Technology as a challenge for school curricula

Witold Rogala & Staffan Selander (Eds.)
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Technology as a challenge for the future – some introductory remarks

With this issue we will present a discussion about the crossroads between, on the one hand, technology in its traditional sense, which has its roots in the modernization process, in industrialization and the development of delimited things and processes based on the science of technology, and, on the other hand, a wider understanding of technology in its post-modern appearance as ways of designing and creating the environments, including the consequences for the future of our societies. Technology is no longer seen only as a hope for the future; it is also seen as a threat in itself because of pollution and environmental problems.

Sjöberg shows in his article how young boys and girls from many countries around the world distrust science and technology. Many of them seem to identify the roots of environmental problems in technology itself. Large-scale technologies result in large-scale consequences. Thus technology enters the field of ethical matters – where it also challenges traditional ethical solutions. A wider understanding of technology also embraces the very acts of creating, designing and forming – the constructional fantasy seen both in relation to physical and virtual artefacts and in relation to new models of thinking and understanding.

Technology in this wider sense is of utmost significance for all members of our societies since it embraces questions concerning ethical matters in a world of large-scale technologies. It includes not only technological consciousness but also historical, cultural and social consciousness. Evoking an interest in technology in basic education is therefore not, as we see it, the same as introducing mathematical modelling models for the solution of technical problems.

Blomdahl & Rogala present a model for the learning of technology in the (Swedish) school context based on the humanities and the creative aspects of technology. Skogh follows along this line in discussing a “theory of action.” Sjögren places a more explicit emphasis on the creative aspects of technology and discusses technology in relation to artistic aspects. Granath focuses on the design aspect of technology, and Lindström adds a discussion of how to assess creative processes.

Furmanek & Walat highlight technical thinking as a psychological category. Franus follows up by presenting the idea of the dual nature of technical thinking. Walat relates these discussions to the technical education system in Poland, and Furmanek suggests a new general model for technical education.
Finally, Kjölberg’s article on serendipity and technology as a school subject can be seen as a conclusion to the discussions covering a wide and partly disparate field, albeit a central field in the education of future generations.

All the aspects presented are important. However, there seems to be a huge distance between the culture of technology and the culture of design (for instance at universities), between the culture of “science” and the cultures of “the social sciences and humanities.” Will it at all be possible to establish a dialogue between such extreme positions? Or is it actually the case that we now, after the industrial epoch, indeed have the tools to overcome old categories and lines of demarcations, to invent and design new models for the learning and understanding of technology? We would be happy to see the discussion continue!

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Staffan Selander
The authors

Eva Blomdahl is a lecturer in technology pedagogy and is involved in the training of teacher candidates at the Stockholm Institute of Education. She has previous experience as an elementary school teacher in the lower grades. Pursuing her PhD in technology pedagogy, she is interested in the didactic effects of models in the teaching of technology. Blomdahl is one of the founders of Teknikum, the regional center for the development of teaching technology as a school subject, at the Stockholm Institute of Education.

Jan Åke Granath, PhD, is professor of Design and Architecture at Chalmers University in Gothenburg – the most prestigious technological institute in Sweden. He is the co-director of Facilities Management at Chalmers and heads the Facilities Management, Department of Architectural Design. He is a member of the editorial committee of Henry Stewart Publications (see www.henrystewart.co.uk) and a board member of EuroFM (see www.eurofm.org/site).

Edward Franus is professor emeritus in psychology at Jagiellan University (JU) in Krakow and has been the head of the Department of Work Psychology and head of the Faculty of Philosophy at JU for many years. In the 1970s he helped in the formation of the Commission for Ergonomics at the Polish Academy of Sciences. His research interests have focused on the connection between technology problems and ergonomic humanist ideas. Prof. Franus has written a number of books and articles based on his research results. Among his most well-known works is Technical thinking (1978); his most recent book is The major functions of the technical intellect (2000).

Waldemar Furmanek is professor of psychology and technology pedagogy, head of the Department of Technology Pedagogy and vice-chancellor at the University of Rzeszow, Poland, where he has focused in particular on problems relating to the theory and practice of general and vocational education in technology. His interests include anything related to changes in the human psyche of children, students and adults, especially when they are involved in various technical activities. Prof. Furmanek has written a number of books and articles based on his research results. His most recent book is Understanding Technology (1998).
Jin Kjölberg is currently a PhD student at the Interactive Institute in Stockholm. She comes from a background in Engineering Physics (MSc) focusing on multi-modal interfaces for human computer interaction, and in Dance Education (BFA). In her PhD dissertation she is working on the development of digital interactive environments for learning and experiencing mathematics using body movements. This work will contribute to her PhD in pedagogy from the Graduate School for Aesthetic Learning Processes (Forskarskolan i estetiska läroprocesser) based at The Stockholm Institute of Education.

Lars Lindström is professor of pedagogy specialising in practical-aesthetic subjects at the Stockholm Institute of Education. From 1976 to 1994 he was a lecturer in pedagogy at the Konstfackskolan (University College of Arts Crafts and Design), Stockholm, Faculty for Teacher Training in the Visual Arts. His research includes studies of students’ creativity as part of the Swedish National Agency for Education’s 1998 Evaluation of the School System, and he is currently head of a project on young people’s perceptions of school, financed by the Swedish Association of Local Authorities.

Witold Rogala is a lecturer in technology pedagogy and is involved in the training of teacher candidates at the Stockholm Institute of Education. He has previous experience as a teacher at the upper grades of elementary school and high school. Rogala heads the technology section and Teknikum, the regional center for the development of teaching technology as a school subject, at the Stockholm Institute of Education. He is the author of several textbooks for the teaching of technology in elementary schools.

Staffan Selander has a PhD in education and is a professor in curriculum theory and learning at the Stockholm Institute of Education. He is also a professor at Vestfold University College in Norway and president of IAR-TEM – The International Association for Research on Textbooks and Educational Media. He has been working with research on texts and other social artefacts for learning, toys and communication and professionalisation. Selander heads the research school in curriculum studies and learning and one in aesthetic learning processes. Selander is the scientific head of the program Didaktik & Design (“Curriculum studies, design and learning”, see www.didaktikdesign.nu). He is also responsible for SLOC – the Stockholm Library of Curriculum Studies.

Svein Sjöberg is Professor at the University of Oslo and the University of Copenhagen. He is a board member for an international society for science education and the principal investigator of many cross-cultural studies on young people’s attitudes towards science and technology.
Jan Sjögren is a lecturer in design at the Department of Arts, Craft and Design, Linköping University. Sjögren studied at Konstfackskolan (the University College of Arts, Crafts and Design), Stockholm, and also pursued studies in the history of art and in teaching methods. He presented his dissertation Teknik – genomskinlig eller svart låda? Att bruka, se och förstå – en fråga om kunskap [Technology – transparent or black box? Using, seeing and understanding – a question of knowledge] (1997) at Linköping University’s interdisciplinary Department of Themes, under the theme Technology and Social Change, Linköping University. Since 1982, Sjögren has been involved in creating the design program that is now offered at Linköping Institute of Technology.

Inga-Britt Skogh has a PhD in pedagogy. Her research is focused on didactic aspects of technology teaching. She is a lecturer at the Department of Curriculum Studies and Communication at the Stockholm Institute of Education.

Wojciech Walat has a PhD in pedagogy and is a university lecturer in technology pedagogy at the University of Rzeszow, Poland. He does research in the modeling and optimisation of textbooks and teaching aids in technology for elementary schools and high schools.

He has participated in the development of the Polish national curriculum for technology in elementary schools and is in charge of publishing the teaching theory magazine Alternative technology education in the schools. Walat has been working with the Polish Ministry of Education since 1998 as an expert on textbooks and teaching aids for teaching technology as a school subject. He has written a number of books and articles on the teaching of technology as a school subject as well as textbooks in technology for the elementary and high school levels.
Pupils’ experiences and interests relating to science and technology:

Some results from a comparative study in 21 countries

Abstract

By comparing your national or local situation with the state of affairs in other countries, you come to see your own choices and priorities with new eyes. There are, however, many different approaches to international and comparative studies. Some studies rank countries by level of achievement, and may indirectly define norms and universal standards. Other studies may focus on cultural variation and provide options for different choices. This paper presents a study of the latter category.

