henry Ford (1863-1947) and other car manufacturers had many a good argument
for mass production. Among these was the environmental problem that the many horses caused, which in those days were used for transportation. In a world still without cars, animals like horses, mules and oxen constituted the traffic, and the traffic jams, in the city streets. Thousands of animals were needed in everyday transport, to be ridden, for taxis, pulling trams etc., and their droppings were a serious problem which the automobile manufacturers could resolve.

During the first decades of the 20th century, cars were manufactured and sold in large quantities, thus replacing animals in the cities, first in the US and then worldwide. One major local environmental problem was replaced by a larger one, of global magnitude. The latter was to have enormous consequences for nature and life. But it should be noted that from the first part of the 19th century, during the Industrial Revolution, a city covered with black coal smoke, emitted from a silhouette of parallel chimneys, was a sign of progress and generally not seen as a problem. Today countries meet to negotiate, buy and sell rights to how much pollution they are allowed to contribute.

**The Multidisciplinarity**

To sum up, so far we have discussed some of the problems with technology as a subject in education and, in trying to define the field, we have presented some examples of what the historical dimension of technology and innovation can provide us. This article aims to provide some suggestions on how to proceed and overcome the obstacles that are encountered. The use of the historical dimension pedagogically is called the history method here. What else can be done by teachers to approach the discipline of technology and innovation successfully in our schools? I believe that we need to approach the subject from many angles and that when we teach technology and innovation we must:

- Show the various forms in which technology and innovation exist.
- Show why and how a technology or innovation is developed or hindered.
- Show who the actors are – inventors, innovators, entrepreneurs, financiers, producers, users, women, children, men, animals etc.
- Show the “life” of the technology or innovation: the products, the methods and theories – from birth to death – from sketches to drawing boards and computers to the material realising it, to its use, reuse, recycling, destruction and abandonment.
- Show the function – how and why it works (or how and why it does not).
- Show the multidisciplinary framework in which technology exists.
Technology and Innovation – A Multidisciplinary Approach

In doing our job as educators of technology and innovation, we need to understand and grasp the huge multidisciplinary concept in which technological changes take place. Technology and innovation, being a result of human action – culture – are of course connected to all other forms of culture and aspects of nature. Technology and innovation constantly affect and interact with aspects like science, religion, language, legislation, economics, geography, climate, raw materials, and technology and innovation.

The last two items in the list, technology and innovation, indicate the fact that innovations also interact with each other. We must set our minds to grasp the full scale of the holistic picture in which technology and innovation are embedded. In addition to this awareness, we also need to be able to convey the multidisciplinary model to students. With this knowledge, and with the adoption of a holistic view, technology and innovation can be fruitfully studied and taught. Let me give you some examples to illustrate this.

Let us look at religion and technological development. The pyramids, the temples of Babylon, the Roman and Greek temples, the medieval cathedrals etc. would not have been built at all if religion was not a driving force behind them. The architects, the scaffolding builders, workmen of all kind, went through ordeals to complete these enormous structures designed to the glory of God. A medieval cathedral is a beautiful and very impressive building, where height, volume, stained glass windows and music give glory to the Lord. Detailed forms interact to create a unity of function and religious symbols. But some parts of the building which might appear to be of aesthetic origin are not. They were not primarily created for beauty, although they may be considered beautiful. One good example is the flying buttresses, the sloping beams of masonry which extend to the ground to support the sides of a cathedral, like on the Cathedral of Notre Dame in Paris. See Fig. 3. The reason this structure exists in a cathedral is technical. They support the walls of the building to prevent them from being pushed apart by the weight of the stone of the inside vaults, thus keeping the cathedral from collapsing.
The high altitude of these buildings was perhaps the result of a desire to come closer to God. With the invention of cathedrals, man could make buildings higher than the greatest Egyptian pyramid, that of Cheops, 146 meters above ground. It took many decades, sometimes more than 100 years, to build a cathedral. The lack of machinery during this period was one reason for this – all the parts of the cathedral were handcrafted. But social factors, like politics or war, or natural/medical factors, like diseases such as the plague, could also mean long delays in completing these large buildings. For religious and other reasons, the life span of a cathedral was to be “forever”. Who would ever want to build a monument that would not last? This “built-in time control” is an interesting aspect of technological design.
Forever is a long time. In contrast, a modern car is designed to last for about ten years, when ideally, from the manufacturer’s point of view, it should be so worn that it must be replaced with a new one. Modern houses are normally not built to last for many decades and certainly not for a century. The massive Öresund bridge was built between Copenhagen in Denmark and Malmö in Sweden at the end of the last century. With pride, the builders announced that it was built to last for 100 years. Times have changed, and it would have been beyond understanding for any cathedral builder to talk in such terms.

More examples can easily be found which show how institutions, like the Catholic Church, have interacted with science and technology. Thus, for instance, the first mechanical clocks were probably developed during medieval times within the Church or were at least quickly adopted by the Church. This remarkable machine could be used to call people to prayers in monasteries and churches, and it could also show time and activate bells to call people’s attention to church services in villages and towns. As centuries passed, this key religious machine in Western culture became an innovation also adopted by the profane world. Now it guides our lives in detail.

It is also well known that there were differences in perspectives regarding nature between representatives of the Church and scientists of the emerging Scientific Revolution of the 16th century. Many centuries ago, St. Augustine (354-430 A.D.), the leading philosopher of the Catholic Church, discouraged scientific inquiry and explained “... the only type of knowledge to be desired was the knowledge of God and the Soul, and that no profit was to be had from investigating the realm of nature”.1 Clearly such statements were to have an effect on many fields of human endeavour, such as technology and innovation, science and religion itself.

Until the beginning of the 15th century, dissections of human bodies were not allowed by the Church. This had also been the case earlier, among the Greeks and Romans of Antiquity. Yet the incorrect descriptions of the human anatomy and physiology produced by these peoples were used and spread to students of medicine by the universities and other parts of the education system. One teacher and doctor of medicine, Andreas Vesalius (1514-1564) of Brussels, was able to change this situation through his work at the University of Padua, in northern Italy. He thought that his own experience from investigations in anatomy was of more value than what others had written long before without the correct and necessary analysis. After a vast number of dissections, he published his book, *De Humanis Corpore Fabrica*, in 1543. It was the first of its kind – a valuable contribution to medicine and to the Scientific Revolution. The book contained pedagogical

---

1 Koestler 1968, p. 88.
and detailed pictures of the anatomy of the human being, drawn to a quality and beauty hitherto not seen. What existed before his book can best be described as children’s drawings, from which very little information of value could be obtained. But Vesalius was met with scepticism and earned him many enemies among university professors and men of the Church. One reason for this was that his pioneering actions revealed a vast number of errors in the ancient literature. Among other things, he showed that the information on the human anatomy that had been spread up until then – turned out to be based on guesses and the dissection of animals. His book eventually led to the abandoning of the old knowledge. Thus, prior to Vesalius and his followers, new knowledge was obstructed, in this case, by religious rules.

But, we might ask, is this technology? His research was science – anatomy – but his method – dissection – was technology. The artefacts involved, the knives, the other tools; the dissecting methods; the making of the pictures – the drawing, the woodcuts, the printing of the book: all this was technology and innovation.

Another famous example is the story of the Italian scientist and engineer Galileo Galilei (1564-1642) and his contributions to science. In the 17th century, he used a telescope he had developed to study the Universe. Without fear, he published his results in astronomy and other fields, in Latin and Italian, and made himself an enemy of the Church. His books were banned and destroyed, and for his actions he was put under house arrest by the Inquisition in 1633 until the end of his life. But a new technology, the telescope, brought new knowledge to science.

To sum up, these examples of interaction – in this case, between religion and science, technology and innovation – hopefully also demonstrate the ability of the history dimension to attract interest. With illustrations and material of various kinds, the pedagogical advantage is vastly enhanced.

**Development and Interaction**

When new innovations enter the market, they make changes in our world, to a greater or lesser extent. They affect what surrounds them – humans, animals, nature, our legal systems, religion, even technology itself. Innovations have consequences – foreseen or unforeseen.

One example of consequences is the telegraph. In 1837 Samuel Morse, one of many inventors of a system to transfer messages over long distances, made his first telegraph. It operated and was connected to other telegraph apparatuses in a system based on wires – electrical cables. His system, including the Morse alphabet, was a great success. It must have been amazing to see how messages could rapidly be transmitted over long distances only
by wires. But a superior technology was to come. In 1901, Guglielmo Marconi (1874-1937) transmitted a Morse signal across the Atlantic Ocean – without wires. The wireless telegraph was born. The use of this technology at sea turned out to be the best and most unexploited market for Marconi. In 1909, a new law was passed in the US which declared that all seagoing passenger vessels should have a wireless telegraph aboard. But, on April 15, 1912, the ship Titanic sank; 1,500 people died and 700 were saved. Many more could have been saved by the ships that were close to the Titanic, but their radiotelegraphs were not manned. After this technological tragedy, a new law was introduced, declaring that all ships should have a telegraph manned 24 hours a day.2

**Technology Didactics**

With the examples given above, I hope that I have made clear the possibilities of using a combination of the *history method* and the *multidisciplinary model*. In addition to adopting these didactics of technology and innovation, I suggest that we try to teach our subject by using as many channels of learning as possible. There are so many ways to do this and which can be combined: technology storytelling; discussions; artefacts; films, sounds, music, pictures, slides, etc; building and trying things; case studies; study trips to industries etc; interactivities; lectures by students; visits to museums and science centres; theatre; role play; and literature work.

**Conclusion**

This article is aimed at giving a set of didactic guidelines for teachers and others working with technology education. I would like to add some other general suggestions from my own experience as a teacher, which might be useful in the work of others with technology and innovation, both as a teacher and a student:

- Do not fear the subject.
- Do not love or hate technology and innovation.
- Analyse it – be objective – draw your own conclusions.
- Let it be funny.
- Let it be amazing.
- Let it be scary.

---

2 Skruen uden ende ... p. 141.
• Show the diversity.
• Do not tell everything – make good choices.\footnote{“Simplicity is the ultimate sophistication.” Leonardo da Vinci.}
• Remember the primary goal.

\textit{Epilogue}

What is the primary goal in teaching technology and innovation to future generations? I believe that:

• If we can make people want to become engineers or scientists, that is good.
• If we can make them become empathetic, responsible engineers or scientists, that is even better.

But the primary goal must be another one:

• To create educated citizens who can make the right altruistic choices of technology for the future humane sustainable world of tomorrow.

\textbf{References}


At least in Scandinavia and likely in the rest of the industrialized world, higher engineering education is not among those careers that young people turn to as their first choice today. This is even more true among young women. There are however some exceptions besides booms of interest in information technology and other “new areas”. In Sweden we can see how schools of architecture as a part of technical universities, attract many times the number of students they can accept. The situation is similar with new engineering educations that combine disciplines like economy and technology or take new standpoints like engineering for sustainability or combinations of arts and engineering.

Our economy is less and less dependent on manufacturing of things and hardware. Our future lies in production of soft qualities like advanced services, systems design and management and also innovation and research in areas where vast intellectual and economic recourses are needed to compete. These new areas do need a qualified engineering education but also a new kind of engineers that can handle new types of problems that were out of reach of the traditionally educated engineer.

**A design theoretical discussion**

From time to time pedagogues and educators in engineering turn to architecture practice and schools of architecture to find inspiration in their methods of learning and addressing design problems. In addition, many design theorists use architecture practice, as an example of design behaviour and quite a few theorists in the area are architects by training.
A few words on the meaning of the word design might be useful as the broad English meaning, that is used in this chapter differs from at least everyday Swedish meaning of the word. Design could be a noun\(^1\), meaning e.g. the style, form and other properties an object has been given, and a verb\(^2\), meaning e.g. to give form.

**Proessions in transition**

In this chapter I will elaborate the problem field of learning in technology from a design theoretical point of departure. In technical universities, we see a turn towards an engineering profession that lean on a technological education there natural sciences and humanities are both core components. We can also see how new areas of engineering bridge over not only between traditional fields of engineering but also to medicine, humanities and social- and behavioural sciences. This also calls for developments in the areas of epistemology and methodology.

My empirical foundation (Granath, 1991) for the discussion has developed over almost three decades of very inspiring practice in design, research and education with architects and engineers of different specialities. As a genuine believer in design as a learning method (Schön, 1983), my insight in the subject is a result of constant loops of action and reflection combined with theoretical studies of other experienced designers, teachers and theorists.

---

\(^1\) a: a particular purpose held in the view by an individual or a group (he has ambitious \(\sim\)s for his son) b: deliberate purposive planning (battle was joined … more by accident than \(\sim\) -John Buchan) \(^2\): a mental project or scheme in which means to an end are laid down 3 a: a deliberate undercover project or scheme: PLOT b \(pl\) : aggressive or evil intent – used with on or against (he has \(\sim\)s on the money) 4 : a preliminary sketch or outline showing the main features of something to be executed: DELINEATION 5 a: an underlying scheme that governs functioning, developing, or unfolding: PATTERN. MOTIF (the general \(\sim\) of the epic) b: a plan or protocol for carrying out or accomplishing something (esp. a scientific experiment); also: the process of preparing this 6: the arrangement of elements or details in a product or work of art 7: a decorative pattern 8: the creative art of executing aesthetic or functional designs **syn** see INTENTION, PLAN. Webster’s Ninth New Collegiate Dictionary. Merriam-Webster Inc. Springfield, Mass. USA, 1984.
With this text I like to contribute to a discussion on how the learning situation in elementary and high school might be designed in a way that prepare the students for a future career in engineering and other professions based on technical understanding. I will also suggest that a design theoretical view on technology shows that technology is close connected to questions of importance to nowadays-young people of both genders. To do this I use architects’ and engineers’ training and professional practice to illustrate the possibilities of future technological professions. The final part of this chapter reports on a design assignment given to first year students in architecture. The assignment is based on the design theory that will be discussed in this chapter.

**Engineers and architects – two design professions**

Engineering and architecture are both design professions. I will demonstrate important similarities between the way professionals think in action but also describe some obvious differences between and within each profession. In his book, *The Reflective Practitioner* the American design theorist Donald Schön distinguished between a technical rational and a reflective way of connecting knowledge to practice. Schön argues that both engineers and architects take advantage of both ways in their practice but the engineers are taught to treat knowledge in a technical rational way while architects mostly depend on reflective behaviour in their practice. I come back to this later in the chapter.

I am attracted by Herbert Simon’s (1984) view that “*Everybody designs who devises courses of action aimed at changing existing situations into preferred ones*”. In this chapter I will however, for the sake of reasoning, focus on certain aspects of the design of artefacts. Artefacts are always designed for a purpose in the real world and have therefore always an

---

3 The traditional definition of artefact is closely connected to physical things. It is something manufactured by man. My view is however that this definition is not sufficient in the modern society there so many things created by man are non-physical, virtual or mental products. I therefore focus on the other part of the traditional definition, namely artefacts as not being natural phenomenon. My definition of artefacts therefore includes anything created by man, also those that originally lack physical form like ideas, theories and mental models.

4 I use the expression *The Real World* to distinguish it from the Cartesian division into disciplines that is the tradition in engineering and natural sciences, and other sciences too for that matter. The Real World means a more holistic approach to the problems at hand there we can bridge over between traditional disciplines and take on problems that traditionally have been difficult to deal with. The concept is not new as it was used by the American designer Victor Papanek in his book “*Design for the Real World*” already 1985. He however focused more on the appropriation of the artefacts than on the knowledge behind its design.
intended or sometimes not intended effect on human beings and society. (Papanek, 1985) Both architectural and engineering practices are design professions in this sense.

**Self fulfilment and architectural design**

Some professionals have an urge to self fulfilment. By this I mean and urge to express oneself through professional performance beyond what most others can do. This urge is mostly an ambition due to the personality and the talent of the professional. In training of architects this is however a central aspect of the curriculum as in training of performing or fine artists. For some architects this becomes the paramount driving force of their work. It could be regarded as a *pure artistic dimension* of architecture practice. Even if the purpose of self fulfilment in architecture, in most cases, is to make something pleasing, I do not simply connect this to *aesthetic* ambitions of two reasons. The first reason is that my experience from co-operation with engineers, and other professionals, has convinced me that any serious professional has an aesthetic dimension in the way they design or perform. This is often implicit and often even denied by them though. The aesthetic ambitions are therefore not only restricted to artistic work. The second reason is that engineering designers often look on aesthetics as a part of the functional properties of the artefact rather than as a quality in itself or a way of expressing themselves. The aesthetic form in product design is i.e. a semiotic property of the artefact aiming to communicate with society and individuals.

In this sense I think of self fulfilment as an important aspect of designing. The driving force for the artist is often to have an impact on the real world but this is not an absolute necessary condition. The driving force could be merely introvert. Some philosophers (Hinman, 1994, Chap 4) would argue that this urge to fulfil your own dreams or express yourself is the only valid driving force among human beings. Research done in USA by Robert Gutman (1988), the sociologist and professor of architecture at Princeton, shows that practicing architects’ main goal is to get appreciation from the fellow architects rather than users and society as a whole.

**Engineering construction and engineering design**

On the other hand, we have what I call *engineering construction*. Here I do not talk about construction in the sense of erecting or manufacturing something but the intellectual activity of giving the artefact its normative qualities, properties and dimensions due to good professional standards. This reminds of a common definition of design, but in this case, I will suggest *engineering construction* as a more restricted view on design in the same way as I distinguished *pure artistic work* as a special aspect of design.
In my conception of design, there should be a dimension of uncertainty and ambiguity in both the problem definition and the process and of the outcome to be. What I call engineering construction, different to engineering design, lacks to a large extent this uncertainty and ambiguity. I talk about engineering construction as a design situation where the engineer knows very much what the outcome will be of his/her construction efforts. The intellectual process is mostly about defining quantities rather than qualities. The process of construction is often linear and predictable and it is obvious when the problem is solved. The engineer uses methods and theories from his/her professional education in a formal way to solve the problem. And most important, the mastering of these theories and methods makes it clear from the start that the designer is proficient to solve the problem and that an acceptable result will be arrived at in the end.5

Therefore, on one hand I have distinguished pure artistic design as a design activity in cases where the urge of the creator to express him/herself is of paramount importance. On the other hand, I have described what I call engineering construction as a special aspect of design where the lack of ambiguity and uncertainty in the problem definition and a linear cognitive process is favoured. It is however important to point out that we find very few professionals that fit totally into these two categories, if any. When we discuss education in engineering and architectural design, I however find it useful to make these somehow “artificial” distinctions as the two opposite ends of what we think of as design activities.

Dealing with real life problems

The most demanding area of design is that dealing with poorly defined or wicked problems6. In these cases the ambiguity and uncertainty is always present concerning the problem definition, the relevance of theories and methods and often even the actual conceptual context of the solution. In

5 Swedish professor in Informatics Bo Dahlbom suggested a distinction between the Swedish concepts of “konstruktion” and “design” in a contribution to a design seminar at Chalmers University of technology in the early 90's. I have elaborated this suggestion in my own way since then.

6 Architect Peter Rowe identifies three categories of problems: 1. Well-defined problems, 2. Poorly defined problems and 3. Wicked problems. In the case of poorly defined problems you know essentially what the problem is, but during the course of your work you are forced continually to gather more information and redefine and specify the problem further in order to reach a viable solution. "Wicked" problems are those, which elude clear definition. Further, you cannot be certain you have found a solution. Rowe, 1987.pp. 39-41. Rowe’s points of departure are: Churchman, 1967, Rittel, 1972 and Bazjanac, 1974. (See Granath, 1991).
these cases design can be described as a simultaneous and iterative process of i) decision-making, ii) problem solving, iii) communication and iv) considerations on aesthetic and ethic values.

The decision making process involves rational logic. This involves the ability to master professional methods to collect, and structure data, set up and evaluate alternative actions and be familiar with concepts, rules and regulation of the profession and finally have the professional skills to follow them. These skills depend mainly on what Schön calls technical rationality in its view on knowledge and professional design behaviour.

Problem solving on the other hand involves a more intuitive logic there questioning rules, bending and breaking rules and developing of new rules are essential aspects of design. The problem solving process involves very much the ability to look at a thing as if it were the other way around.

Communication in design

Communication in design has two important dimensions, the communication with the real world in terms of users, co-designers and other actors and the dialogue with the design situation itself. Schön describes the dialogue with the design situation in terms of assessing provisional structures and solutions to the situation and how the design situation “talks back” to the designer. We all recognize this from everyday design situations. We only have to think about one way to solve a problem to immediately realize that it was not such a good idea and we modify our thinking and try it another way. The idea of communicating with co-designers and user has two main purposes. One is to collect information and learn about the situation; the other to make sure the solution will be satisfying to the real world situation. (Granath, 2001) Simon’s statement above that everybody being a designer indicates a collective design process as something that not just involves professional designers like engineers or architects.

7 I here allow myself to use an expression that with a special meaning of rational could be a tautology. I use the term rational logic to distinguish from intuitive logic used below. Intuitive logic would by some be regarded a contradiction so, by combining a “hard” tautology with a “soft” contradiction I try to make a pedagogical point about the difference between the aspects of decision making and problem solving.

8 By intuition, I mean the ability to recall earlier experiences that is understood by the designer. Refereeing to Simon and to discussions with Rudolf Arnheim (Ann Arbor, MI. 1988) I see intuition as something individuals experienced from certain situations can use to solve problems within similar situations.

9 Inspired by Schön I suggested the concept collective design as a reflection on the process of designing a new automotive assembly plant for Volvo. The process showed all the properties of what Schön would call a reflective design activity but while Schön mainly spoke about individual professionals my experience involved groups of designer like assembly workers, engineers, architects etc.
The problem-solving and communication dimensions of design could, in Schön’s terms, be described as a reflective behaviour. The reflective behaviour is well suited to situation where we do not or cannot, due to the character of the problem, fully define it initially. The problem becomes gradually understood and changes character with closer contact with and growing understanding of the design situation. This also means that the uncertainty of the relevance of theories and methods and the development of theories and methods are parts of the reflective design behaviour.

Due to Schön, every designer uses a combination of technical rational behaviour and reflective behaviour in their professional practice. Technical rational way of thinking is however more predominant and regarded as norm in engineering education as reflective behaviour is in architect education. Because of this, those engineers occupied mainly with engineering construction often feel less professional when they “degenerate” to what they feel is a “sloppy” reflective behaviour. Artistically inclined architects on the other hand do not develop too many normative methods and general solutions in their work. To do so would be regarded uncreative and a hindrance for artistic quality. As detailed data and normative methods is crucial to the traditional engineer, too much knowledge and information sometimes makes the design too complicated for those architects seeking merely for the artistically consistent solution.

**Dealing with uncertainty**

A reflective behaviour is essential to solve poorly defined problems and to innovate and technical rational behaviour is needed for taking advantage of expertise and scientific knowledge and above all as a controlling behaviour of intuitive suggestions. Reflective and technical rational designers have different strategies to deal with overflow of information and ambiguity in the design situation. Technical rational behaviour delimit the problem to a safe area there the methods and theories at hand is relevant for the reduced problem. This makes it difficult to deal with true real life problem that does not easily are reduced to fit into single professional areas. This restriction is no problem for the reflective designer. He/she instead relates the collection of information and data to the actual design situation, which sometimes can be quite opportunistic and ad hoc. Architects include information and data that is more general in the form of rules and regulation set up by authorities.
or taken from handbooks and manuals. The presence of such normative data is however controversial among architects. It is argued, on one hand, that such norms is a help to guarantee certain qualities that are essential to users and society and still give the architects a large freedom to concentrate on the artistic aspects of the design. Another view is however that these normative regulations are restrictions to creativity.

In an ideal situation, the collection of data should be retrieved from what is scientifically proven, from the context and through communication with the other actors and the situation. A combination of good methods of taking advantages of scientific knowledge and earlier personal experiences could make many of these normative regulations obsolete and let the design be trusted to reflection and creative thinking in the actual situation. The architecture praxis is however far from ideal when it comes to feedback from earlier design situations, procedures and methods that enhance the ability of reflection-on-action. This is an area where engineering practice have a lot to offer.

**The importance of context and values**

The last aspect of design I mentioned above was considerations on aesthetic and ethic values. For this purpose I introduce a diagram that I have modified from a model originally presented by the Swedish design theorist and architect Jerker Lundeqvist and modified in other contexts by the design theorist and informatics scientist Pelle Ehn. The original ideas are related to the elements of architecture: commodity, firmness and delight by the ancient Italian architect Vitruvius (last decades B.C). Ehn used the model to describe properties of artefacts in general. I have modified the model to discuss the education of architects and engineers.

---

10 This is an interpretation of the original Latin text in *De architectura libri decem* where Vitruvius presents his ideas of the elements of architecture; originally from an English translation by Sir Henry Wotton (1568 - 1639)
The technical rational point of view is, according to Schön, that knowledge based in science is the sole basis to build design practice on. Skills, on the other hand, are a result of knowledge and not really regarded as knowledge at all. We know that discussions in pedagogy on life long learning and problem based learning on one hand and discussion on practice generated theory and hermeneutic sciences on the other hand has put this in question as the sole basis for professional education.

Two education traditions

Engineering education

Engineering education is of natural reasons based on structural knowledge (see figure on page 151). Structural knowledge is here defined as scientific knowledge, not dependent of the context i.e. rules for how to calculate a concrete beam are the same regardless if it supports a church or a soccer stadium.

To relate the professional knowledge to the context has traditionally been left to after the professional degree. In practice, the engineer has acquired true engineering design skills, including reflective behaviour in his/her design practice. With a growing awareness among engineers of the need to deal with poorly defined and wicked real life problems without delimit them to abstract pieces of a problem field; the contextually related training has been more and more important in engineering education.

The first experiments with developing a method for using real life problems in graduate and post-graduate training in Sweden was made at the School of architecture at Chalmers University of Technology in late 60’s and is still an important part of the pedagogy in the school (Kjellgen et al., 1993). Unlike some modern problem based courses the basis has always been real real-life problems where the students have intervened in and cooperated with people in their every day situation whereas it has been workplaces, housing projects or redesign of public facilities or communities. Several projects has seen its realization or contributed ideas to later realization.

Engineering education has still its basis in structural knowledge but adopts increasingly the ideas of using real life contexts or at least simulated such, as basis for professional training.11

Aspects of ethical or aesthetical values were for long “off limit” in engineering education. Scientific knowledge is neutral and a stands above po-

11 I distinguish between real life problems as those solving an existing problem together with people affected by the problem setting, and simulated real life problems where the situation is realistic but not real.
litical or moral considerations has been a strong standpoint. This is supported by the conception that all problems are or can be reduced to well-defined problems with optimal solutions. There is a growing awareness that this might not be a preferred standpoint in all situations. New cross-disciplinary areas of research closer to real life have also appeared. This has made also the scientific truths of natural sciences subject to discussion and considerations based on values among individuals and society.

**Architect education**

We can find two main lines of development in architectural education. The “académie de beaux-arts”, where the architect’s education is mainly artistic is one. This tradition has always been and is still strong in some countries. In other countries, the architects’ training is part of an engineering school. The Swedish architects’ education was traditionally more similar to engineering education and had a larger part of the curriculum than today in the area of structural knowledge. The contextual aspects and training on real life problems has however always been important. Before the change in the late 60’s the real life project were more mono-disciplinary and formed the basis for exercises in interior design, landscaping, housing design or structural design. They were also often made up problems that simulated real life situation or fantasy problems just formulated to stimulate creativity or challenge the students without feeding any useful solutions back to those who lent their reality to students’ exercise, if they at all existed. This later use of real life or fantasy in architects training still exists and has a value but the importance of interaction and usefulness is predominant today. It is interesting to note that in school of the “académie de beaux-arts” tradition real life problems and communication with laymen often are regarded not preferable. The argument is that reality will restrict creativity and a need to adjust to users demands and wishes, other than in the architect’s own interpretation, will harm the artistic quality of the result. Real life restrictions will come soon enough in real practice anyway is the argument.

*Values* have always been present as an important factor in architecture education and practice when it comes to aesthetics. In education are also values on other areas like social, humanistic and environmental issues important. Those who see architecture mainly as an artistic profession put aesthetic values among designers, tutors and fellow professional in focus as something of major importance. It is clear that the balance between context and real life considerations on one hand and the artistic and ethic values of the designer on the other hand changes over time both in education and practice. So does the focus on interest in aesthetic and ethic values.
It is interesting to observe how traditional engineering education is based on structural knowledge but increasingly tend to involve contextual and value based aspects in education. Architects’ education is traditionally founded on learning from the context and embracing values in terms of aesthetics and ethics. In co-operation with engineering schools like civil engineering there are at least at Chalmers University of Technology efforts to marry structural knowledge in technology with the context of human life and the build environment.\textsuperscript{12}

#### Theoretical reflections

In this text, I like to suggest that a design theoretical approach to education in technology could widen young people’s conception of technology. To introduce techniques to accept and to solve fuzzier problem definition might make technology more demanding and interesting. To discuss contextual and value based problems and solutions might, in the eyes of young people, expand the relevance of technology to areas of greater importance to them. To approach technology in a multi-disciplinary way that bridge over to humanism, art and social- and behavioural sciences might make it more interesting and meaningful. I also use the engineering construction tradition in engineering practice and too strong focus on artistic self fulfilment among architects to illustrate a kind of professional traditions that might be hindrances to adopt and handle real life problems.