The study is called Science and Scientists (SAS). The SAS study explores cultural and gender differences on issues that are of relevance for the teaching and learning of science and technology (S&T). More than 40 researchers from 21 countries have collected information from some 10,000 13-year-old pupils from every continent. This paper presents selected results from three different items in this study. The three (out of seven) items that are considered here are related to the pupils’ prior experiences, their profile of interests and their expressed plans and motivations for their own future. The results indicate some rather universal trends in the gender profile of children’s experiences as well as their interests in S&T topics. Gender differences are particularly (and surprisingly) high in some of the Northern European countries and in Japan. These findings are discussed in some detail.

The SAS study provides empirical evidence for informed deliberation about priorities in the S&T school curriculum. The purpose of the study is to stimulate the debate on how S&T curricula can be made more relevant and suited to fit the experiences and the needs and interests of different learners in different countries. The SAS study was meant to be only a modest and exploratory study but has become a rather large undertaking. Plans for a more detailed and carefully planned study of a similar nature are also presented.
Large-scale comparative studies – Limitations and side-effects

S&T curricula and textbooks in different countries have striking similarities. Some consider this fact to be a reflection of the cultural neutrality and universality of science, while others see it as an unwarranted consequence of the cultural domination of some countries over others. Large-scale comparative studies like the IEA TIMSS (Third International Mathematics and Science Study) (see e.g. TIMSS 1998) may have as a (possibly unintended) side effect pressure to harmonise or universalise science curricula across nations. Test formats as well as S&T contents may provide standards, ‘benchmarks’ or norms for participating countries as well as for other countries. Furthermore, the international and cross-cultural nature of TIMSS-like studies has necessarily implied the development of items that can be used independent of educational or social context to avoid cultural bias. Hence, test items tend to become decontextualised and therefore rather abstract. This development runs contrary to recent thinking in teaching, learning and curriculum development, where key concepts are ‘situated learning’, ‘context-dependence’, ‘relevance’ etc. The publication and availability of TIMSS items in many countries provide an ‘incentive’ to use tests that both in their closed multiple choice format and lack of social context run contrary to national or local traditions.

Comparative research in education is important, but there is an obvious need to complement the valuable data from TIMSS-like studies with more open and culturally sensitive information and perspectives (Atkin and Black 1997). The recent OECD PISA study (Programme for International Student Assessment) is an ongoing attempt to widen the scope of such large-scale studies, and the underlying framework for PISA is, in contrast to TIMSS, not bound to the school curricula, but focuses on competencies that are considered important for participation in modern society. The publication of the first results from PISA (OECD 2001) indicates that the PISA studies will meet some of the criticism raised against IEA-based studies like TIMSS.

But TIMSS and PISA still have some common characteristics, and PISA still has assessment as the key concept. They are both high-level initiatives ‘from the top’ to monitor scholastic achievement, and the main results are various rankings on league-like tables. The studies are also (with some exceptions) confined to the rich countries in the OECD. In most countries these studies are initiated and (rather heavily!) funded by governments and ministries of education. Such studies stem from the decision-makers’ and politicians’ (legitimate!) need to have comparable data on the scholastic achievement of their pupils and to have some measures of efficiency and cost-benefit aspects of their national educational system. In an age of glo-
balisation and economic competition, the national authorities are increa-
singly concerned about how their own system compares with other sys-
tems, measured against common standards or 'benchmarks'. Similarly, na-
tional authorities have a legitimate need to get international comparable
data on unit costs, the effects of teacher training, class size, effects of re-
source usage etc. One may, of course with some exaggeration, characterise
projects like TIMSS and PISA as the educational parallel to what is known
as Big Science. The scale and costs of these studies are considerably higher
than those of the kind of research that most educators are involved in. The
institutions that perform these studies are often government agencies for
research and development, or research institutions from which the govern-
ment may expect a certain degree of loyalty. Such research does not emerge
from an independent and critical academic research perspective.

The SAS study: a small-scale comparative study

The comparative study reported here is very different from the large TIMSS
and PISA studies. It is low-cost, it emerges from the 'bottom' instead of
from governments and ministries, it includes not only the wealthy nations
but also developing countries, and its prime purpose is to generate critical
discussions and deliberations about priorities and local variation in the S&T
curricula. The concern is not any ranking from good to bad, or comparisons
with given standards or benchmarks. The purpose is to stimulate critical
discussions about priorities, based on empirical evidence gathered in diverse
cultures.

In many countries, mainly industrial ones, there is currently a kind of
disenchantment with science and technology. There is a fall in the recruit-
ment to (some) S&T-related studies and careers, although the situation
shows interesting variations between countries. The SAS study emerges
partly as an attempt to understand and to address these trends, but also from
the perspectives of critical pedagogy, with a critical perspective on the role
and function of S&T curricula. There is today widespread concern to try to
make S&T curricula meaningful, relevant and adapted to different groups
and different cultures, with an underlying concern that the culture of school
S&T is alien to many learners (Cobern and Aikenhead 1998, Ogawa 1995). The lack of relevance of the S&T curriculum is probably one of the greatest
barriers to good learning as well as to an interest in the subject. In any
discussion about relevance, it becomes important to know more about the
views, experiences and perspectives of the learners.

The present study is a modest attempt to shed light on differences as well
as similarities in what pupils bring to school, what perspectives and plans
they have and what kind of interests they have. The study is called Science and Scientists, the SAS study. The prime concern is diversity due to different cultures and gender. The intention is to provide data and perspectives that may give an empirical foundation for an informed discussion about the relationship that the learner has to the S&T curriculum and teaching. The development of the SAS project is a joint undertaking, involving science educators from very different cultures.

Methods and Samples

The SAS project used a questionnaire that was drafted, piloted and finalised in a co-operative effort between this author (from Norway), Jane Mulemwa from Uganda and Jayshree Mehta from India. We met on several occasions through our joint engagement in organisations like GASAT (Gender and Science and Technology) and IOSTE (International Organisation for Science and Technology Education), and we were also jointly involved in FEMSA (Female Education in Mathematics and Science in Africa), a large African project that addresses gender equality in science education in Africa.

The SAS questionnaire consisted of 7 groups of items. The aspects that were studied were the following: The pupils’ S&T-related out-of-school experiences, their interests in learning about different S&T topics, their perceptions of science as an activity and images of scientists as persons – and their priorities for future life or work. The questionnaire also consisted of some open-ended questions, like “What would you like to do if you were a scientist?” The “draw-a-scientist task” was also included, and the pupils were asked to comment on their drawing in writing.

The final instrument was made available to researchers from other countries through various S&T education networks like IOSTE and NARST (National Association for Research in Science Teaching). The participating researchers collected national data, following common procedures for sampling, administration, data collection and coding. Empty data files in SPSS and Excel were provided by the project, which also covered some costs, in particular for researchers in developing countries. Data files were returned to this author, merged into a larger file and recoded for analysis. Details of procedures, sampling etc are given in Sjöberg 2000a.

Some 40 researchers from 21 countries provided data from about 10,000 pupils at the age of 13. The countries are, in alphabetical order: Australia, Chile, England, Ghana, Hungary, Iceland, India, Japan, Korea, Lesotho, Mozambique, Nigeria, Norway, Papua New Guinea, Philippines, Russia, Spain, Sudan, Sweden, Trinidad, Uganda and the US.
Several national reports have been published; the participating researchers and the list of publications are given in the SAS report (Sjöberg 2000a). A brief report is also available as a chapter in a recent book (Sjöberg 2000b). The data files for the SAS project are now available from the author for further analysis by the participants.

**Results: General observations**

The data document details about the (rather obvious!) fact that children in different parts of the world come to school with a variety of different S&T-related experiences. Their interests in learning about different S&T topics show great variations, and their plans and priorities for their future life differ. If one wants to build on children’s experiences and meet their interests and perceived needs – a ‘given’ for most educators—such information is of crucial importance. In spite of the variations within each country, the average values for participating countries seem to come out in clusters on many aspects, often reflecting the country’s level of development. Children from African countries seem to share many background experiences, and they also seem to have the same interests, similar priorities for future job and they have the same (very positive) image of science and scientists etc. There also seem to be gender-related differences that follow similar cultural patterns. This means, among other things, that the definition of feminine and masculine behaviours and attitudes seem to follow cultural patterns. Also developed countries have some likenesses with each other, and the Nordic countries come out as a group with strong similarities. In the following, some more detailed results are given, although the available space does not permit much detail.

**Results: Prior experiences**

One group of items is called *Out of school experiences: What I have done*. This is an inventory of 80 activities that may have bearing on the teaching and learning of S&T. This item has also been used in previous research in a slightly different form. (Sjöberg and Imsen 1987, Whyte, Kelly and Smail 1987). Attempts were made to sample activities that might be of relevance for the learning of S&T, and to try to make the list balanced concerning gender and cultural differences. The calculated overall score (Sjöberg 2000a) showed that we had been successful in this respect; most countries had similar averages and most countries had only small differences in the overall activity score for girls and boys.

On this item, we often observed what we might call a traditional gendering pattern. Boys in nearly all countries have considerably more experience
with activities such as these: Using guns, bows and arrows, using new technologies, car-related activities, (using car jack, charging batteries etc.), mechanical activities (using pulleys and levers) electrical activities (fixing leads, using batteries, motors, bulbs) using tools (saw, hammer etc.), mending bikes.

Girls had in general more experience with nature-oriented (and more peaceful) activities like collecting gems, flowers, mushrooms, observing the sky, the moon and the stars. Girls also had more experience in household-related activities like preparing food. On the other hand (and maybe surprisingly?) boys had, in most countries more experience than girls in preserving and storing food (salting, smoking, drying etc)

Some sorts of experience had different gendering patterns in industrialized and developing countries. Caring for animals and other farming activities are boys’ activities in developing countries, while the same activities are typical girls’ activities in industrial countries. The underlying reason may be that agricultural activities are basic economical, life-sustaining activities in developing countries, while they are more related to leisure and hobby in industrialized countries.

Some typical experiences among the Nordic (here: Norway, Sweden and Iceland) children seem to be strongly related to outdoor life. Nordic children (girls and boys) have more experience than others in activities like setting up tents, making fire, using binoculars, making flute of straw or wood, collecting mushrooms and edible berries. We also note that Norwegian children (in particular boys) have the highest score of all on ”using air-gun and rifle” – possibly a reminiscent of an old hunting (and fishing) tradition, still surviving as a leisure activity?

The results can be presented item-by-item, or grouped in larger categories. An example of each of these is shown in Figure 1.
Figure 1. Results for the activity "Used ropes and pulleys for lifting heavy things". Means in percent are given for girls (black) and boys in each country. The countries are sorted by increasing frequency of total.

Figure 1 shows the results on "Using rope and pulley to lift heavy things" – an activity that gives background experience to learn about classical 'simple' mechanics. As one can see, this activity is strongly gendered in all countries, with boys’ score in some countries three times higher than the girls’. It is also interesting to note that children in developing countries score relatively high on this item, probably because such activities are closely related to technologies in common use in their societies.

Figure 2. The average value of five Electricity-related experiences. Means in percent for girls (black) and boys in each country. The countries are sorted by increasing frequency of total.
Figure 2 shows the results for a composite variable (a ‘construct’) that is the mean of several activities relating to electricity. The activities are the following:

- Played with electric batteries, bulbs and motors
- Used electric toys (cars, torches etc)
- Changed a fuse or attached electric lead to plug
- Charged a car battery or other battery
- Studied the inside of a radio, TV, video or similar

As one can see from Fig 2, electricity-related experiences are strongly male-dominated in all countries. In some countries, boys seem to have twice as much experience in this field than the girls. One also notes that children in richer countries in general have more experience than children in poorer countries (Japan is, as often in the SAS study, an exception to this pattern). Given that these activities do require resources like bulbs, motors, batteries, electric leads etc., this is no surprise. But it may be a surprise that boys in even the poorest countries have more experience with electricity than girls in industrialized countries?

**Results: Interesting S&T topics to learn about**

This group of items is called *Things to learn about* and is a similar list to the one about experiences. It is an inventory of possible topics for inclusion in the S&T curriculum. 60 topics are listed. Some results from the analysis of interests in these topics have been published elsewhere (Sjöberg 2000a and 2000b). Figure 3 gives one example of the results taken from this list of 60 items:

*Figure 3. Learn about: "Latest development in technology". Means are given for girls (in black) and boys in each country. The countries are sorted by increasing frequency of total*
We note from Fig 3 that children in developing countries are much more interested in learning about new technologies than children in more wealthy countries. We note (again) that the results for Japan are extremely low. The gendered pattern is obvious, and mostly so in the Nordic countries, Japan and Korea.

This leads us to comment on some general trends. Children in developing countries are interested in learning about nearly everything! This is possibly a reflection of the fact that for them, education is a luxury and a privilege, and not seen as a painful duty, as is often the case in more wealthy nations! Japanese children are less interested in S&T than children in other countries — in particular about the car, new technologies and communication! We return briefly to this at the end of the paper. The Nordic countries (and Japan) are more gendered in children’s interests than other countries! We also comment on this observation at the end of the paper.

This item provides a wealth of data that may be of value for a discussion on how to construct a S&T curriculum that meets the interests of different learners in different cultures. To illustrate this point, we give one example; see table 1, where some of the data for two selected countries are contrasted – based on the gender difference.

Table 1. "What I want to learn about” – (part of the list) sorted based on the difference between girls and boys. The list shows data from Norway and Japan. For each country, the topics with the most female gender difference are shown (on top) and (at the bottom) the topics with the strongest boys’ profile are shown. (Note that this list should be read 'from the bottom’.) The number is the difference in percent between boys and girls who have indicated that are interested in the topic.
### "Girls’ S&T” Norway vs. "Girls’ S&T” Japan

<table>
<thead>
<tr>
<th>Subject</th>
<th>“Girls’ S&amp;T” Norway</th>
<th>M-F</th>
<th>“Girls’ S&amp;T” Japan</th>
<th>M-F</th>
</tr>
</thead>
<tbody>
<tr>
<td>AIDS: What it is and how it spreads</td>
<td>-24</td>
<td></td>
<td>How to heat and cook food the best way</td>
<td>-26</td>
</tr>
<tr>
<td>The rainbow, what it is and why we can see it</td>
<td>-22</td>
<td></td>
<td>The rainbow, what it is and why we can see it</td>
<td>-26</td>
</tr>
<tr>
<td>Why people in different parts of the world look different and have different colours of the skin</td>
<td>-19</td>
<td></td>
<td>Why the sky is blue and why the stars twinkle</td>
<td>-18</td>
</tr>
<tr>
<td>What we should eat to be healthy</td>
<td>-18</td>
<td></td>
<td>What are colours and how do we see different colours?</td>
<td>-17</td>
</tr>
<tr>
<td>Why the sky is blue and why the stars twinkle</td>
<td>-17</td>
<td></td>
<td>Music, instruments and sounds</td>
<td>-16</td>
</tr>
<tr>
<td>Birth control and contraceptives</td>
<td>-16</td>
<td></td>
<td>Sounds and music from birds and other animals</td>
<td>-15</td>
</tr>
<tr>
<td>What are colours and how we see different colours?</td>
<td>-15</td>
<td></td>
<td>Plants and animals in my neighbourhood</td>
<td>-13</td>
</tr>
<tr>
<td>Sounds and music from birds and other animals</td>
<td>-12</td>
<td></td>
<td>How birds and animals communicate</td>
<td>-12</td>
</tr>
<tr>
<td>How birds and animals communicate</td>
<td>-12</td>
<td></td>
<td>How science and technology may help disabled persons (blind, deaf, physically handicapped etc.)</td>
<td>-11</td>
</tr>
<tr>
<td>How we can protect air, water and the environment</td>
<td>-11</td>
<td></td>
<td>What we should eat to be healthy</td>
<td>-9</td>
</tr>
</tbody>
</table>