Experiences from our university indicate that those programs and courses that have focused on the above issues have been successful both in terms of attracting students from different schools in the university, but also to attract women. I suggest this could be further enhanced if the students were introduced to technology in a different way in their earlier learning experiences.

#### A practical design assignment in architecture

##### Background

When students start a university program in architecture or engineering they already have a number of conceptions and behaviours that affect their understanding of knowledge and skills. Added to this they will adopt a set of conceptions in their education, mainly based on professional tradition communicated by the teachers. Some of these conceptions form the basis for professionalism, but some are less functional in their future professional

\textsuperscript{12} A new strategic program on Aesthetic form and Technology (Gestaltning och teknik) is about to be launched in co-operation between the Schools of Architecture and Civil engineering. Also strategic programs in Facilities management and Design try to bridge over between engineering, architecture and other disciplines outside the technical university.
life and should therefore be seen and discussed early. Through carefully
designed design exercises and discussions the students can relate to these
conceptions and formulate their own standpoints.

Some students are not explicitly aware of the existence of other than
well-defined problems. They are seeking optimal solutions for every pro-
blem defined. At least their conception of good performance from earlier
education does not focus on other conceptions than the elaboration of well-
defined problems and learning about facts. On the other hand some students
are strongly affected by the notion in the post-modern society of everybody’s
right to formulate their own believes rather than knowledge and the relativ-
ity of knowledge and scientific facts. Both these views can be enhanced in
a less functional way by professional education and future practice.

Described in design theoretical terms there is a risk that the student de-
velop either a very strong construction behaviour or embrace their urge of
self fulfilment in a way that restrict their professional abilities to solve real
life problems.

The aim of the following exercise is to make the students aware of the
dynamics and uncertainty of problems in real life. They meet problems that
are not well defined and do not have optimal solutions. They also get a
chance to deal with the balance between their own artistic self fulfilment
and construction behaviour in a made up real life situation.

Added to these goals the students get a chance to understand the impor-
tance of scale, repetitiveness and simplification. For the first time, they be-
come familiar with the concepts of briefing and goal setting and practice to
communicate intentions and solutions to others.

The students

The students meet this exercise during their first semester in the architectu-
re curriculum. The students are accepted to architecture studies in mainly
three ways: Through grades from earlier education, secondly through re-
results from The Swedish Scolastic Assessment test for university studies
and thirdly through special national ability test designed by the three archi-
tect school in Sweden.

All our students are high performers in their field and top ranked in their
categories. There are mostly more than eight applications for every accep-
ted student in architecture schools in Sweden. Either they are top performer
from earlier education and have grades very close to the highest possible, or
they are top scorers in The Swedish Scholastic Assessment Test for university
studies, or have showed outstanding abilities for the architect’s profes-
sion. Their abilities go from extreme performance in school to be highly
well educated in general matters or to be creative and have high artistic
skills and are mostly a mixture of all these.
The setting of the exercise

The setting is a little island in the Gothenburg archipelago. There is no electricity, no sewer and actually no roads to the site. The island is very barren. Only a few bushes cling to the bare rock landscape. The site is sloping down to the sea less than 100 meters away.

The task is to design a little cabin on this island. The purpose of this cabin is a hide-a-way for a young person and maybe a friend, a place for reflection, contemplation and relaxation.

The conditions for the design are very restricted. No roads, electricity or disposal of garbage or any other human waste from toilets or cooking is allowed in nature or water. In this step they have a lot of 60 m² and are allowed to use the entire lot for building if they choose.

Formulating a vision

The students are asked to formulate their vision of such a cabin for themselves. They should do this by choosing three pictures that in a metaphorical way express and communicate their vision to the other students. If they wish they can use maximum 200 words to support the understanding. This should be presented as a poster in format 70x100 cm portrait and displayed on the wall of the studio for other students to read.

Choosing a partner

From what they find out from the posters the students pair with another student. The next step is to be each other’s client and architect. This means every student designs a cabin for someone else and each student is the client of another.

In this part of the exercise they are left very mush to each other and the role of the tutors is mainly to explain the rules of the exercise and provide them with certain facts they need.

Presentation and discussion

The whole class takes part in the presentation. It starts with the architect explains how he/she has interpreted the vision as it was presented on the client’s poster. The client comments on it and a discussion takes place on the vision and the interpretation of it.

The architect then explains how these interpretations have been realized in the proposed design and the client gives his/her views on how well the architect has succeeded in satisfying the visions of the client. He/she also comments on the co-operation taken place between the two.

It is now time for the class to discuss and question the design. Something interesting occurs when other students criticize the design. In many cases
the client defends his/her cabin against the other students and the architect is quite passive. This is very unusual for practicing architects or more experienced students that mostly regard the design as their own rather than the client’s. By doing this role-play it has been obvious to the students that the design has a purpose in the real world beyond expressing the talent of the designer. This part of the exercise also meant that each student have taken part in two design projects and found out that there is not really a big difference in dedication and value of input if you are the designer or the future user of a building.

**Briefing – the link between the abstract and the concrete**

A good brief should be normative enough to secure essential qualities and the vision of the project, but should also be dynamic and vague enough to allow many interpretations in terms of concrete designs.

It is our experience that the transformation between the solution and the brief, and the other way around, is hard to grasp for the students even later in the education.

Students might have difficulties writing a brief without thinking in terms of concrete solutions and therefore make the brief too normative or leading to the solution they favour, or it is hard for them to understand the need for a brief at all when they have reached a solution. They cannot remember or understand that there were other ways of doing things, or thinking, when they have reached a solution.

We therefore ask the students to take notes of all discussions and decisions between the client and the architect during the design process. It could be matters of materials, relation to nature and water, constructions, aesthetic aspects or functions they like to meet in the design of the cabin.

Based on these notes, the original vision as presented on the posters and the discussion during presentation, we ask the students in pairs to reconstruct a brief for the cabin.

All aspects that have occurred in the suggested briefs are put together and presented to the student by the teachers. Mostly this list covers well what could be included in a brief, but of course quite a few aspects are contradictive to each other.
Making it more difficult through simplification

The students are now quite familiar with the design task and have a feeling of accomplishment but also of having found the solution to the problem. As their experience of design is very short this exercise might have increased their experience a lot. They are much more able than they were before the exercise.

We now tell them to redesign the cabin individually with somehow more restrictions. We decrease the allowed area of the building’s footprint to 15 m² and also imply other restrictions on the design that we, from the first step, have learned, otherwise being easy ways out.

The first thing they have to do is to use the compiled brief that everybody contributed to and pick out relevant parts and write their own brief for the next step of design. The new restrictions we have given them must be included in this brief.

In the following stage of the design process the teachers tutor every student. If they wish they can modify their design drastically from the first step.

Presentation and critique

The result of this design stage is mainly a quite detailed model in scale 1:20 and a poster presentation with attached brief. The presentation and critique after this stage follow very much the format we normally use in our education. It is an open session mandatory for all students. Students present their own project. They state the goals for the project and their interpretation of the brief and the outcome of the design. They also discuss difficulties in the design process and how they have dealt with them. Often another student is assigned to do the opening critique. Teachers and other students discuss the design in relation to the brief and teachers give advice and discuss alternative ways and point out special qualities in the design. Principal comparison between individual designs is made to show different approaches.

More is different

After this critique session, the students are quite content with their design. Some of the designs are quite elaborate while some are subtler. Notions of that are good solutions are being established among students. We therefore take them a step further to make them understand that what they regard as a good design could be less relevant if the context were different.
We therefore ask them to design a little holiday village with 12 equal cabins. They have to use the cabins they already designed, but may modify them. They are now confronted with new problems of relations between cabins originally designed as a solitary building now multiplied by twelve. The cabin that seemed so appropriate and interesting in its splendid isolation on the slope of the rock might be something totally different in the new setting.

**Presentation and critique**

This critique session is not taking up every individual design but is more of a discussion on how the new situation affects the design of the individual cabin in relation to the brief. Many of the student’s designs are used as illustration to this. It is also interesting to discuss how twelve times as many people in the area affect the original visions of the cabin and how that can be met by design of the village and the design of the individual cabin.

**Understanding theory through own practice**

The practical design exercises are taken as point of departure for more advanced theoretical lectures. The role-play in the beginning is followed by an interactive lecture on theory and methods for participation in design. Later in the exercise we have lectures on design theory, which is described as the theory of understanding “what we do when we do what we do as designers”. The briefing exercise is followed by a lecture on theory and methods of briefing. We know from experience that these lectures can be hard to include in the active knowledge and bridge over to the design situation. We believe that connecting them directly after a practical design situation and relate to that in the lecture might help to include the theory in the professional knowledge.

**Conclusions**

For many years we have used design thinking in the architecture program. As I mentioned above we were the first higher education in Sweden using Problem Based Learning. At that time we did not know of the concept PBL but did things from a more intuitive experience of how we could learn better. It is important to understand that the students were those who took initiative to this change in late 60’s, with support of a few open-minded teachers. Design thinking has been implicit in the architecture program for a very long time but not before we could articulate the basic theories of design was it possible for us to understand what we had tried to do and most important to improve our methods of learning. My experience is that design thinking is not just helpful in learning technology and other professional
matters. It is also a way of thinking that unfolds more complicated matters like professional attitudes and roles, and conceptions of professional knowledge that are imbedded in the professional tradition. These matters are very difficult to address by teaching through lectures and reading, but become quite obvious if you first, build on a good design theoretical knowledge and secondly, let the students find things out themselves through clever exercises build on design thinking.

Referenses


Also to download: http://granath.arch.chalmers.se/guestbook.php


10. Addressing modern technology: a Systems Approach

A way to augment relevance to Science education and to achieve greater attention from students, is to address the everyday life experience by young people of technology. This is not an easy task; the technology of today is very often complicated. Mobile cell phones, MP3-players, computer controlled toys are hard to explain and to understand. The scientific method of Physics is to reduce and find general laws and models of the smallest parts in nature. To be able to address and to understand modern technology one needs to use the methods of technology, i.e. of engineering design. One must use two, for science education uncommon, perspectives on knowledge and understanding of artefacts. These are function vs. structure and a systems approach.

**Function and structure**

There are two different ways in which a technological artefact can be described: its structural physical properties and its function. At Delft University of Technology in the Netherlands a group of researchers are engaged in a project on "The Dual Nature of Technological Artefacts". Peter Kroes (2002, p. 294) writes:

"Technical artefacts are objects with a technical function and with a physical structure consciously designed, produced and used by humans to realise its function. But as a mere physical object, it is not a technical artefact. Without its function, the object loses its status as a technical artefact. This means that technical artefacts cannot be described exhaustively within the physical conceptualisation, since it has no place for its functional features."

The idea of functional knowledge is not new. In 1809 Jean Hachette and others at the Ecole Polytechnique tried to classify mechanical devices by function and produced synoptic charts of elementary mechanisms, which enjoyed wide popularity for over 100 years (Ferguson, 1992). Even earlier, around the year of 1700, the Swedish engineer Christopher Polhem established a “Laboratorium Mechanicum” to promote the study of machines that might aid the economic development of Sweden. Polhem devised a series of models, “The mechanical alphabet”, as necessary for a “mechani-
cus” to know of and keep in mind as he designed complex machines. Polhem saw the five powers of Hero of Alexandria – the lever, the wedge, the screw, the pulley and the winch as the vowels. “Not a word can be written that does not contain a vowel”, he averred; “neither can any machine limb be put in motion without being dependant on one of these”. The students had to manufacture their own models in wood and were able to understand and design complex machinery. The Polhem alphabet survived him and it was used in the first technological educational institutes in Sweden until the 1840’s.

Early in the nineteenth century, Robert Fulton of steamboat fame, took up the idea of a mechanical alphabet. Brooke (1981) quotes him: ”The mechanic should sit down among levers, screws, wedges, wheels etc. like a poet among the letters of the alphabet, considering them as the exhibition of his thoughts, in which a new arrangement transmits a new idea to the world.”

The emphasis on design and problem solving has put focus on functions now more than ever. Hirtz (2002) describes a functional language designed to enhance and expand the frontiers of research in design repositories, product architecture, design synthesis, and general product modelling:

"In engineering design, all products and artefacts have some intended reason behind their existence: the product or artefact function. Functional modelling provides an abstract, yet direct, method for understanding and representing an overall product or artefact function.”

When researchers have tried to describe the design process, they talk about a problem state, a search space and a final goal state. Middleton (2002) emphasizes that to define the problem state is part of the problem. He presents a modified model with a problem zone and a satisfying zone. In both descriptions, the first part of the problem is about functional properties, the second of structural properties of the artefact. The task of defining the first and finding the latter is the core of design work. There are some findings showing that experts are more able to describe problems in functional terms. They also seem to reason backwards, trying to link and adapt “old” problems to the task in question. They try to find a problem similar to the one at hand, to be able to use their experience of linked function-structures knowledge to extract a solution. Novices are more straightforward and seek immediate solutions to the problem, by the method of “trial and error” (cf. Lars Lindström’s chapter in this book).

A systems approach

Technological developments very often address ”individual technologies” or components (Laudan, 1984). Examples of this kind of artefacts are the
steam engine, the propeller and the transistor. Together they are used to build technological complexes or systems. A complex has a long lifespan; the embedded components will evolve and may be changed without a change in the overall systems function. Edvard Constance (1984) describes the hierarchic structure of a system and Richard Kimbell (1997) use the term hierarchy of tasks which has – at one extreme – a very open and ill-defined context and – at the other – a highly specified task. A systems approach is in this context used as an analysing tool to understand the constructed world. By selecting an appropriate level of detail, even very complex systems are understandable.

In design work, it is of utmost importance to choose the appropriate system level. The cognitive restriction of the human brain makes it impossible to handle details that are too complex. This limitation has been circumvented by designers through a clever organisation of knowledge and design tasks on different system levels. It has made the design of the large technological systems of today feasible. Very much like an architect, the engineer will move between different levels of detail during the process of design. In large projects, tasks can be divided and distributed to different individuals or teams working on different system levels.