### "Boys’ S&T” Norway vs. "Boys’ S&T” Japan

<table>
<thead>
<tr>
<th>Subject</th>
<th>&quot;Boys’ S&amp;T” Norway</th>
<th>&quot;Boys’ S&amp;T” Japan</th>
</tr>
</thead>
<tbody>
<tr>
<td>How radioactivity affects life and my own body</td>
<td>11</td>
<td>How science and technology may help us to get a better life</td>
</tr>
<tr>
<td>The possible dangers of science and technology</td>
<td>12</td>
<td>Satellites and modern communication</td>
</tr>
<tr>
<td>New sources of energy: from the sun, from the wind</td>
<td>15</td>
<td>The possibility of life outside earth</td>
</tr>
<tr>
<td>Important inventions and discoveries</td>
<td>17</td>
<td>The origin and evolution of the human being</td>
</tr>
<tr>
<td>How science and technology may help us to get a better life</td>
<td>18</td>
<td>New sources of energy: from the sun, from the wind etc.</td>
</tr>
<tr>
<td>Light and optics</td>
<td>20</td>
<td>Rockets and space travel</td>
</tr>
<tr>
<td>How things like telephone, radio and television work</td>
<td>20</td>
<td>The possible dangers of science and technology</td>
</tr>
<tr>
<td>Acoustics and sound</td>
<td>21</td>
<td>How things like telephone, radio and television work</td>
</tr>
<tr>
<td>Atoms and molecules</td>
<td>22</td>
<td>Important inventions and discoveries</td>
</tr>
<tr>
<td>Computers, PCs and what we can do with them</td>
<td>23</td>
<td>Computers, PCs and what we can do with them</td>
</tr>
<tr>
<td>What an atomic bomb consists of and how they are made</td>
<td>24</td>
<td>What an atomic bomb consists of and how they are made</td>
</tr>
<tr>
<td>Chemicals and their properties</td>
<td>25</td>
<td>Atoms and molecules</td>
</tr>
<tr>
<td>Rockets and space travel</td>
<td>26</td>
<td>How a nuclear power plant functions</td>
</tr>
<tr>
<td>Electricity, how it is produced and used in the home</td>
<td>27</td>
<td>Lightning and thunder</td>
</tr>
<tr>
<td>How a nuclear power plant functions</td>
<td>27</td>
<td>X-rays and ultrasound in medicine</td>
</tr>
<tr>
<td>Satellites and modern communication</td>
<td>29</td>
<td>Electricity, how it is produced and used</td>
</tr>
<tr>
<td>Latest development in technology</td>
<td>37</td>
<td>Latest development in technology</td>
</tr>
<tr>
<td>The car and how it works</td>
<td>43</td>
<td>The car and how it works</td>
</tr>
</tbody>
</table>
The list of possible S&T topics in this item consists of 60 items, and only the top and bottom parts of the list are shown in table 1. In this table, only the difference between girls’ and boys’ score is shown. We note that the actual gendered differences at the ends of ‘the spectrum’ are extreme. This means that in both countries there are topics in S&T that stand out as exceptionally gendered in the favour of girls (the top of the list), and even more topics with a very strong boys’ profile (the bottom of the list). We also note that there are strong similarities between the lists for the two countries, in spite of the large cultural difference between these countries. For both countries, girls show a greater interest than boys in aspects of biology, health and nutrition. They are also more interested in aspects with a possible aesthetic dimension (colours, sound, music, blue sky, twinkling stars etc.) Boys in both countries, however, express much greater interest than girls do in cars, technology, PCs, rockets, nuclear power plant, electricity etc.

Some of these results are hardly surprising; they actually fit well with what one stereotypically calls girls’ and boys’ interests. The surprise is, however, that the actual difference is so extreme. Take learning about “The car and how it works” as an example. In Norway, 76 % of the boys and 33 % of the girls are interested. Japan is even more extreme, although the actual numbers are much smaller: 36 % of the boys, and only 6 % of the girls are interested! Similar details can be noted at the other extreme of the spectrum.

What we can learn from this is that the ’ideal’ S&T curriculum for girls and boys are indeed very different – although they may both be considered good and valid S&T contents! Data like these should be kept in mind when curricula are written and textbooks produced. If one puts early emphasis on the technological aspects of science, one will definitely turn off the potential interests that girls might have in the subject!

The data also contains some surprises compared with what one might stereotypically expect. Boys are in most countries more interested than girls on topics like

- The possible dangers of science and technology
- How science and technology may help us to get a better life
- How science and technology may help handicapped
- New sources of energy, from the sun, from wind etc.
- How radioactivity affects life and my own body
- Famous scientists and their lives

These results run contrary to what is often assumed, e.g. that girls are more interested in the possible misuses of S&T, that they are interested in the human and historical aspects of science and that they are interested in how
science and technology may improve life and help people. The SAS data do not give support to these claims, at least not as general claims.

In spite of the great gender disparities, some topics seem to be high on the list for girls as well as boys in most countries. (Then we focus on actual percentages, and not on differences in score!)

**Most popular** among girls and boys in most countries are the following topics:

- The possibility of life outside earth
- Computers, PC, and what we can do with them
- Dinosaurs and why they died out
- Earthquakes and volcanoes
- Music, instruments and sounds
- The moon, the sun and the planets

Similarly, one can identify a list of the **least popular** (for girls and boys) in most (mainly the rich) countries:

- How to improve the harvest in gardens and farms
- How plants grow and what they need
- Plants and animals in my neighbourhood,
- Detergents, soap and how they work
- Food processing, conservation and storage
- Famous scientists and their lives

From this list we see that the concern to make S&T more relevant by concentrating on what is ”concrete, near and familiar” is not necessarily meeting the interests of the children. They may, in fact, be more interested in learning about the possibility of life in the universe, extinct dinosaurs, planets, earthquakes and volcanoes!

**Results: Important for future job**

This item is called *Important for a future job* and consists of a list of 15 factors that might be important for the choice of a future job (if such a choice exists!). The pupils are invited to judge the personal relevance of each of these factors. An example of the data is provided by Table 2.
We see from Fig 4 that although there is general agreement between girls and boys on the importance on some of the factors, there are also remarkable differences on other aspect between the priorities of girls and boys. We see that the difference is 'in favour' of boys on factors like "Make and invent new things", "Become famous", Control other people”, ”Earn lots of money”, while the girls put considerably more emphasis on ”Working with people instead of things” and "Helping other people".

In order to simplify these matters, a factor analysis was performed. We identified the following four components. (The suggested name is 'invented' as a label that seems to fit with the contents.)

1. **Ego-orientation** (famous, rich, controlling others, easy job)
2. **Time and security** (time for friends, family, myself – and a secure job)
3. **Self-development** (using talents and abilities, developing knowledge and skills, taking decisions, exciting job)
4. **Others-orientation** (Helping others, working with people)
When applying this to the participating countries, we find that factors 2 and 3 ("Time and security" and "Self-development") are rather gender neutral in practically all countries. The other two factors are strongly gendered.

In all but 2 countries, boys seem to be "Ego-oriented", with Iceland, Sweden, England and Norway as the most extreme! Details are given in Fig 5. On the other hand, in all but two countries girls seem to be much more "Others-oriented" than boys. Also on this aspect, Norway and Sweden are the most strongly gendered.

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**Job-priorities: "Ego-orientation"**

*Fig. 5.* "Ego-orientation" (famous, rich, controlling others, easy job) in the SAS-countries. Data are given for girls (in black) and boys. The countries are sorted by total frequency. Maximum score is 1.0.