These two aspects of knowledge about complicated systems are related:

a) When you move to a higher system level, knowledge of functions becomes more important;
b) The knowledge is transformed from structural detail to more extensive functional properties.

An example from another educational field may clarify these two aspects further. When you learn a foreign language, for example Russian, you have to recognise the new letters, how to pronounce them and how to draw them. You will have to learn words, how to spell them and how to pronounce them. The grammar makes you apprehend the rules of the language and how words are connected and modified in different ways. This structural knowledge is not enough to make you a good writer or speaker; you need to grasp the meaning, the function of the language components and how the meaning is changed with the context. This is achieved by experience, i.e. by listening, talking, reading and writing. Every language teacher acknowledges these two aspects of learning and recognizes the systems aspect. Interpretation becomes different depending on the level. On the top level the text must be seen into a larger context, ways of speaking, cultural tradition etc. At the bottom level meaning is nearly incomprehensible as the individual letters or even the words convey very little information. The whole is more than the sum of its parts!
Implications for education

An educational subject such as Electronics will also benefit from the use of the system/function approach. Electronics is very often treated as part of science curricula, usually in the Physics curriculum. The structural part is about atoms, electrons, charges, electrical fields, current, conductors, isolators, resistors, capacitors, transistors, amplifiers, integrated circuits etc. The opinion formed by students and teachers is that Electronics is very complex and not easily comprehended. The “magnificent” idea of making and using integrated circuits, IC’s, is completely misunderstood. Textbooks and teachers often try to explain the inner structure of the chip instead of concentrating on the functional properties of this super component, which is constructed to enable design on a higher system level.

Electronics in Technology education

<table>
<thead>
<tr>
<th>Function</th>
<th>Materials</th>
<th>Energy</th>
<th>Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transform</td>
<td>Elec.Flash</td>
<td>Rh-sensor</td>
<td></td>
</tr>
<tr>
<td>Store</td>
<td>Backup</td>
<td>RAM</td>
<td></td>
</tr>
<tr>
<td>Transport</td>
<td>CCD</td>
<td>CF-memory</td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>Filter</td>
<td>Timer</td>
<td></td>
</tr>
</tbody>
</table>

Fig. 1 Function of the Capacitor according to Lpo94

In the Swedish National Curriculum (Lpo94, 1994) there is a rather new subject or discipline, Teknik, which is using a systems/functional approach. Teknik is a very broad subject including concepts and principles from the social sciences, the natural sciences, the visual arts, design, craft and other subject areas. Contents are not specified but address several important aspects of modern technology.

One of the aspects to consider in teaching Teknik is: "What technology does. Technological problems and solutions can be categorised in different ways. The following fundamental functions can be identified: transforming, storing, transporting and controlling.” (Fig. 1)

If you add three different areas of action: Materials, Energy and Information, the resulting matrix will organize knowledge of almost any kind of artefacts. The teacher makes a choice of suitable technology according to local interest and resources. The area of Electronics is very well suited to this kind of structure. A common component as the Capacitor stores electrical energy. It controls AC-current and can be used as a filter. It will be used for timing purposes and as a transforming sensor capable of detecting humidity, acceleration, etc. Its storage property can be used in a digital memory transporting music in a MP3-player. The functional properties of
a Capacitor can be discovered and learnt in hands-on practice without complicated theories. On this systems level there is only one more electronic component, the resistor. Termistors, transistors, diodes can all be considered as variants of the basic resistor. In principle, therefore, it is possible to use electronics as a basis for addressing all modern everyday technology. Lessons of this type have been developed and tested by the present author in classes of 15-16 year-old students; preliminary results have been very encouraging. Since the knowledge apprehended was directly linked to a utilitarian use, meaningfulness and motivation was high.

**Artefacts and Black boxes**

The idea of the Black box is used in both Science and Technology education, very often to address something too complicated to handle thoroughly. When it comes to open up or to understand the Black box, scientists and technologists use different approaches. The scientist’s analytic way is to try to reduce the Black box to its elementary parts in order to study these in detail and understand the interactions that exists between them (de Rosnay, 1997). By modifying one variable at a time, the scientists try to infer general laws that will enable them to predict the properties of systems under very different conditions.

The scale is getting smaller and smaller, from molecules via atoms to subatomic levels. It is tempting to believe that if we know the innermost parts and the most fundamental laws, everything else can be deducted. Many scientists, especially biologists, do reject this as being a myth, however. They realize that the great complexity of real systems and the strong interactions of its diverse elements makes addition of properties difficult; 1+1 is not always 2.

A physicist uses the Black box model in a special way. Phenomena, like gravitation, are explained by a mathematical model. This use of a mathematical Black box has been debated and criticized ever since Newton published *The Principia* (Gingras 2001). Michael Faraday wrote to Maxwell: “Mathematics cannot of itself introduce the knowledge of any new principle”. Maxwell insisted that for him: “natural philosophy is and ought to be mathematics, that is, the science in which laws relating to quantity are treated according to the principles of accurate reasoning”. Mathematization contributed to the formation of an autonomous scientific field. As Mathematics is a language and foreign one, young learners very often are unappreciative for the abstract world of Physics.

In Technology the normal way of understanding the Black box is to investigate its interactions with the environment, how it is influenced by and what it is “doing” with its surroundings. The Systems box, well known
from technology education in many countries, uses the following description of a Black box: one or several inputs of data, an internal process or function and an output.

**The dual use of artefacts**

Technological artefacts are usually designed for a transformation of some part of the Nature, a tool for changing the world for some utilitarian use. This type of action could be termed “pragmatic” (Verillon 2000). Most technology curricula deal with these kinds of artefacts. The artefact embodies knowledge and may help an unskilled person to manage complicated tasks. The walking stick, the shovel, the calendar, the car and the computer are good examples. The development of the American manufacturing system was a way of dealing with inexperienced, temporary workforce, immigrants just waiting for a westbound train.

An artefact can be used as a mediating tool to help us investigate and understand the world. By converting aspects of the world not immediately accessible to us, it will enable us to detect, register, measure and make meaning to different kinds of phenomena. Gravity, electric fields and light are typical examples of what could be investigated and measured with the proper instrument. However, an instrument is a twofold entity comprising the artefact and the operator. To obtain the proper handling, the appropriation of an instrument, the user has to learn how the artefact interacts both with its object and with the user himself. This can be a time-consuming process. The digital instruments of today are very different from the tools of the pioneers of electricity. Alexandro Volta (1800) used his own body and no mediating artefacts when he described the effects of his newly invented battery:

“A person who now puts one hand into this water, and with a piece of metal held in the other hand touches the summit of the column, will experience shocks and pricking pain as high as the wrist of the hand plunged in the water, and even sometimes as high as the elbow.

It has been ascertained by repeated trials, that these effects are stronger in proportion to the greater distance of the metallic pairs, which are made to communicate… with a column of about sixty pairs of plates, shocks have been felt a high as the shoulder…

The sensible effects... do not, it seems, consist merely in shocks, contractions, or spasms in the muscles or limbs; but, besides affecting the sense of touch, they are also capable of exciting an imitation in the organs of taste, sight and even hearing.”
Some parts of the Science curriculum, like Mechanics, could be investigated without artificial instruments, since students benefit from a long experience with their own bodies and its interaction with gravity. Some teachers relate to this experience with good results. However, even the understanding of Newton’s laws could gain from the use of an appropriate artefact, as Jonte Bernard (1998) has shown, utilising computer-based instruments in lab work.

My hypothesis is that to be really effective and useful, the measuring artefact must be well known and the user familiar with its interaction with the phenomena in question. If we want to measure electric current, the artefact must be “mentally” connected to the concept of electricity. A lamp bulb or an electric motor may be appropriate tools for a teenager, but a digital voltmeter certainly is not.

Accurate measurement is a cornerstone of science, but is not considered a science of its own. Nevertheless, it is the most important part of technology, the foundation of regulation and control. Georg Stiernhielm, a Swedish poet and engineer, declared in 1648: “No one can deny that she [the art of measuring] is the most outstanding, most worthy and most indispensable of all arts known to man.” (“Så kan ingen förneka att hon [mättekniken] är den värdigste, ypperste och högnödigste av alla konster som en dödelig människa i världen lära må och bör.”) Most of the scientific discoveries of today are caused by better measurement technologies; in this respect science can be understood as applied technology.

The concept of measuring is very well suited for practical work and has also been tested on the same group of young students mentioned earlier in this paper. The final part of this paper will give detailed information on the experiment and present some results from observations and assessments of knowledge and attitudes of the students.

Method of investigation

The object of study was two classes in the Swedish compulsory school, ”Grundskolan”. The students were 15 and 16 years old and in their final, 9th year. The school subject was “Teknik”, the Swedish version of Technology Education. The original purpose of the project was to change girls’ negative attitudes towards technology, electricity and electronics in particular. Several international studies, interviews and inquiries show that girls tend to have a very low interest in these boy-dominated subjects. The literature proposes some remedies to the gender problem and together with a female teacher, I tried out several of them in a development project: gender separated classes, female teacher, context-rich problems, work in groups, diaries, oral examinations etc. The project was considered a success by students.
and the school staff and has been repeated several times with other classes. One of the “girls only” groups of 19 students was observed during 15 hours. Lab work was video-taped, interviews recorded and written inquiries were made. Diaries/logs were collected and analysed. Part of that data material is used in this paper to tell the story of what took place in this particular group of students.

In this study, Electric and Electronic components were handled as technological artefacts, Black boxes, with an emphasis on functional aspects. Education was inquiry-based with a lot of practical work in small groups of 3 or 4 girls. The objectives of learning were:

- How do these artefacts interact with the surroundings?
- How can these artefacts be used to solve a problem?

**Measuring devices**

We needed an instrument that could detect small currents and their direction. We decided to use a light emitting diode (LED) instead of an ordinary lamp bulb. Since it is a diode it has to be connected in the right way and it will detect current only in one direction. The high sensitivity of a LED facilitates the detection of small currents. To strengthen the relation between the students and the artefact, i.e. the LED-probe, the students designed and manufactured it by themselves, soldered the LED, the current limiting resistor, the wires and the connecting clips. A student’s own documentation is showed in Fig. 2.

![Fig.2 LED-probe](image)

The second measuring device, the Motor, was equipped with a large and easily visible red propeller and indicated both the intensity and the direction of an electric current. The two devices were considered Black boxes with a function of measuring intensity and direction of electric current. In the students’ diaries, several entries indicate that they understood and used the LED-probe, the lamp, and the motor as indicators of electric current:

"When you heat the legs of the thermistor, which is a resistor, it will open up for more current and the lamp will glow stronger”

"The propeller did spin. It was fun! There was some smoke, we got too strong current.”
“I’ve soldered the wires so they will conduct current… We will test the connections with a lamp. If the lamp glows everything is correct.”

“When you heat the thermistor, the resistance will be smaller and more electrons will pass and the lamp will glow stronger.”

“We connected a switch diode, which is rectifying. Then we had to connect the LED-probe in a correct way to make it light up.”

The third measuring artefact is procedural or intellectual; when you want to measure something, you must compare it with a standard. The task is to find a state, a position, of equilibrium between two entities, one known and one unknown. We therefore needed to find a method to compare two electric voltages. We asked the students to investigate how the intensity of a current related to potential differences. This is a very difficult area in the conception of electricity. Hans Niederer (1996, p. 16) studied the conception of pressure as an analogue to voltage and concluded:

“The following ideas get no resonance in students’ thinking:
– Pressure balance: two high pressures result in no movement.
– Pressure difference.
– Pressure in all directions; pressure in the backwards direction hinders movement…

These ideas are so crucial to understand voltage with the analogy of pressure and pressure difference. Only if students think of pressure going in all directions they can understand the importance of pressure of difference being responsible for the movement and current of electrons. Only by balancing pressures they can understand, that high pressure on both sides of a resistor means that no current is running.”

The LED-probe and the motor were at this stage habitual mediating tools that indicated intensity and direction of the electric current. The object of investigation, the artefact, was a resistance wire made of NiCr, suspended between two connecting posts on a rather long, 75 cm, wooden pole or batten. The wire, forming a kind of open potentiometer was connected to a 10V DC power source. The “Electric Pole” should preferably be standing vertically, making an embodiment of “high and low” voltage easier. The teacher used a metaphor of a waterfall and some notion about high and low pressure to introduce this new Black box. Explanations using this kind of model appear in the diaries of a small number of students.

The task for the student was to investigate the electrical properties of the artefact and to find out how current would change according to the placement of the two connecting clips along the wire. The following questions were asked:
• How would you connect the probe to achieve the brightest light?
• How should the connecting clips be placed to minimize light?
• If you move both clips up or down the wire, with the same distance, what will happen?

A majority of the students were able to find maximum and minimum values for the detected current and they explained how to find them, in their diaries, in text and in pictures as in Fig. 3

“The lamp is glowing strong when the difference in voltage is large. The light from the LED will be of the utmost brightness when the connecting wires are as far from each other as possible… It has to be a difference in voltage to make the lamp glow”

![Fig. 3 Intensity of light as a function of potential difference](image)

Some students used the term “pressure” instead of voltage as these excerpts from the diaries show:

”You keep the legs of the lamp far apart from each other, this will make the pressure difference larger. The voltage will also be larger.”

“When the lamp goes out there is no difference in voltage.”

It is of utmost importance to know that it is the relative positions, not the absolute ”altitude”, that matters. This example suggests that the student has grasped the idea:

“When you move the lamp back and forth with the same distance between the contact clips, it will glow with identical strength. If you change this distance, the intensity of light will change”

In the following transcript of a video clip, two students, “2” and “3” seems to have a working understanding; the third, “1”, is still revising her theories:
F: What will happen if you move the lower contact along with the upper?
3: It will be approximately the same pressure
1: … approximately the same (not confident)
   There it is such pressure, I don’t know.
3. The pressure will stay the same!
1: …It… will… stay… the same pressure, in spite of them being far away
   It will be higher pressure? (seeking eye contact with student 3)
F: So, the distance between them is important?
1: Well, I, I think so (uncomfortable), if my theory is correct (wags her head)
F: What will happen with the motor if you change the connectors (pole reversing)
2: If I take this (lower clip) and move it to that place, but then it will be lower, cause
1: Both of them are up high.
2: No, but it is a smaller gap (watching the motor)
3: It will be lower, I can feel it and the vibrations!
2: But it is because of the smaller gap, if I move the lower clip it will be higher

Girls number 2 and 3 seem to have understood the concept. Number 1 is seeking advice. This is something that is typical of girls only groups, “a willingness to ask for help and just as importantly a willingness to provide that help”. (Underwood et al., 2000)

An interesting fact of this class was that not one girl did notice that the propeller sometimes changed the direction of spin. A follow up test with a Peltier-element showed that no girl, nor boy noticed that one side of this component became cold while consuming electrical energy.