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**Discussion: Some paradoxes and surprises**

Many findings in the SAS-study are hardly surprising. The overall gender profile follows a pattern that is well documented. But some results are rather unexpected (at least for this author). Two such examples will be briefly discussed here: (1) The low interests in science and technology among Japanese children and (2) the seemingly paradoxical situation regarding gender equity in the Nordic countries.
Japan: Top in score – lowest in attitudes and interests!

Many results from Japan call for attention, in particular when they are seen in connection with other kinds of information. Let us look at some of the paradoxes: Japan tends to be on top on most international tests on pupils’ achievement in science and mathematics (SISS, TIMSS etc.). Even on the recent PISA (2001) study, Japan comes out on the international top on achievement in mathematics and as number 2 in mathematics (right behind Korea). In spite of the high scores on achievement testing, the TIMSS data (TIMSS 1996 p 121 ff.) also indicate that Japanese children have more negative attitudes to both mathematics and science than pupils have in any other (of the nearly 50) TIMSS countries.

The data presented in this paper and in the other SAS-reports (Sjöberg 2000a and b) support and give more detail to this observation. Item by item, we find similar results: Japanese children are much less likely than others to be interested in most S&T items – in particular those related to modern advances in technology – an area where Japan is among the world leaders, and an area of prime economical importance for Japan.

Gender differences are in many aspects large in Japan. According to our study, Japanese girls are at the lowest place when it comes to interest in S&T, both when the question is a global one like ”Is science interesting?” and on the very specific topics briefly mentioned in this paper. Japanese girls also state that they find science more difficult to understand than any other group in this study. (Sjöberg 2000a) (In spite of this, they actually score higher than girls in most other countries!)

S&T educators in Japan have recently become very interested in these matters, since the low interest in science and technology and the lack of interests to pursue studies and careers in these fields may create serious problems for Japanese economy. The low birth rate in Japan and the highest life expectancy in the world further exacerbate the problem. Possible explanations as well as possible policies and remedies are debated. It falls beyond the scope of this paper to explore this issue, but it is expected to be an area of interesting debate and an area where one can learn from cross-cultural research. Professor Masakata Ogawa has recently initiated an international comparative research to shed light on science education and the importance of gender, language and culture. He was also the Japanese partner in the SAS-project. Perspectives and results from the SAS study and the planned ROSE-project (see the last paragraph) will be an important input in the ongoing Japanese project.
Norway and the Nordic countries: What about the gender equity?
The SAS-study has shown that the Nordic countries (here represented by Norway, Sweden and Iceland) on many aspects come out with greater differences between girls and boys than most other countries. In particular, we have documented large differences in the interest to learn S&T (Sjöberg 2000a). The data presented in this paper about priorities for a future job also indicate a very strongly gendered value profile among Nordic children: Girls as "others- oriented"; they want to help other people and work with people instead of things. Boys, on the other hand, are "ego-oriented"; they are more oriented towards making money and getting personal benefits. The analysis of children’s drawings and their free writing on ”Me as a scientist” (both reported in Sjöberg 2000a) also documents large gender differences in values and perspectives among the Nordic children. Data from TIMSS and PISA provides similar evidence on large gender differences in achievements as well as attitudes to science.

The Nordic countries are often considered “world champions” in gender equity. Gender equity has been a major political concern since the mid 70s. Much has been accomplished, and the overall picture is undoubtedly rather positive. Legal barriers have been removed a long time ago; laws against discrimination and unequal pay are in operation. Female participation in politics and the labour market is among the highest in the world. In the education system, girls and women dominate the overall picture, with some 56% of tertiary students being female.

Official statistics and international reports confirm the leading position of the Nordic countries regarding gender equity. UNDP (United Nations’ Development Program) publishes an annual Human Development Report. The analysis and conceptual development behind these reports is well respected. The main indicator that is developed by UNDP is the

*Human Development Index* that is used to describe and monitor progress in this complicated area. All the 5 Nordic countries are among the 15 on the top of this list, which includes nearly 200 countries. In 2001 Norway was no 1 on the list.

The UNDP report has also developed indices that describe the situation of particular social sectors. In 1995 the focus was on gender, and from that year, UNDP has also reported on a so-called *Gender Empowerment Measure*. This index measures the degree of achieved equity regarding aspects like health, education, salaries, participation in politics and on the labour market etc. In the 2001 report, the Nordic countries have the following ranks on this list: 1 Norway, 2 Iceland, 3 Sweden, 4 Finland and 12 Denmark (UNDP 2001). As one can see, the overall picture seems to be positive, and the three Nordic countries taking part in SAS are actually the first three on
this list of gender empowerment. *But equity does not exist in the field of science.* The percentage of women in science and engineering is very low – lower than in most other parts of the world. The enrolment of women into these fields has actually gone down the last years. And the gender difference in achievement and attitudes are large, also in the TIMSS and PISA studies.

The issue is of great political concern in these countries, where the gender equity is considered a pride. The reason for the observed differences in career choice does not seem to be the girls’ lack of ability or lack of self-confidence! Even very able girls turn their backs to science and engineering. The girls’ choices seem to be rather deliberate, based on value-orientations and emotional, personal factors. Some of the underlying values for girls are indicated above: The girls’ high person-orientation and relatively low ego-orientation towards money, career and things.

If this is correct, it shows that we should pay more attention to the underlying values, ideals and ideologies in S&T education. Textbooks as well as classroom teaching carry implicit (sometimes also explicit) messages about the nature of the subject and the underlying values. If we believe that these values are not strictly determined and logically deduced from the nature of science per se, we should analyse, discuss and possibly reconsider these aspects.

We have through the SAS-study documented large differences between the experiences, values and interests of girls and boys. It is very likely that girls encounter a S&T curriculum that neither builds on their prior experiences or fits well with their profile of interests. We hope to use the SAS data to argue for a reorientation of the Norwegian science curriculum.

**Some conclusions and implications**

It is evident from this study that children come to school with a rich variety of relevant *experiences* that could and should be utilized in the teaching and learning science at school. This study does not indicate whether this resource is actually used in a systematic way or not, but it may indicate how this might be done.

The *interest* in learning seems to be much higher in developing countries than in the rich and technologically developed countries. An explanation for this may be that education in developing countries is largely seen as a privilege that everybody strive for, while many pupils in the rich countries see school as a tedious duty that is imposed on them. The same perspective may explain the strong interest in S&T expressed by girls in developing countries: Girls in these countries often have less access to all sorts of edu-
cation than boys have, therefore learning S&T may be seen as a very positive option.

The profile of the experiences and interests does, however, vary strongly between countries. This fact should call for caution when it comes to importing foreign curricula and it should indicate a need for some scepticism against the pressure to harmonise science curricula against universal common standards or benchmarks. Although science per se may be universal (a debate that is not pursued here!), S&T curricula for children should reflect the needs and priorities for children in each country. Data from projects like SAS may provide a basis for deliberations about curricular priorities.

It is also evident that the profile of experiences as well as interests is rather different for girls and boys in most countries. In general, the gender differences in interests are greater in rich countries than in developing countries, both when summed over all topics and when these are studies separately. Gender differences are very high in some North-European countries and in Japan, an aspect that is discussed a little above. If gender equity in science education is a national concern, one should go in some detail in analysing possible biases in the curricula, textbooks and classroom teaching. A study like SAS may be one approach to such issues, because it can shift the debate from a general theoretical level to a more concrete level, based on empirical evidence.

The image of science and scientists is more positive among children in developing countries than in the rich countries. Children in the developing countries seem to be eager to learn science, and for them, the scientists and engineers are the heroes. This is in marked contrast to at least a significant part of the children in the rich countries, who often express sceptical and negative attitudes and perceptions in their responses to several of the SAS items. The notion of the crazy or mad scientist is often found in rich countries. Very few children in the rich countries envisage the scientist as a kind, human and helpful person, whereas this is often the image of scientist in developing countries. (Details are given in Sjöberg 2000a)

This study does not tell which image is closer to reality. But many of the data indicate that science and (even more?) technology has a problem with its public image in many developed countries. Most OECD countries are currently worried about the falling recruitment to science and technology studies. Why do children develop these critical attitudes to S&T, although they live in societies based on such knowledge and its applications? One possibility is that this is a result of low public understanding of science, caused by bad teaching as well as a low or negative profile in the media. Many scientists hold on to explanations like these. But there is an-
other possibility: It may be seen as an indication that many young people have a rather well informed sceptical attitude towards certain aspects of modern society. Maybe their doubts are based on real fears about an unknown future that scientists may lead them into?