Electrical energy could be transformed into heat but not chill. This indicates that we observe using our experience of what might happen.

One of the girls asked the teacher if she and her mates were allowed to raise the voltage that supplied the resistance wire. Permission was granted, the wire became hot, glowing hot, started to shine with a white light and was burned out in a few seconds. The class was hilarious and every girl wanted to “make” a wire glow, wires were destroyed en masse, wooden poles burned and the students learned something very important. In almost all diaries this event was highlighted:

"When we connected it, all the wires became long and yellow, then we burned it.” “…and we also played, burned wires and pencils. It was great fun cause we were allowed to play with the electric current.” ” The most enjoyable moment was when we "blew up” the wire… we were playing with electricity!”
In the class with boys only, every group burned their wires, without asking for permission.

*To measure, the electrical pair of scales*

The students now were able to detect differences in potential/voltage. They were now invited to work together with an adjacent group. The “Electrical Poles” were connected to the same DC-source, giving them a common ground (Fig 4). The first group attached one of the connectors to the LED-probe somewhere on their pole and the second group tried to figure out where, on what altitude this was done. Almost all students knew or found the answer of how to succeed:

“When the lamp goes out there’s no difference in voltage!”

“You’ve found your mates position when the lamp goes out”

The instrument consisting of two potentiometers and a null detector is well known under the name of The Wheatstone’s Bridge. Charles Wheatstone presented this “Rheostat” to the Royal Society in London in 1838.

The concept of comparison is fundamental to all types of measurement technology, even the soundcards of modern computers uses the same principle and compares the signal from the microphone with an internal variable reference.

*Calibration of the voltmeter*

The next step for the students was to calibrate their “Electric Pole” with electrical sources of known voltages:

I have made a voltmeter [Fig. 5] and played with a solar cell, we used different batteries to calibrate the Electric Pole. I had great fun doing this. The solar cell produced 2.5 Volts in direct sunshine and 2 Volts in the shade.”
Some other students used sensors as thermistors and photo resistors to build voltage dividers that could be measured with the Electrical Pole. The calibrated tape could be substituted for new ones marked in Centigrade and Candela. The null detector could be improved by using a more sensitive motor. The null is very easily detected when the motor slows down and suddenly changes direction of spin. An amplifier made the null detection even more sensitive, very small error would show up and the error signal could be used to control a fan or some other form of actuator in a feedback control system.

**Discussion**

Most of the activities during this project could have been done in a Physics class, but the emphasis on technological concepts and functional properties seemed to have created a positive atmosphere where most students took the opportunity to experiment and play.

Playing with electricity was initially considered very dangerous and prohibited; girls seem to be very observant on rules of engagement in laboratory work. This is a correct attitude towards safety-regulations, but will deprive them of much experience and knowledge boys take for granted. As teachers we should have this in mind when we design practical projects and laboratory tasks. The event with the propeller and the burning wire are typical examples.

The idea of separating boys from girls was assessed by some girls in one of the interviews:

1: I think it has been more fun; well maybe not fun, but usually the boys are doing everything, we just stand there watching, as always!
2: They don’t think we can manage …they just want us to watch!
1: Yeah
3: Yes, now we took an active part, we were allowed to do much more.

Attitudes to “Teknik” were very positive, every girl used words as fun, enjoying, nice, amusing in their diaries. In one of the interviews a girl expressed her feelings:

“In the beginning I believed it would be boring, it’s boy’s stuff, but we started and when I was allowed to experiment and play it became great fun, I’d say this is important for us.”

Another girl expressed her positive attitude to the subject of “Teknik” in this way:

“In Math and Science there is only one correct answer, one way to do things, but in Teknik there are several ways of doing things and you are allowed to make mistakes.
The idea of a Functional Alphabet is not new in history and seems to have a strong importance for design abilities. Our idea of concentrating learning efforts on the functional properties of resistors and capacitors was successful in one sense. The students were able to analyse everyday technology and recognize possible electronic letters; the large capacitor in the camera flash, the photo resistor in the computer mouse, the potentiometer in the volume control etc. However the level of detail was too small to enable them to design and construct electronic apparatus on their own.

I am now planning a longer study on design and creativity with a material on a higher systemic level, the “Event boxes”. I will follow and observe a class of learners together with their teacher in a kind of action research. The students will be working on a large constructional project where differences in approach and method are probable. The teacher will be trying to assess product and process abilities according to the benchmarks and standards of the curriculum. What the project will help to understand, can be framed in terms of the following research questions:

- How do young learners use structural and functional knowledge?
- How is the concept of systems level experienced?
- Is the ability to use these two aspects of artefactual knowledge something that can be taught and assessed?
- How can this ability be described by product and/or process criteria?
- Is it possible to describe progressive stages in this ability?
References


WHAT RESEARCH ADDS UP TO
11. The Shaping of School Technology  
- Research on Technology Education from a Swedish Perspective

“Education in the subject of technology breeds familiarity with its essence.” (Quotation from the Swedish Compulsory School Curriculum 1994)².

The syllabus for the Swedish school subject of technology is ambitious. Pupils are meant to acquire a general education in and about technology, understand how technological artefacts and systems relate to everyday life and society, develop the ability to design and build constructions and to become familiar with the essence of technology, something that is of course open to interpretation. I understand the formulation as an urge to teachers and students to find something of technology’s specific, distinguishing, and knowledge-building components in the learning process.

In broader social debate, that children and adolescents understand technology and its role in social development is often ascribed critical importance, both to the lives of individuals and to social development. Several ambitious programmes are in progress aimed at sparking greater interest in science and technology. The Science and Technology for Everyone programme is one Swedish example directed at compulsory school teachers and pupils. Two prestigious academies, the Royal Swedish Academy of Sciences and the Royal Swedish Academy of Engineering Sciences, are promoting and steering the programme.

New technological systems are changing conditions for communication and the spread of information. Familiar patterns for where and how activities take place are metamorphosing. New artefacts are being incorporated into everyday routines. Devices are becoming more complex and loaded with information and knowledge. Technology is solving and creating environmental problems. New symbioses between science and technology are emerging. Technology touches the core of life. Technology appeals to us, pleases, worries, and challenges us.

¹ This paper is an edited and abridged version of a research overview done by Jan-Erik Hagberg, Linköping University, and Magnus Hultén, Stockholm Institute of Education. The Swedish Research Council has funded the study.
² This translation of the quoted sentence is more in accordance with the Swedish original than the official version.
Undeniably, an unusually exciting field of exploration for researchers is right before our eyes. There is a great need for research that constructs new perspectives and examines new approaches; research that may be theoretical and an aspect of reflection on the conditions of education in the post-modern society; research that may have to do with the nuclei of technological knowledge and be closely related to teaching; research that may involve practitioners of various kinds – teachers, engineers, technical researchers, artists and artisans – research that may focus on understanding of everyday technology or that may generate didactic perspectives on “technoscience” expressed as life sciences or media technology.

This paper discusses the evolution of such research. The empirical foundation is an overview I wrote with Magnus Hultén on behalf of the Swedish Research Council’s Committee for Educational Science. The Committee had noticed that few applications for research grants dealt with technology education and wanted to know what could be done to generate greater interest in the field and enhance its quality.

As we began the work, we were well aware that several developmental projects were in progress in Sweden and many other countries whose purpose was to define the content of technological literacy as a base for technical education. But were that kind of efforts supported by and grounded on research on teaching and learning technology as a school subject? We encountered a range of assertions from the people around us. Some even claimed that it did not exist – need I write that they were wrong? It does exist and it is intriguing and meaningful, however still at least in Sweden marginalized at the universities.

As an emerging research area it can borrow inspiration and vigour from the generally rising interest in research on subject-oriented education in Sweden. The trend has perhaps been clearest with respect to science education. Nowadays, there is also relatively extensive experience with subject-oriented education research at several Swedish universities. It is to be hoped that the expansion of research on subject-oriented education reflects growing interest in problematising and re-examining the content of various

---

3 “Didactics” as research on teaching was conducted in Sweden throughout 20th century, but was relatively tenuous and mainly descriptive (Bengtsson, 1998 pp 141-172). Nowadays, its hallmark is that the content of a subject/field is being put in focus for research and the Swedish term “didaktik” is more consistent with the English term education. There are eclectic features; a variety of pedagogical, sociological, philosophical, theoretical and methodological approaches are mixed.

4 For instance at Uppsala University, Göteborg University, Umeå University, the Stockholm Institute of Education and Kristianstad University.
educational programmes. In the area that I am addressing – learning and teaching in technology – a critical discussion of content is unavoidable. Teachers have no given, generally accepted subject core upon which to build. At the post-secondary level, technology appears as specialised technical disciplines. Swedish schools lack a tradition of a cohesive subject; technology has been a required, independent subject for only ten years. The difficulties inherent in developing a subject identity have been obvious.

For technology educators, it is also noteworthy that humanistic and social science research on technology has generally broadened in scope and is increasingly focusing on issues of knowledge and education. There are several examples to be found, including within gender studies (Berner, 2003). In the wake of new information technology, there is growing interest in how schools are using technical tools in teaching and in how knowledge represented through/in/by ICT-based tools is perceived and learned.

**Technology as a school subject - tradition and subject formulation**

Practical subjects were introduced in Swedish schools in the late 19th century, marking the beginning of the school’s transfer of knowledge of a technical nature to pupils. In manual arts classes, for instance, boys and girls encountered newfangled inventions like sewing machines, carpenter’s benches, and electric saws (Hartman, Trotzig et al., 1995). Content, emphasis, and programme methods have obviously varied according to what was regarded in each era as relevant in relation to working life, industry, and the needs of the individual and society. The subject of manual arts in particular, with its ambitions to teach fundamental understanding of tools and materials, is one of the traditions upon which the modern subject of technology is built.  

5 The legacy of manual arts education illustrates the nearly inevitable insertion of technology education into the gender order: boys went to wood and metal shop classes, the girls to sewing and textile arts. In the first half of the 20th century, subjects such as home economics, local history and folklore and eventually geography gave pupils fundamental technical knowledge. Technological knowledge was also addressed in subjects such as Swedish, reading, and social studies, something one can see illustrated in classroom wall charts and primers.

The Swedish compulsory school system was developed in the late 1950s and early 1960s, an era when industrial growth and technical development were central policy issues. Belief in scientific and technical knowledge as

---

5 See, e.g., Lindström, 1984. He writes that the original focus of the manual arts subject on technical skills that began in 1920 is declining and that the subject is becoming more oriented towards aesthetics and general education.
wellsprings of prosperity ran high. In studies and curricula, the schools were tasked with educating labour for a modern industrial society. The foundation was optimism about the future and technology was seen as critical to prosperity. Anders Westlin has shown that there are two dominant discourses to speak of: technology and science were regarded as outer forces that reshaped the lives of individuals and therewith their need for knowledge, while social problems were regarded as the business of scientifically trained experts. The “modernisation discourse” and the “technocrat/expert discourse” are both present in the discussion of basic schooling for the rest of the 20th century and characterised the view on technology education in the schools. But there are competing, or rather complementary discourses. When the risks of modern technology became a pivotal issue in the political debate of the 1970s, demands that the schools should also address the social impact of technology flourished. Westlin speaks of a “colonising” discourse in which technology and its rationality are regarded as a threat to core human values. In this discourse as well, however, technology is understood as an outer force, a force not subject to influence in the normal social and cultural sphere. Therewith, it also becomes difficult to deal with critically in the school setting.

In contrast to views in which technology as seen as “a thing apart” stand those which emphasise that technical systems and artefacts are components of social systems and are developed and ascribed their value in interaction between various social actors and individuals. Technology is thus regarded as enduringly social and as a phenomenon utilised to gain and exercise power. The potential, limitations and risks of technology should accordingly be aspects of continuing social debate. Westlin discusses two points of view, or rather lines of argument. The first stresses that a communicative social dialogue on technology must be conducted, the second that technical, rational thinking must be responded to with a different “rationality” because a given (technical) solution always entails unintended and unwanted consequences.

These various perspectives meet in the ambitions expressed in curricula and textbooks to impart technological knowledge to children and adolescents. When the Swedish compulsory school system was established in 1962, the dominant discourse was that of the optimism of progress. One question was how the schools could impart knowledge that facilitated individual adaptation to the “high speed changes” brought about by science and technology. A few themes were introduced in a 1961 government report, “The

---

6 Anders Westlin (Westlin, 2000) has explored the presence of technology-related questions in socially oriented subjects during the 1990s.

7 The expression is borrowed from one of the grand old men of Swedish education research, Thorsten Husén, 1961.
Compulsory School,” that later recur in the debate on education: the schools must provide general education in technology and science; such knowledge is also the basis for social orientation; pupil interest must be “aroused”; individuals must learn to master the technical tools of the modern era (Westlin, 2000 p. 142). The 1962 curriculum did not separate science education from technology education; technology was emphasised as applied science. Differentiation between the two was introduced in the higher grades of compulsory school: eighth-grade pupils could choose technical electives such as ‘introduction to technology and engineering’ while a specialised technical/practical programme was available to ninth-graders (Elgström and Riis, 1990 pp 15-19). The attitude towards technology education was thus divided. On the one hand, technology was regarded as applications within the science subjects and teaching was meant to be within those subjects while on the other hand, technology was seen as applied, vocationally oriented practice that should be addressed in separate subjects/variants.

There were no critical changes in the next compulsory school curriculum (1969), but progress towards introducing general technology education can be noted. Technology in everyday life is incorporated as a main section in the local history syllabus. Teaching is to be based on pupils’ own observations and to deal with how machinery and devices work (Westlin, 2000 p. 148). The science syllabus states that the goal of the subject is to provide an introduction to natural phenomena and technical phenomena, as well as to human beings and their status in the worlds of nature and technology (Andersson, 1988 p. 19).