Comparative research is important, and it is important for science educators to get involved in cross-cultural research. It often helps you see your own culture from outside, and it may open up for new insights and new alternatives. Data from the large-scale studies like TIMSS and PISA are valuable and important, but should be complemented by less ambitious and more explorative studies like the one presented here. Together, they may provide a foundation for informed debates about priorities and alternatives in S&T education.

**Future plans: The ROSE project**

The SAS-study was planned as a modest and exploratory study. The overwhelming international interest in joining the study took us by surprise. As it stands today, the study has several weaknesses stemming from its somewhat ad hoc development. But the results have received great attention, and there is a widespread interest in the further development of a joint study like this, catering for participation from all sorts of cultures.

Plans for a more systematic follow-up study of the SAS-project have been developed under the acronym of ROSE: The Relevance Of Science Education. The target population will be 15-16 year old pupils, i.e. towards the end of the compulsory school in many countries, and before streaming usually takes place. (A description is given at http://folk.uio.no/sveinsj/) Researchers and research institution in more that 30 countries have expressed their interest in participating in this project. The Research Council of Norway will fund this project for a period of three years, and other funding sources are now approached. An international workshop with participants from all continents took place in Oslo in October 2001. Here the research hypotheses, the research instruments and the logistics were discussed. Piloting and finalizing of instruments and logistics is (May 2002) nearly accomplished. Data collection will start in 2002, and researchers with an interest in the project should contact this author.

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In search of a didactic model for teaching technology in the compulsory school

"Reflective thinking does not begin until a person is confronted with a problem and has to solve it.” John Dewey

Introduction

Over the 30 years that we have worked with teaching technology in elementary schools, secondary schools and teacher training programs, the nature of the subject of technology has changed considerably. The pendulum has swung in tandem with advances in technology, with the subject moving from a purely optional workshop course in the 1960s and 1970s to some kind of applied natural science in the 1980s that was a required course for everyone. Not until the current national curriculum, Lpo 94, was designed was the subject given a separate curriculum. However, there are still weaknesses in terms of the identity of the subject, its content and methods of working. Reports from the field also indicate that teaching in technology is provided to only a limited extent in schools today (see CETIS’ survey, 1998/1999. Rapport från skolinspektörerna i Stockholms kommun, Utbildningsförvaltningens rapportserie, 2002 [Report from the School Inspectors of the Municipality of Stockholm, Educational Administration Reports, 2002]).

In this article, we will try to formulate our thoughts on the identity, content and goals of technology as a school subject. The model we present is the result of extensive practical experience, experimentation and studies of technical education in other countries as well as literature on the subject. The most important resource, however, has been our work with students, who have impressed us with their inexhaustible inventiveness in the creative, constructive teaching of technology. Questions that we will try to answer in the presentation of our model are why should we have technical education in Sweden and, in that case, what should it result in, what should be dealt with in technical education and how should this be carried out.
Foundation for a didactic model

View of knowledge and of learning

Knowledge can be defined as generally accepted truth. This is neutral, and when knowledge becomes established it holds authority. The pedagogical consequence of this view is that knowledge is something that can be conveyed and transferred. Knowledge can also be seen in a context where this knowledge can not be understood isolated from its context. By working in a context, students participate in the knowledge that is part of the context. The pedagogical consequence is that knowledge must be studied in such a way that it includes the context and the interaction of students with that context (Carlgren & Marton, 2000).

Technological knowledge is based on experience. This experience-based knowledge is specific and linked to various applications and concrete situations. It is an amalgam and cross-disciplinary in nature, and the content of knowledge seldom fits within the boundaries of academic subjects.

John Dewey (1998) has made a significant contribution in teaching theory giving his view on thinking and the role of thinking in the learning process. He bases his theories on his conviction that knowledge is directly related to people’s interaction with the world around them and stresses the importance of practicing thinking. Skrøvset and Lund (2000) write that Dewey has determined the following principles to be important to teaching. These are also central foundations for our model.

• Knowledge should be useful.
• Teaching should be based on experience and create experience.
• Students should set their own goals in their work.
• Students should be active (“learning by doing”).
• Work must start with tasks, not with school subjects. (p. 20)

By useful knowledge Dewey (1969) means, as we understand it, that learning is to be carried out in conditions that are similar to the actual conditions that students will then apply that knowledge in. Otherwise, there is a risk that knowledge which is gained in school will be an abstraction that can not be used anywhere else except in a school context. Teaching is to be based on experience and create experience, according to Dewey. It is the teacher’s task to discover the experiences of students early on and identify how these can be used in teaching. Experience is the mainspring in the development of students and will thus also be a prerequisite for students to be active. Students who do not recognise their experiences in teaching or understand how knowledge is to be used in reality will easily think school is boring.

Students should set their own goals in their work. We interpret Dewey to
mean that students’ work will only be meaningful when students experience the task as their own. It is the task of the teacher to first determine what abilities, needs and previous experience students have; based on these, the teacher will let the task develop into an assignment with the help of suggestions from the students in the class.

Dewey recommends that empirical methods be used in teaching to stimulate students to be active. In his view, empirical methods are not specialised techniques but ways of working that allow us to grasp the import of our everyday experiences of the world we live in. According to Dewey, teaching should transcend school subjects and be interdisciplinary. The different subjects each reflect one and the same world and can thus not be separated from one another.

In the national curriculum for compulsory school, Lpo 94, a view of learning is expressed in which the goal is that:

“Schools should work so that all students develop curiosity and a desire to learn, – develop their own way of learning, – establish a habit of expressing points of view on their own /…/ – develop an understanding of their own way of learning and an ability to evaluate their own learning – develop the ability to work both independently and with others.” (p. 29).

We have developed our model based on Dewey’s philosophy and on the approach of the national curriculum and its goals. This means that students are not to learn a number of separate items, but that the basis of education is to be tasks in which students work toward goals that they determine together with their teacher. Active students who plan and carry out tasks that transcend subject boundaries – this is the foundation of all work with technology in the schools.

The term technology

Technology is a term that is used in a variety of contexts and has been given different meanings. It is important to know how teachers understand the term technology when technical education is to be designed in the schools. Waldemar Furmanek (1998) defines technology in a loose translation below:

“The term technology covers a specific history-creating, civilisatory phenomenon. Technology is seen – through its results – in its support
of all kinds of human activity. By using their potential opportunities, people work to change and improve their own life quality and that of others.”(p.70)

This definition is the basis of our model of technical education.

**The national curriculum in technology**

Technology is a required school subject in the national curriculum for compulsory school (Lpo 94). The reasons given for this are:

- We are required as citizens in a democracy to try to understand and evaluate technology and technological systems. Many of the important social issues today concern different choices of technology. Schools are to work to ensure that students develop this understanding of the traditions of what knowledge is in our technological culture and that they develop an ability to reflect on, criticise and evaluate the consequences of how technology impacts people, society and nature.

- By letting students test and develop technical solutions on their own, they will become familiar with the technology that permeates their everyday world.

- Our society is dependent to a large degree on our educating enlightened natural scientists and engineers in a growing number of professional categories, and the schools should work to ensure that, through teaching, students develop an interest in technology and gain confidence in their ability to solve technical problems.

The new national curriculum covers grades 1 to 9. Technology is thus no longer simply a subject for older students but is to be taught from the very first year of school.

Lpo 94 entailed major changes in the teaching profession. Teaching is to be carried out on the basis of set goals, and students are to work toward these goals. The curriculum in technology emphasises the goals that are to be reached and stresses that technical education is to be carried out on the basis of five perspectives with the aim of putting technology in a context.

- development
- technology, nature and society
- components and systems
- what technology does
- construction and operation
The national curriculum essentially presents only a structure that provides direction and basic perspectives. The rest is left to teachers, who themselves develop the content and working methods so that the goals are reached. There is no single approach or way of working with technology in the schools. Responsibility for developing knowledge about what subject material is relevant and important for achieving the goals that have been set is thus given to teachers.

### The essence of technology

In the introduction to the national curriculum, which describes the aim and role of education, it is stated that:

“Education in the subject of technology develops familiarity with the essence of technology.”

The philosopher Martin Heidegger (1977) addressed the subject of the essence of technology by analysing the derivation and meaning of the term. He describes technology as a bringing-forth, a way of revealing.

“Techné is a mode of ἀληθεύειν [revealing]. 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. Whoever builds a house or a ship or forges a sacrificial chalice reveals what is to be brought forth ... This revealing gathers together in advance the aspect and the matter of the ship or house, with a view to a finished thing envisioned as completed, and from this gathering determines the manner of its construction. Thus what is decisive in techné does not lie at all in the making and manipulating nor in the using of means, but rather in the revealing mentioned before. It is as revealing, and not as manufacturing, that techné is a bringing-forth.” (p.295)

We interpret Heidegger to mean that creativity in technology occurs in two stages. The first stage extends from the idea to a model and a technical drawing. The second stage involves the transformation of the technical drawing into a technological process that results in a finished good. The first stage can be illustrated by the creation of an architect which results in a model and technical drawing of a house. In the next stage, the constructional engineer, using his specialist knowledge, transforms the architect’s idea from a drawing into the production and building of a house.
With regard to technology as a school subject, it is the first stage that is of interest, that is, the creative process. To put it simply, the student is the architect or designer and not the engineer. We have chosen to call this technological creative process ‘the shaping of technology.’

The prototype for the kind of technical education we are talking about is the way architects and designers work by shaping, where experiences with all the senses and training in shaping and thinking in three dimensions provide a foundation for an understanding of volume, space, artifacts, technical systems and time. An example of knowledge that shapes is taken from Donald Schön (1987), who describes “project-based teaching” in an architectural school, which is characteristic of educational programs in architecture the world over. What is typical of this type of education is that the role of the teacher is to create a teaching situation that resembles a work situation in reality as much as possible. Thus reality, according to Schön, is a source of knowledge and understanding. This means that the most important thing to study is our way of thinking about reality. We act and we reflect. And how we reflect is a result of the conceptions we have.

“A designer makes things. Sometimes he makes the final product; more often, he makes a representation – a plan, program, or image of an artifact to be constructed by others.

“He shapes the situation, in accordance with his initial appreciation of it, the situation ‘talks back’, and he responds to the situation’s back-talk”. (p.78)

The shaping process is a process of developing knowledge where theory and practice are interwoven. The shaping process in technical education is similar to the design methods of engineers, industrial designers and in particular architects. However, unlike them, students will not discover, create or develop useful technical products but will instead gain insight and knowledge about the origin and function of technology and its importance to people, nature and society. It links school subjects together and places them in an everyday context. Education in technology, according to our model, should largely be oriented toward the shaping of technical products. We
consider the shaping of technology to be the visualization/clarification of an artifact or technical system.

_Shaping technology is learning._

Heidegger (1974) further writes about the essence of technology:

“Likewise, the essence of technology is by no means anything technological. Thus we shall never experience our relationship to the essence of technology so long as we merely conceive and push forward the technological, put up with it, or evade it. Everywhere we remain unfree and chained to technology, whether we passionately affirm or deny it. But we are delivered over to it in the worst possible way when we regard it as something neutral; for this conception if it, to which we are particularly like to do homage, makes us utterly blind to the essence of technology.” (pp. 287-8)

It is stated in the national curriculum that school subjects are to broaden minds and help students to develop as individuals who can participate in our democratic society in such a way that they are independent and reflective. With regard to the subject of technology, we will introduce the term ‘technical literacy,’ which provides a clearer and more explicit link to the intentions of the national curriculum, that students are to understand and evaluate technology, have an understanding of the tradition and development of technological culture, and assess and critically examine the consequences of how technology affects people, society and the environment. Jan Sjögren (1997) describes technical literacy below:

“Technical literacy is among other things a term for what we consider to be an important collection of knowledge and attitudes enabling individuals to lead a rich, active and responsible life in society.

The term technical literacy differs from other educational terms in that it emphasizes the technology that people come into contact with in some way. We are dealing here with an educational term that includes knowledge about evaluating and critically examining technology in many guises and an ability to do so.

Technical literacy means both teaching, in the sense of actively working to ensure that people have the opportunity to learn, and learning, that is, acquiring knowledge about technology and various ways of evaluating technology.” (p.328)
The place for learning

Technology constitutes a rich, multifaceted landscape for learning. Schools must remain open to the environment around them. It is here in this expansive learning landscape that students come into contact with technological, economic and social issues. In our opinion, technical education should take place in the interaction between reality and the everyday world both at school and beyond it. In order to illustrate this shifting between the classroom and society, we would like to introduce the term ‘place’ as an arena for learning. ‘Place’ is a concrete term for environment. What do we then mean by ‘place’?

A typical use of the word is in the sense of actions and events ‘taking place.’ It is meaningless to imagine an event without referring to a location. Place is clearly an integrated part of our existence. Belonging to a place means having an existential foothold in a concrete, everyday sense.

Once again, we need to look to philosophy for guidance. Christian Norberg-Schulz (Arkitekturteorier, 1999) analyses ‘place’ based on Heidegger’s philosophy. The author writes that Heidegger labels what is found between heaven and earth ‘the world’ and states that “the world is the house that mortals dwell in.” The parts of the environment that are made by man consist first and foremost of “residences” of various sizes, ranging from houses and farms to villages and cities, but also “paths” which connect these residences, as well as different elements that transform nature into a “cultural landscape.” Man-made environments include artefacts or “things” which together determine the character of the environment, which is the essence of the place. In order to gain an existential foothold, people must be able to identify with their environment; they have to know how they are in a given place. Heidegger thus writes that our environment is not only a spatial structure that facilitates orientation; it also consists of concrete objects of identification. Human identity presupposes the identity of place. Identification and orientation are primary aspects of man’s existence in the world.

Place is the students’ surroundings, their immediate environment, their neighbourhood and the surrounding landscape, their home, the district, people, infrastructure, social organisations, culture, politics, leisure activities, systems in society – in other words “everything between heaven and earth” as Heidegger formulates it. Place, with its technological environment consisting of systems and artefacts, is the students’ existential foothold – an identification, an instrument for navigating reality. Place becomes the object and the content of technology as it is to be taught in schools. In order for students to understand the processes that form and reform the growth, development and use of technology in society, they must be able to relate to this ‘place.’ By dealing with place in school, students find larger pieces that
they can fit into the puzzle, and as more pieces are fitted, students learn to recognise and understand in a more nuanced way increasingly larger pieces of the complex puzzle that is the technological landscape.

Construction of a model

Some key terms in technical education that we present here are ‘place’ with its technological systems and artefacts which are objects of study, and ‘shaping’ as a method, with the result being technical literacy. In schematic terms, the model can be illustrated as below:

The routine for performing a task can be summarized as below:

1. Work proceeds from the notion of ‘place,’ that is, the students’ reality, where important human needs are the basis for choosing a technological system, like a system linked to housing.

2. The shaping process begins with the teacher and students together formulating the “task,” for instance, shaping a house of their own. Students learn general knowledge about the current technological system, like the history of houses, the different systems in houses, the construction of houses and knowledge directly linked to the design process, like a sketch/drawing/model.

The last stage of the shaping process is documentation of the task with the help of sketches, descriptions, models and simulations, which show the students’ work.

3. The work is then presented and finally evaluated.

Below we will explain each stage in this didactic model.
1. Technological systems

Technology is needed, not just for the modern, high-tech society we live in but for all human life – everything from stone axes to today’s advanced energy systems and the Internet. The Internet has been called one of the world’s greatest machines and highlights how our existence is increasingly dependent on major technological systems.