Technology became an obligatory subject in the next compulsory school curriculum (1980), although it was incorporated into the science-oriented block. In terms of content, focus was on the “rising importance of technology in the everyday lives of pupils”. Vocationally oriented technology education is eliminated and environmental aspects are introduced. Compared with past curricula, it is clearer that teaching is meant to address the social aspects of technology. One critical difference from previous years is that technology education is now to be provided in earlier grades as well. One purpose of the expansion of technology education was to make it gender-equal in relation to the choices and interests of boys and girls (Richardson, 1985; Skogh, 2001 pp 24-27). Despite its status as a subject in the curriculum, technology education hardly gained “subject nature” if by that one means education whose content, at least in a number of core areas, is consistent from one school to the next. Elgström and Riis believe that the lack of a penetrating and general discussion of what the new subject should contain led to varied interpretation in the schools and the annexation of the subject by various teacher groups on pragmatic grounds.
Still, when technology education became obligatory in the compulsory schools in 1980, it led to the problematising of content and teaching methods. When technology later was given its own syllabus in the 1994 compulsory school curriculum, more extensive continuing education for technology teachers was commenced. Different schools adopted different solutions for how technology education should be organised; perhaps the most common was that it remained part of science education and thus was shaped by the view that technology is either applied science or a tool for science. The relationship between technology and science has ever since been one of the central issues in the debate on technology education in the schools. The 1994 syllabus, however, emphasises that the subject of technology belongs to a different tradition of knowledge. Teaching should be characterised by an exploratory, development-oriented method in which drawings and designs are used in tandem with analytical reasoning. The syllabus also says that technology should be dealt with in its context, i.e., studies should include the everyday and social aspects of technology. Technology education should endeavour to illuminate a number of central perspectives, regardless of the area of type of technology, rather than strive to cover wide areas. Examples of the perspectives mentioned include development of (new) technology, humankind/technology/nature, the tasks of technology, components and systems, design and mode of operation (Ginner, Mattsson et al., 1996 pp 24-33).

Technology as a subject-didactic field of research, clarifications and definitions

The general subject of technology in Swedish compulsory schools has thus grown out of several different traditions of knowledge - manual arts (e.g. wood-, metal- and textile-sloyd), industrial arts (e.g. vocational technical training), everyday life (e.g. home-economics and local history) and humanistic and social studies. The content of the subject crystallised in the encounters between those traditions, but also as a consequence of a general social debate on the modern or post-modern society’s relationship to and

---

8 Curriculum for 1994. Revised in 2000 (www.skolverket.se/kursplaner/grundskolan/amnen/teknik) Text in English is available. The syllabus covers the entire compulsory school system and states goals for grades 5 and 9. Continuing education of teachers in connection with the implementation of the 1980 curriculum is discussed by Andersson, 1988 pp 61-64. There are now university courses intended as advanced education for teachers in the subject of technology, usually providing 5 credits, but there is also a 20-credit programme.

9 The history of the development of upper secondary and vocational programmes in technology is different and is not covered by this paper. See, e.g., Berner, 1989 pp 28-34.
dependency on technical progress and technical knowledge. It would indeed have been surprising if the result had been generally accepted subject content and nature. In addition, representatives of the subject have not been able to seek guidance on content from academic subject departments, as there is no education or technological scientific research within a “general” technology subject at the university level. Fundamental educational questions – what content, what methods of teaching and learning, for whom and on what grounds choices of content are made and who should influence those choices – are all open to alternative answers.

When the question is expanded, it becomes clear that research on teaching is in several respects part of research carried out within the philosophy of technology. Technology educators should thus also follow Carl Micham’s motto by thinking through technology and taking the path between engineering and philosophy, which entails clarifying the characteristics of knowledge in technology and analysing how technology is incorporated into other fields of knowledge and into social conditions (Micham, 1994).

**New technology, new education, new general knowledge?**

All research into subject-oriented education must basically relate to how the area of knowledge one is dealing with changes. It may perhaps be a peculiarity of technology education research that the field of knowledge changes in such an extraordinarily complex way. If we presume that technology as a subject consists in part of a large number of sub-areas that are rather dissimilar and in part of a set of general principles or phenomena that are shared and work as a cement between the sub-areas, a fundamental didactical question becomes how shifts over time between new and old sub-areas take place and how the general principles change. It can be claimed that technology and its sub-areas are changing paradigmatically: technical artefacts are becoming increasingly “intelligent”, new materials are changing both the mode of operation and the scale of technical constructions, user knowledge is becoming more important to how artefacts and systems can work, knowledge and information systems are being decentralised, the boundaries between technology and science are dissolving as technical systems become critical to representing scientific knowledge (Ihde, 1998; Dourish, 2001; Ihde and Selinger, 2003; Hagberg, 2004).

Issues of learning, communication of knowledge and warehousing of knowledge have become increasingly central in university programmes in information technology, media technology, and cognitive science. There is research into those questions that can be labelled as technology education research, but usually is not. I would like to draw attention to two clear tendencies. The first and familiar one is that methods of learning and teaching
are becoming more dependent on information technology devices. Research and development projects on the potential and limitations of using technical tools in various educational programmes are increasing. The second and less obvious tendency may very well change how the content of technology education is understood. In pace with the incorporation of increasingly sophisticated information and communication technology in virtually all artefacts and technical systems, the need for knowledge is changing, both for those who develop technology and for those who use it. It is becoming more important to be able to understand and use advanced interfaces between human and machine. The artefacts contain increasingly advanced knowledge of various types and application of that knowledge is either automated or routinised or, which is more pertinent to technology education, presume various kinds of exchanges between the user and the technology (Dourish, 2001).

The advent of new technology changes the requirements for what is characterised as general knowledge. But the requirements are also changed as a consequence of public policy and social debate. In such matters, technology education research can lean on research into “Public Understanding of Science and Technology” (PUST). PUST was introduced in the 1980s, driven by ambitions to find an approach to increasing public understanding of science and technology and therewith, it was hoped, also increase acceptance of research and education.10 PUST research is less normative these days and often deals with how the public (and policymakers) should be able to participate in a dialogue with researchers on how scientific and technical knowledge impact social conditions. Therein, PUST has become a branch of wider research into the sociology of science, which addresses how science and technology are understood in their social and cultural context. One can also assert that PUST is a branch of technology education research because they share an interest in the content of general technical knowledge as well as its relationship to specialised technical knowledge.

**In and about technology**

The relationship between general and specific knowledge about a particular technology is an intriguing question of education and knowledge theory. Likewise, the relationship between knowledge in and knowledge about technology is worth problematising. The school’s mandate is to impart both

10 The first programme text published by the Royal Society in 1985. The main purpose was to pave the way for greater understanding of science by increasing public knowledge. These days, PUST is usually rephrased to “Public Engagement in Science and Technology” (PEST) to emphasis a shift of perspective from citizens as recipients to citizens and social actors as shapers.
knowledge about technical methods, concepts, theories, methods, materials, designs, etc., and knowledge about technical artefacts and systems as parts of everyday life and as woven into social and cultural conditions. Accordingly, talking about knowledge in and about technology is perfectly justified. My essential position is, however, that while that distinction may be justified in order to emphasise the breadth, it is less appropriate for analytical reasons because it solidifies a division into a technical and a social scientific approach to the content of technology education. Accomplishing the integration of various dimensions of knowledge in/about technology is also a primary didactical issue. For that reason, I usually write knowledge in technology but ask the reader to keep the breadth in mind.

Consequently, I define technology education research as research that deals with how people learn skills and knowledge in technology, how teachers teach technology, the content of learning and teaching, what knowledge is central and which contextual circumstances are significant to learning and teaching technology. In so doing, I stretch the limits of the concept of didactics and allow it to cover both teaching and learning. As I also apply a broad definition of what constitutes knowledge in technology, my area of focus is extensive. How the boundaries to other fields of research are changing is to a certain extent a separate research question.

Therewith, I have stated a platform for future discussion of Swedish and international technology education research. The development of technology education benefits most from a diversity of research approaches and openness towards what technology education research is or should be. This is no obvious conclusion, at least not for the schools; one can assert that technology education primarily needs research support to develop concepts and methods that are closely related to the subject. But even if one makes that prioritisation, one quickly lands in the midst of contextual issues because there are always two sides to technical expertise and understanding – knowing how technology works and can be constructed and knowing why a particular technical solution is interesting and meaningful.

**International research on learning and teaching in technology**

I will now move on to review and discuss technology education research. In this section, I deal with international, English-language research and in the next section will provide a brief overview of Swedish research to date, primarily as it appears in published monographs.

---

11 See Bengtsson, 1998. It is now usually the rule to allow the concept of “didactics” to include learning as well as teaching and more or less coincide with the English term “education”.
Under the general term *Technology Education Research*, the field has been a relatively well-established outside of Sweden for at least a decade, if one looks at the occurrence of international journals and scientific conferences. But most people believe that the tradition of technology education research is still considerably weaker than others, such as that of science education (McCormick, 1999).

A few overviews of the field of technology education research have been written. In 1997, Karen Zuga published the results of a review of papers and dissertations in the United States from 1987 to 1993 (Zuga, 1997). She concluded that the bulk of research dealt with the design of syllabi and other documents that guide technology education. Most studies were descriptive and many were based on classifying statistics. Only isolated studies addressed how teachers taught or what pupils actually learned. Stephen Petrina came to the same conclusion after reviewing papers in the *Journal for Technology Education* 1989-1997, as did Marc de Vries after reading the contents of the *International Journal of Technology and Design Education* 1994-2000 (Petrina, 1998; de Vries, 2003). Both call for research that focuses on what happens in the classroom and on how teachers actually teach technology. De Vries found more research on teaching than he expected, but nevertheless concludes that research questions should be guided more by what teachers need to know and that the research should help teachers towards a more comprehensive understanding of how and what pupils learn. He believes the lack of knowledge about how pupils understand technical/technological concepts is a critical barrier to improving teaching. He gives the following example:

“Do pupils recognise that a washing machine is something that has input, process and output? Or do they consider it to be a collection of nuts, bolts and other parts? We simple do not know, and to the best of my knowledge *there is no research programme anywhere in which this research has been planned for*” (de Vries, 2003 p 204) (emphasis mine).

Karen Zuga’s review of general technology education in American schools in the 20th century illustrates the importance of a historical perspective. One interesting connection to the Swedish tradition is that the direction of Swedish manual arts education influenced American *industrial arts* programmes in the schools early in the last century. The main line was nevertheless

---

12 The American *Journal for Technology Education* and the European *International Journal of Technology and Design Education* are the two leading journals in the research field.
that the contents of technology education were taken from vocationally oriented technical programmes. That has been the case even after 1980, when the official objective became for the schools to provide general technical education and an understanding of technology as a social phenomenon within the framework of a general subject. Initiatives have been taken during certain periods towards changing the grounds of technology education, but none of them lasted; the traditional form and content abided. Zuga’s main explanation is that technology education in the schools has culturally and socially belonged to or been pursued in close relation to vocational programmes. Teachers and educators of teachers have adopted the view on education that characterises industrially oriented vocational programmes. Zuga particularly emphasises that the strong male dominance in the area has suppressed interest in technology among girls and women (Zuga, 1997; Zuga, 1999).

The research overviews I refer to deal with papers and dissertations published up to 2000 at the latest. Our general review of the contents of international journals in subsequent years (2000-2004) shows greater variation in the research than is evident in the summaries of the reviews. I cannot judge whether this is because the reviews stress uniformity or because the field of research has developed. The latter is supported by the greater attention accorded the issue of children and adolescents’ learning of science and technology in political debate and that many countries are engaged in long-term, goal-oriented programmes aimed at making children and adolescents more knowledgeable. 13

Several papers in more recent editions of the Journal of Technology Education demonstrate ambitions to connect to the wider discussion within the philosophy of technology. Richard Walton begins with Heidegger’s classic text from 1954 The Question Concerning Technology when he discusses the nature of informal learning of technology at science centres. Heidegger provides arguments for the necessity of the combination of critical reflection and creativity in technology learning (Walton, 2000). John Williams compares the difference between the ontologies of science and technology in his paper Design: The Only Methodology of Technology? (Williams, 2000). W.J. Haynie addresses lack of equality and discrimination against women technology teachers in Gender Issues in Technology Education, but that particular paper, although it has several merits, lacks any connection to general gender theory (Haynie, 2003).

13 For instance, the American “The American Association for the Advancement of Science. AAAS project 2061 in science, mathematics, and technology” and the Swedish KVA/IVA project Science and Technology for Everyone (NTA).
Three leading researchers in the field produced a follow-up of research overviews in 2004. They assessed the main lines of argument in submissions to the three major international conferences (Middleton, 2004). They found that an emerging significant theme was what pupils learn and how learning can be achieved in various educational settings, thus in part that which de Vries had called for. Their discussion led to a special issue on pupils’ learning in the International Journal of Technology and Design Education.

Several papers in the special issue declare that research on learning in technology is “undertheorised” and that it would reasonably gain by utilising modern theories on learning. The papers illustrate the ambitions to contribute to more distinct incorporation of technology education research in an educational/didactical main line. Lines of demarcation familiar in science education research emerge. John Stevenson, for instance, questions whether technical knowledge can be acquired at all by means of the transfer of general knowledge from books and teachers to pupils. He criticises endeavours to develop general timetables, theories and concepts based on cognitive science research or analytical attempts to crystallise core knowledge. They lead to one-sided simplifications because it is extremely difficult to make those abstractions meaningful to pupils. He argues for process-oriented learning in which pupils move between concrete examples and overarching concepts such as systems, materials, processes and information. Stevenson believes that teaching in technology must always encompass the context of technology, begin with the meaning of artefacts to pupils, build on the notion that learning takes place in exchange with others, and that the activity itself must harmonise with the purpose of the learning. He cites sociocultural theories and what he calls “cultural-historical-activity theory”, which I see as emphasis on learning as an activity that takes place in a practice with open agendas that compete with the hidden (Stevenson, 2004).

McCormick’s argument is similar. His thesis is that technical knowledge is primarily qualitative, i.e., it is predicated on clear connections to the areas in which it is learnt and used (McCormick, 2004). Papers by De Miranda and Zuga illustrate a partially conflicting view on learning in which the prerequisites for individual learning are central. De Miranda and Zuga argue that knowledge in cognitive science should be the basis for developing concepts and knowledge timetables and for making them cohesive (De Miranda, 2004; Zuga, 2004).

Howard Middleton, Marc de Vries and Fernando Cajas.
Summarising discussion of international research

**Breadth and basis**

We have only assessed research published in English in English-language journals and conference documents and I thus cannot comment on international research as a whole or on the situation in individual countries. In his review of papers in the *International Journal of Technology Education and Design* (published by the Dutch publishing house Kluver), Marc de Vries found that the majority of papers were written by researchers in the United States, Canada, England, Australia and New Zealand, with a few written by researchers in the Netherlands.\(^{15}\) One of the express goals of Davis Jenkins, editor of the journal from 1990 to 2000, was to expand the international character of the journal, something that was obviously not easily accomplished.

One interesting question is the extent to which technology education research utilises and contributes to other subject-oriented education research and to more general educational/didactical research on public education. We have not been able to explore the subject in greater detail, but everything seems to indicate that such contributions are exceptions.\(^{16}\) The same one-sided relation seems to exist towards the philosophy of technology; very few researchers in technology education contribute, in spite of their general interest in the epistemology of technology.\(^{17}\)

**The development of research and central issues**

I have so far described the field of technology education research through a number of examples taken from researchers who are part of a relatively small international network. For that reason, the discussion has its given limitations; focus orientation, questions and theoretical points of departure are implied. The examples do not entirely do justice to the diversity of the field.\(^{18}\) With that reservation in mind, I would still like to describe the development of the field of research in general terms.

\(^{15}\) Eighty-five percent of the papers were written by researchers from the first five countries mentioned.

\(^{16}\) A search in the ISI Web of Knowledge for some of the authors published in 2003-2004 in IJTDE returned few citation hits. We have found citations in a few publications within Science Education (mainly the Journal of Research in Science Teaching, *International Journal of Science Education* and *Science Education*) and a few in Educational Research.

\(^{17}\) One exception is De Vries, 2003.

\(^{18}\) A few additional key references are Heinz Ullrich, 1973, Eggleston, 2000, Owen-Jackson, 2002, Theuerkauf and Graube, 2002. Examples of other studies of integration of technology and science in teaching are found in Zubrowski, 2002.
The research has long had difficulty asserting its importance in relation to a pragmatic field of education populated by teachers and planners with tenuous academic roots. Zuga, for instance, believes that how traditional vocational programmes (“industrial arts” in the United States) understand the knowledge to be taught has impregnated the view on the contents of technology education in the schools. The breakthrough of the new educational plans’ emphasis on general knowledge in technology has been impeded. One can thus speak of a cultural lag that has slowed down the revitalisation of technology education in American schools. There have also been attempts to mark the changes of emphasis in other countries like England, where the concept of design has become central to putting stress on technical expertise as the ability to design and create. The gap between research and “practice” is also discernable if one looks at the content of research; for a long time it was concerned more with the general pre-requisites and goals of technology education than with its everyday content and practice. Zuga has called for teacher involvement in research. De Vries has challenged researchers to take up questions that are relevant to teacher practice.

Emphasis has shifted in recent years and these days priority seems to be on research that addresses the prerequisites of learning in technology. Researchers have thus followed a general current in education research and other subject-oriented education research towards an interest in problem selection, question formulation and material content. Therewith, how teachers teach, how pupils learn and questions of how creative learning environments can be created have come into focus, as have concrete questions of content: what skills and knowledge in technology are essential and how should the content be organised to facilitate learning? Influence from science education research is clear. The parallels become distinct, for instance, when one looks for development and clarification of terms and concepts that can organise knowledge in technology and a stronger connection to the theories of cognitive science.

There is however no consensus to be found. Some researchers are examining a variety of cornerstones in general technological knowledge and are looking for integrated concepts. Others assert in a sociocultural spirit that the hallmark of knowledge in technology is precisely its context-dependent nature; it is thus uncertain whether pupils can transfer insights, terms and skills within one area of technology to another or one technical construction to other areas or other artefacts. Authenticity in learning is considered necessary.

Keeping in mind the latter position, one might suppose that extensive research on learning within specific areas of technology had high priority.
Some such studies do exist, including studies of learning in electronics, robot designs, properties of materials, agricultural technology and biotechnology. But its scope is minor compared with studies that apply to the general conditions of technology education in the schools.

The issue of the connection between technology education and acquiring knowledge in science is often explicitly and implicitly present in technology education research. There are a few basic positions here. One is the often unexamined belief that technology and science are essentially the same thing. It can result in research that does justice to the knowledge traditions of neither the sciences nor technology. The connection in research and teaching is often institutionalised in that curricula, conferences and journals treat science and technology as one field, with common problems and questions. It seems, at least when it comes to research, that the boundary is mainly problematised and maintained by those oriented towards technology, while those who focus on science rarely think it is meaningful. The latter often treat interest in technical artefacts and systems as a means for bringing science closer to reality and therewith making it more interesting.

A great deal of energy has thus been devoted to arguing on behalf of the separate nature of technology and thus that research within technology education is in qualitative terms something other than research in science education (Ginner, Mattsson et al., 1996). The argument has been that engineering and technology have a different (and older) history than science and that technology is based on entirely different premises and asks different questions than science. Naturally, the strong bonds between scientific and technical knowledge that have existed since the 19th century cannot be denied. Ginner summarises the connection as follows: “Technology and science are basically two separate domains,…which are now close to or partially overlap one another. Science often has to be repackaged so it can be used by the technician. David Layton et al. have asserted that such repackaging must also take place when it comes to technology education in the schools” (Layton, 1985; Ginner, Mattsson et al., 1996 p. 26).

The question of relationship has become increasingly complex in recent years, or put differently, it has become more difficult to determine whether knowledge is technical or scientific. The reasons are many, but in several new fields of knowledge such as the life sciences, technical and science research are integrated in such a way that the one is always predicated on the other. One of the most dynamic fields of research within the philosophy of technology and the sociology of technology is technoscience, i.e., research and development whose hallmark is the integration of technology and science. Naturally enough, this often triggers hopes that technology education at various levels could also be developed through new links bet-
ween the two areas. J.L. Bencze recounts a thorough example in *Technoscience Education: Empowering Citizens Against the Tyranny of School Science* (Bencze, 2001).\textsuperscript{19} Perhaps one can see it this way: as teaching in technology ever more naturally incorporates technical knowledge in a social and cultural contextual understanding (Petrina, 2003), it becomes easier to move back and forth between the different ways that science and technology ask questions.

**Swedish research**

If one looks at Swedish technology education research from the international research scene, the resulting impression is one of lack of presence. We have found only one paper in the leading journals written by someone working in a Swedish university department.\textsuperscript{20}

This does not mean that Swedish technology educators lack international contacts. The Stockholm Institute of Education, for instance, has a multiyear cooperative agreement with German and Polish researchers.\textsuperscript{21} The Swedish National Centre for School Technology Education (CETIS) is part of an international network and is collaborating with several English, Dutch and Australian universities.\textsuperscript{22}

It is of course also entirely possible that Swedish research to date has been inspired by research abroad, but that Swedish researchers have despite that fact not published their findings internationally. One possible explanation is that education research tends primarily to address issues that are topical in the national debate on education, and is performed with the express purpose of primarily being relevant to various actors in the Swedish school system (especially teachers). This may have been reinforced by that technology education in general and technology as a compulsory school subject in particular have for nearly twenty years been regarded as incomplete in content and form and therefore in need of basic development and skills-enhancing continuing education for teachers.

\textsuperscript{19} Examples of other studies of integration of technology and science in teaching are found in Zubrowski, 2002.

\textsuperscript{20} Alison Druin and Carina Fast at the Swedish Royal Institute of Technology report the results of a project on methods of developing children’s storytelling about technology in the *International Journal of Technology and Design Education* (Druin, 2002).

\textsuperscript{21} See, e.g., the Rogala and Selander anthology, 2003. It is based on collaboration with technology educators in Poland (Krakow).

\textsuperscript{22} For instance, the Department of Education at Brunell University, Eindhoven University of Technology and the Center for Learning Research at Griffith University.
Swedish doctoral dissertations (and one Norwegian)\textsuperscript{23}

With my broad definition of the field of research, there are a significant number of Swedish doctoral dissertations relevant to learning and teaching in technology. I will remark here on about ten of them, most of which were published in the last decade, although the first dissertation I would like to mention is from 1981: Boel Berner’s *The world of technique: technical change and technical labour in Swedish industry* (Berner, 1981). Berner primarily discusses the content of technical and engineering work and how the Swedish engineer appears as a member of a profession. The dissertation does not directly discuss issues of education or teaching, but it does introduce a new research interest in the content of technical knowledge. In several later publications, Berner put technical knowledge into the educational setting. In *The Roads of Knowledge: Technology and learning in Schools and Working-life* she explores technical vocational programmes and in *Gender, Technology and Science in Schools* girls’ interest in technology and science and how girls perceive and act in relation to the school’s organisation and provision of teaching in science and technology (Berner, 1989; Berner, 2003).\textsuperscript{24}

The first dissertation to directly refer to technology education in the schools is Yvonne Andersson’s study of the introduction of the subject of technology to Swedish compulsory schools in the 1980s, *Technology as a Subject in the Compulsory School* (Andersson, 1988). Anderson analyses the goals that compulsory school technology education is meant to fulfil and studies teacher and pupil opinions on teaching in technology. She points out a number of circumstances that led to the weakness of technology education: goals were vague, many teachers lacked education and knowledge in technology and some had no interest in the subject content, and it was difficult to establish a new subject in a time when subject integration was a main issue.

There are parallels to be found with a considerably later dissertation, Britt Lindahl’s *Lust to Learn Science and Technology?* (Lindahl, 2003). Lindahl’s subject is how pupils’ interest in science and technology changes in the latter years of compulsory school and how their attitudes relate to the very strong social interest in getting more adolescents to choose science or technical programmes. Lindahl finds that pupils are interested in technology and science, but are more interested in other subjects. One conclusion is

\textsuperscript{23} Most of the books mentioned in this and the next section are in Swedish. An English summary is included in the thesis. The translated titles mentioned in the text are sometimes shortened. The full Swedish book title is given in the reference list.

\textsuperscript{24} See also Berner, 2004 and Salminen-Karlsson, 1999.
that the content of education is less problematic for pupils than are teaching methods. Lindahl makes no clear distinction between school education in science and technology, but refers mainly to science-oriented education. Accordingly, it is difficult to determine the relevance to the subject of technology in the compulsory schools.

The most penetrating exploration of technology related education in relation to certain specific social and educational policy values is found in Anders Westlin’s dissertation *Technology and Political Action. Rationality and Criticism in Social Studies Education*. Westlin discusses how social debate and political control of content have an impact, particularly in textbooks used in social studies at the compulsory school level. The dissertation is of particular interest here because it inquires into statements on technology and the nature of technology in subjects other than those that are explicitly technology-oriented. I recounted part of the content in a previous section (Westlin, 2000).

Per Gyberg takes a similar perspective on how the content in school subjects is formed in his thesis *Energy as an area of knowledge – on practice discourses in school*. He has investigated how energy, as a societal phenomena, is interpreted and dealt with in teaching and what is considered to be valid knowledge. Two main discourses dominate and correlate to school practice – a scientific and a supply discourse. Gyberg notes that technology teaching, with its common focus on problem solving, there is a tendency to give an optimistic view of the possibilities to deal with energy and environmental problems (Gyberg, 2003).

The gender dimensions of technology education in compulsory schools are thoroughly explored by Inga-Britt Skogh in her dissertation *Technology and Girls’ World*. She reports the results of interviews with girls age 7-12 about how they “think, talk and feel” about the technology they encounter at home and at school. She finds that girls have a keen interest in technology as long as they get to choose the technology of interest (Skogh, 2001 pp 243-251).

Somewhat unique in its focus on children’s basic learning of technology is Jan Sjögren’s detailed study of how children understand and use simple technical tools and constructions, *Technology – A transparent or black box: To Use, See and Understand Technology – a Question of Knowledge* (Sjögren, 1997).

We have not surveyed the occurrence of dissertations on technology education in the other Nordic countries, but Berit Bungum’s 2003 dissertation, *Perceptions of technology education: A cross-case study of teachers realising technology as a new subject of teaching*, should be given particular mention because it is so closely linked to the Swedish discussion. Bungum
performs a broad review of technology education in Norwegian schools and, like Westlin, discusses how different political perspectives, educational traditions and perceptions about technology influence the content of the syllabus. The main part of the dissertation, however, applies to how teachers approach and carry out the task of introducing the new subject of technology. Her findings include that teachers’ intentions and ambitions are highly significant. She also studies how influences from English technology education’s focus on design are transformed when they converge with Norwegian teaching culture and thus illustrates the importance of comparative (cross-cultural) studies (Bungum, 2003).

**Other Swedish monographs of particular interest**

The development and introduction of general technology education in Swedish schools has been documented and discussed in several studies by Ulla Riis and Ole Elgström (Elgström and Riis, 1990). They claim that technology education has been assigned different and to a certain extent contradictory tasks: Should the user’s everyday needs or the technology producer’s interest in knowledge be the guide? Is the goal to impart general education or specialist knowledge? Should we be most interested in the social and cultural impact of technology or in its building and creation? Can technology education teach experimental, investigative methods that will benefit other school subjects? Does the school teach technology in order to increase interest in engineering education later in life, or to strengthen the civil knowledge required to exercise democratic control over technological progress? Riis and Elgström’s observations show that representatives of various knowledge cultures may have utterly divergent views on the goal of technology education. Some emphasise that technology is part of science education and should therefore have a theoretical orientation, others that it is part of manual arts education and thus should be seen as part of the tradition of manual craftsmanship and still others that it is about practical, vocationally oriented technical knowledge.

The anthology *Technology in Schools, Perspectives on the School Subject* edited by Thomas Ginner and Gunilla Mattson was published two years after technology became a defined subject in 1994. The papers in the anthology contribute to the discussion of the content of technology instruction and some also provide suggestions for teaching (Ginner, Mattsson et al., 1996). A sequel to the anthology, with clearer focus on research issues, is planned for publication in autumn 2005.

The most exhaustive study of how technology as a compulsory school subject has evolved since 1994 is Gunilla Mattsson’s licentiate thesis *Technology in Things and Thoughts: University students in teacher training reflect on pupils’ answers about the school subject technology* (Mattsson,
2002). Mattson interviewed student teachers, teachers working in the schools and pupils about their views on the content and form of technology education. The resulting picture is not entirely unambiguous, but the lack of clarity about the content of the subject is obvious in all three groups. The student teachers emphasise a practical, down-to-earth organisation of instruction while the teachers stress that teaching must be fun for pupils (and they believe it actually is), while it should also provide theoretical connections. The pupils aren’t sure what technology education is, but many have nevertheless become more interested in technology. Mattson asserts that the goals for the subject should be clarified and that the social consequences of using technology should be dealt with more clearly.

One branch of research that helps to broaden the perspective in technology education deals with questions that lie in a borderland between school technology education, manual arts education and artistic programmes, particularly in the visual arts, which share a common interest with technology as a school subject in how various educational approaches and assessment methods influence the creativity and artistic/creative work of pupils (Lindström, 2003).

Future development of the field of research

I have now looked at research and learning and teaching in technology for children and adolescents from a number of angles. I have endeavoured to see the Swedish research arena in relation to other subject-oriented education research and to research on technological development and the social and cultural dimensions of technology. In this concluding section, I shall address the developmental potential of Swedish research. My intent is to contribute with views on how Swedish research can become more firmly rooted in international research and how Swedish researchers, based on the Swedish context, can make meaningful contributions to the wider research community.

Strengths and weaknesses of the field of research

Beyond the review of published research that I recounted above, we have investigated the occurrence of international journals, conferences and societies. In the Swedish study, we also surveyed research environments at universities and science centres. Based on the material, I conclude that in international terms research on learning and teaching in technology is differentiated and dynamic, if yet weak compared to other subject-oriented

---

25 A survey study performed by Hagberg and Hultén on how teachers and researchers at Swedish universities assess the field of research also served as input for this section.
fields (e.g. science education). Its momentum is palpable. Several significant actors see research as a key factor for improving technology education in the schools. The field of research is remarkably in step with the reformation of school technology education that has already taken place or is in progress in several countries.

Meaningful and fundamental dissertations or other major papers in the field have been published in Sweden at least since the early 1980s. Some explore the development of technology education in the schools at an institutional level. Others discuss technology education in relation to a specific social issue, such as democracy or the gender system. Some dissertations focus on children’s learning in technology or their interest in science and technology. So far, they have been isolated contributions; there are few postgraduate students and researchers and there have been no stable research environments. As a result, we have not either had the prerequisites for developing an overall view of research needs. The dearth of senior researchers is another of the field’s weaknesses. There are, for instance, no professorships in technology education or a closely related subject in Sweden. Technology education research is being pursued in some cases, however, by professors with other subject designations.

The low degree of international publication in leading journals and at conferences must be counted among the critical weaknesses of Swedish research. Nor does it seem that published dissertations have been presented in follow-up papers internationally. This is to some extent surprising considering that several of the researchers belong to informal international networks. One possible explanation may be the clear connections between the research and conditions in the Swedish school system. My own reading of Swedish publications leads me to conclude that important contributions could be made to the international discussion, e.g., with respect to technology education’s incorporation into and impact upon gender systems.

To avoid misunderstanding, I would like to point out that in terms of content Swedish research has, as far as I can judge, a solid connection with international research as well as with other subject-oriented education research in Sweden.

There are clear indications that Swedish technology education research is in a developmental phase that will hopefully result in more published research in the next few years. Our survey shows general signs of higher interest; technology education research is being done at several institutions and ambitions are lofty. More solid evidence is the significant increase in the number of doctoral students whose dissertation work is oriented towards technology education, that technology education as a graduate subject has

26 For example, Skogh and Sjögren.
been established at the Swedish National Graduate School in Science and Technology Education Research (FoNTD), that current doctorate students are to a great extent submitting papers at international conferences, that there are several established researchers who are developing research programmes and hopefully will be able to get research grants from research councils, and that a network for research collaboration among academic institutions is being developed.

Also on the positive side, activities at many science centres are providing inspiration to the field of research and scope for development projects related to general knowledge about and interest in technology among children and adolescents.

Despite the clear potential for development, however, Swedish technology education research is going to be a sparsely populated field for several years into the future. Measures that can reinforce the base are for that reason necessary. The most important will be that graduate education is expanded, that post-doc positions are created, that research-leading positions are instituted and that networks are developed that can strengthen joint research projects among the environments that do exist.

**Ambitions and choice of content**

The question now is whether our review of Swedish and international research provides a basis for crystallising the research directions or questions that are particularly urgent and within which Swedish researchers can make meaningful contributions. Two opposing approaches to how the research will best be developed are conceivable. One can say that the area’s breadth, multidimensional nature and fragmented institutional grounds combined with the fact that relatively little has been done so far justifies an ad hoc approach. Equally important research projects are imaginable within all aspects of technology education research and the most interesting will make their presence known as the journey continues. On the other hand, one can assert that we need concentration on certain especially pressing questions and/or areas. Only then can Swedish researchers make research contributions of international interest. I would like to contribute to the latter position by discussing a number of perspectives in terms of content. My intention is thus not to suggest projects or declare theoretical or methodical points of departure, but rather to emphasise the area’s potential in the spirit I expressed in the introduction to this paper: breadth of approach and perspective, clarity in relation to teaching and learning in technology as a general subject.

In light of the vague “school subject identity” of technology education, research that specifically attempts to capture the whole and explore connections between educational policy, curricula, day-to-day reality in the
school setting and pupils’ conditions for acquiring knowledge in technology is urgently needed. Studies with a historical perspective should, for instance, be able to contribute to greater understanding of how the mandate of Swedish schools to impart knowledge in technology relates to other areas of knowledge and to social conditions in different eras. There are very good opportunities here to participate in international comparative studies.

One requisite demand is that technology education research is pursued in harmony with other subject-oriented education research, general education research, and pedagogical research on teachers, pupils and the schools. Much of the development of teaching in technology is going to be based on such more general research. “Translations” may sometimes be required, of course, and technology education researchers should help ensure their quality.

The key to high quality in technology education research is found in the combination of content-oriented research on aspects specific to learning in technology with participation in a broader pedagogical and social science discussion of theoretical and methodological issues. In his analysis of the Journal of Technology Education, Stephen Petrina argues that technology education research should more systematically utilise and participate in developments within Science and Technology Studies (Petrina, 1998). I concur. This also includes an interest in gender issues, ethical questions and environmental issues in relation to technology development.

What then is unique about the content of technology education in the schools? That is a comprehensive question and is in part actually an interesting question for research in technology education. I can only hint at a few circumstances here. One such is that technology has its own historical tradition of knowledge even as the dependency on and boundaries to several other traditions and cultures of knowledge are critical to how content should be shaped and understood. Different threads thus meet in the weave of technology education in the schools – the technician/engineer’s, the craftsman’s, the artist’s, the scientist’s and the social philosopher’s. Practice (the hand), creativity (the intellect), experience (the memory), form (the aesthetic), and usability (the responsibility) also meet in the content of technology as a school subject. How the content of education is opened and closed in the encounter between different traditions of knowledge is a central issue.

The subject matter of knowledge as such is obviously one of the unique aspects. One can presume that the variation of emphases in teaching between schools and over time is great. Research that contributes to laying a more solid foundation upon which to build central areas of knowledge is for that reason important. Here it may be a matter of developing the analytical concepts that are established, for instance, in the syllabus for technology as a compulsory school subject, of examining the educational potential
of various areas of technology, but also of pursuing research on how technical knowledge is used by technology developers and users.\textsuperscript{27} Research whose aim is to contribute to greater understanding of the key concepts and core areas of the field can be pursued to advantage in combination with development projects that involve teachers in the schools.

The school subject of technology shares the difficulty of incorporating new knowledge into established subject matter with several other subjects. The difficulties may be greater in technology education; as a consequence of changed requirements for general technical education resulting from the rapid development of entirely new areas of technology; through the changes in the everyday technology landscape; and because technology as a field of education cannot lean on an academic subject tradition that assists with the definition of central subject content.

Several new areas of technology are challenging the traditional content and for that reason are especially important subjects of education research. Information, communication and media technology are changing both the production of new technology and the use of everyday technology. The artefacts are becoming multifunctional and are gaining the capacity to escape former restrictions in time and space. Miniaturisation is proceeding in parallel through new materials and nanotechnology. An almost paradigmatic change of the construction of artefacts is taking place through biotechnology, and biotechnology in and of itself is having an impact on the content of technology education (Dunham, Wells et al., 2002).

The new “technologies” are changing the technical idiom and the ontology of artefacts, i.e., what an artefact or a technical construction is and how it should be delimited and identified in relation to others. There are interesting opportunities in technology education research to connect and contribute to research within the philosophy of technology on how the “artificial” should be understood (Ziman, 2000; Dahlbom, Beckman et al., 2002). This is closely related to questions about how technology and its idiom are perceived and constructed in various social contexts. In that area, technology education research can contribute with studies of how the schools, teachers and pupils in their practice and their classrooms define for themselves and others what technology is and what technology does and does not do.

The integration of technical and scientific knowledge is a significant component of the development of modern technology. That this is taking

\textsuperscript{27} The syllabus contains the following concepts, among others: technology that transforms, stores, transports or controls. The materials and design of technology. The moving parts of technology. The components and systems of technology. Obviously, a large number of additional terms and concepts occur in teaching.
place is nothing new, of course, but technical applications, technical methods and scientific theories and empirical evidence are in certain areas becoming almost impossible to separate and are dependent on one another. That is why we talk about *technoscience*. The term may refer to a reinforcement of earlier conditions, such as that modern technology development is more often predicated on spearhead scientific knowledge, as well as that the integration applies to the knowledge itself, such as that technical instruments represent and mediate scientific knowledge or that technology development contains biological constructions. These developmental tendencies may seem far removed from the everyday reality of the schools, but teachers must nevertheless take a position on how general technical education may be affected.28 Here there is an obvious field for collaboration with education researchers within science subjects. Likewise, connections may be made with considerable international research on changes in what constitutes *technological literacy*.

There are also several opportunities for connections to international comparative studies of children’s and adolescents’ knowledge in and views on science and technology.29 In particular, it should be possible to make a number of empirical and analytical connections to ROSE (Relevance of Science Education).30 International survey studies within Science Education are going to garner substantial attention in forthcoming years as their extensive empirical results are presented. The participation of technology education researchers in discussion and analysis of the results will be meaningful, as

---

28 There is a growing body of literature on technoscience; one example is Ihde and Selinger, 2003. Some didactical implications are discussed in Bencze, 2001.

29 Pupils’ knowledge in science is surveyed in PISA and TIMSS. The perspective of the comprehensive TIMSS (1995–2005) study is oriented entirely towards scientific subjects, but TIMSS 2003 includes, e.g., questions on the emphasis that learning about technology and its impact on society should have in curricula. (http://timss.bc.edu/timss2003.html).

30 ROSE aims to compare how pupils in different countries view the importance of various issues in relation to learning science and technology. ROSE is coordinated by a researcher network, within which theoretical perspectives and investigative tools are developed. ROSE studies pupils at age fifteen. ROSE has a distinct ambition to explore pupils’ interest in various technical questions and their knowledge about technology and to see the importance of attitudes towards technical ideas and innovations, everyday conditions and design for learning science. Thus, questions that refer to pupils’ beliefs about the connection between society, technology and science (STS) are included in ROSE (www.ils.uio.no/forskning/rose/). The international leader is Svein Sjöberg of Oslo University. The Swedish studies are being conducted by Linköping University and Mid Sweden University. See Jidesjö and Oscarsson, 2004 (www.ils.uio.no/forskning/rose/documents/papers/oscarsson.doc)
there is otherwise an obvious risk that the opinion that technology education in public schools is mainly a matter of illustration or application in science education will become the dominant view.31

A significant but for easily understood reasons neglected aspect of the research is to see the development of learning over time. How do teachers and pupils expand their knowledge over several years or, with respect to pupils, over their years in school? Here we can shed light on one of the central questions of subject-oriented education: is the development of subject expertise mainly a linear process in which various concepts and steps should be “arranged” and misunderstanding eliminated, or is development mainly an individual or sociocultural process in which various components are joined in complex patterns over which the school (the teacher) has only marginal control?

Technology education in the schools has always been open in the sense that children and adolescents learn much, perhaps even most, of what they know about technology outside the school in various informal contexts. Children and adolescents learn how technology is constructed and used in their recreational activities, through media, from their parents and in contact with the work of adults. For many adolescents, becoming interested in “cyborgs” and virtual erector sets may seem more natural than interest in material artefacts and mechanics.32

One can thus approach questions of content in technology education from various angles, from analysis of concepts, theories and elements of knowledge from the perspective of the philosophy of technology and the sociology of technology to general perceptions of the nature of technology; from engineering knowledge and skills on the construction, function and design of technology to the experiences of technology users; from the ideal scenarios and normative ambitions of curricula to content analysis of teaching and learning in the everyday school setting. Questions of content always have a normative side: Who imposes demands on and decides on content issues and what are the justifications? One goal for technology education research should be to provide more solid grounds for the choice of content and methods and better understanding of how general knowledge in technology can be acquired as well as to clarify values-based attitudes.

31 See Sjöberg, 2002 p. 33 for an example of a discussion of technology and STS as elements of science education.
32 Cyborg refers to the integration of mechanical and organic constructions, e.g., man and machine, but also for a person who is particularly interested in cyberspace.
In the preceding text, I discussed research needs from the perspective of the technology educator. But technology education in the schools may also be a particularly rewarding field of inquiry for general education and pedagogical research. One reason for that is that a number of general problems in the schools become clearly manifest in the technology classroom and teaching situations: differences in the interests of boys and girls and the school’s gender system, comprehensive and growing ambitions for what should be included in teaching in relation to teachers’ opportunities to expand and develop their own knowledge and pupils’ learning through the school in relation to their informal learning outside the school, for instance within various youth cultures.

Technology education in the schools may also be a worthy subject of study because the current school subject of technology has been developed without any natural connection to an academic university subject. In an era of subject diffusion in the schools and at universities, the development and problems of technology as a school subject could be an interesting relief.

The essence of technology

I began with a quotation from the syllabus for the school subject of technology: “teaching shall develop familiarity with the essence of technology”. The idea is perhaps that somewhere in the myriads of all types of technology and technical knowledge there is an idea, an approach or an ability that is always required for technology to be created and used – a universal language the can intuitively help us understand technology. Perhaps people like Christopher Polhem, the Swedish engineer with the mechanical alphabet intended specifically for teaching, have clarified the grammar of the language for various types of motion and force machines. Today it is of course necessary to master other languages, such as the grammatical rules and interfaces of computer language.

Some technology education research is aiming for and desirous of developing the universal language of technology. Such research within various areas of modern technology is urgently needed, such as research on electronics, materials, systems and biological technology. Inspiration may be taken, e.g., from research on science learning. This is an area where engineers can make particular and utterly decisive contributions to technology education research.

But the syllabus for the school subject of technology also encourages teachers and pupils to look for “the essence of technology” from the perspective of different users. In the spirit of Heidegger, we can ponder how
modern technology can be close at hand and, like the carpenter’s hammer, strengthen abilities we value highly.

There we are – between the pedagogical, inventive 18th century Swedish engineer, the 20th century German philosopher, critical to the technology of the modern project and our own era’s boundless hopes and fears in the face of the development of technology.

**Literature**


Bungum, B. (2003). *Perceptions of technology education: a cross-case study of teachers realising technology as a new subject of teaching*. Trondheim, Norwegian University of Science and Technology, Faculty of Science and Technology, Department of Physics.