Both technology and society have become increasingly “systematic”. To the same extent, people have become more and more dependent on the smooth functioning of these technological systems and on the notion that these systems are there for the benefit of people.

Technology should not be seen as individual artifacts but should instead be seen as parts of systems. Jane Summerton (Blomqvist & Kaijser eds., 1998) writes:

“What constitutes the foundation of a systems perspective, however, is that all technology can be seen as consisting of closely or loosely linked parts or components, which together form an integrated whole. In order for this whole to work, the different parts have to be coordinated with one another. A system is thus characterized by the strong interdependence of its components.” (p. 21)

Summerton claims that all technological systems are sociotechnological in nature, that is, they consist of both technological and social (political, economic, organisational, cultural) components that are woven together in a complex interplay with each other. Different kinds of knowledge and artefacts are combined without giving consideration to the strict boundaries of school subjects.

We have chosen to structure ‘place’ based on the needs of people. This can serve as support in the choice of technological systems and tasks.
2. Shaping of technology

The shaping process in technical education can be illustrated by a series of stages that in principle are included in every student task: need – formulation of the task – analysis – visualisation/shaping – result – evaluation/reflection. In theory, this series constitutes the basis for all design methods. It is on the basis of this process that students are to plan their work.

a. Formulation of the task

Students are to carry out a defined task or meet an explicit need; this might include improvements in existing systems or products, innovative creativity, new ways of thinking or simply a given technological development. Planning for every task begins with a background description explaining and justifying the planned shaping activity. Students are to summarise the information that has been given out in their background description in such a way that they can show they have understood the task.

It is common in educational contexts to use the term ‘problem’ or ‘problem-based task.’ We use the word ‘task’ instead because ‘problem’ is associated with a mental state, with difficulties or worries. Problem solving can also be translated as meaning that there is only one solution. ‘Task,’ in contrast, is a formulation, an aspect that defines a way or a course of action that allows for different solutions.

The teacher’s role is important when the task is introduced. Creating an exciting task is perhaps the most important thing and at the same time the hardest. Tasks should always be formulated together in a conversation with the students. Important sources when a task is introduced can include newspapers filled with up-to-date technological ideas, children’s books for younger students, events in the local environment, and studies of products that can be improved.

Teachers, together with the students, draw up a plan – an overview of materials available, tools, time allowed, reporting forms and criteria for evaluation.

b. Analysis

Each task presupposes a detailed analysis of the development, function and construction of the product or system as well as an analysis of the advantages and disadvantages in terms of the object’s impact on nature, society and the living conditions of individuals.

The analysis is based on all of the object’s (the system’s or product’s) anticipated functions. This often involves extensive investigative and research work, which frequently constitutes the hardest part of the task and takes the most time; it is therefore important to plan and justify the task.
The idea of function analysis is to get us to learn to think and express ourselves in functions and not in ready-made solutions — learning to think first and act later.

c. Sketch
The sketch helps students to specify the problem, and it provides material to generate conversation and discussions about problem solving. We believe sketches should be used extensively in compulsory education, particularly at the lower levels. A legible sketch can be used as documentation in the form of a technical report.

d. Model making
Models are a very powerful tool in the creative process. Models give thinking material form: it is a case of thinking in action. A simple model made of paper is easier to understand than the most advanced two-dimensional illustration, and it immediately reveals what does not work in practice. The pedagogical value of models makes them suitable for use in the shaping process.

Model making requires certain knowledge about materials, assembly and tools. In making models, students should gain some knowledge about materials, tools, production methods and other aspects, which is needed to transform the model into a real construction. In other words, being able to build a model quickly and using simple means is an extremely valuable method for reflecting on our three-dimensional reality.

e. Technological principles
Technological principles are characterised as being applicable in a number of technological constructions. Some technological principles are laws and rules in the natural sciences, some are mathematical, others are mechanisms, structures, automatic systems etc. Layton (1993) likens the laws and rules of the natural sciences to tools on a factory’s stockroom shelves. The shelves are well-stocked and the tools are arranged in an orderly manner, but the items are intended for practical purposes and for use outside the area they were created for. They are to be used as instruments to achieve given targeted goals, which are outside the subject they are categorised under. The aim is to search among this knowledge material to find what is useful and applicable to the task at hand.

The choice of technological principles depends on what task students are to carry out, and it is important that the teacher is aware that teaching in technology is not aimed at producing engineers but is intended to give students certain knowledge about technology.
What students need above all are: practice exercises, sketching techniques, knowledge about colour and form, techniques for building models and knowledge about materials used in model making.

f. Documentation – presentation
Documentation is also a part of the task. This documentation has several functions. Documentation provides an opportunity to develop in different ways the students’ ability to express themselves, both in language and in pictures.

After the work with shaping is completed, a technical report is to be written based on sketches made, notes about ideas, potential solutions, reflections etc. Included in the technical report are both technical drawings/sketches and written documentation including an analysis based on the five perspectives specified in the curriculum. The requirements for the technical report of course vary, depending on the age and individual qualifications of the students, but an important aspect is having students analyse their own work in language and in pictures.

3. Evaluation – follow-up
Evaluation is aimed at, among other things, stimulating and developing students’ learning and encouraging them to take responsibility for learning, giving the teacher feedback on instruction and providing the teacher with material that can be discussed in parent-teacher conferences.

Assessing and supervising the students in their task is a central tool for achieving results. Students are evaluated during the shaping process and when the task is completed. It is important that the students’ development is mapped out in the shaping process in relation to the goals that have been set for the task. The teacher will then assess and supervise the students’ continuing work on the basis of this.

Evaluations that focus on learning and development entail to a large extent motivating students, creating interest in the task and developing their confidence in their ability to solve problems as well as assurance that the results will be good.

Also included in the final evaluation, along with an assessment of the process, are the students’ technical report, their oral presentation of their report and their model.

Evaluating students is a central problem in the schools. Someone who has provided knowledge about process evaluation is Lars Lindström (2002). In his research, he has developed criteria and developmental stages for art as a school subject.
IT as a tool in technical education

We see four different ways of using computers in the teaching of technology.

1. Strategy and simulation programs

With respect to technology, there are only a few programs designed for presenting a particular concept or technological area. We would also include strategy games available in the general market, like Sims and Civilization, which were not developed for school use but can be used, from a technical education perspective, in instruction involving social planning, city planning and the historical development of such planning. This type of strategy game is constructed so that users develop their own society, which requires a great deal of strategic and creative thinking.

2. Tool programs

Tool programs are generally very flexible and thus require more from their users. There are often special rules that must be known in order for someone to use the tool, and the more a person knows about the rules, the better the tool can be used. An example of a tool program that is relevant in the teaching of technology is CAD. This computer program is intended as support in the shaping process. The program, which uses three dimensions, offers various perspectives for presentation and is quite useful for people who are not good at drawing in visualising their ideas; moreover, the program saves time compared to working with pen and paper. The question is whether this is a useful tool if it makes things so easy. Will students understand the underlying principles in order to interpret a picture? These questions are open to discussion. Hopefully, there will be considerable research devoted to these issues in the next few years.

3. The search for facts

All creative work in technical education requires the acquisition of fact-based knowledge. With the help of modern computer technology, its communications systems and databases, students have access to all conceivable kinds of information, as well as scientific and technical articles from around the world. This aggregate of information and knowledge requires both an ability to get an overview of the flow of information and an ability to structure this in order to understand it. It also requires an ability to sort out and critically examine the information. These are abilities that every teacher, no matter what subject is being taught, should develop in their stu-
4. Documentation of work

Technical tools can also help students today to document their technical work, visualise and illustrate it and finally communicate their work in presentations of different kinds, for instance, via e-mail.

In our view the use of IT holds potential and opportunities in Technology Education for students to work with problem solving and modeling.

Shaping bridges – a practical example

One example from Grade 8, Högalid School in Stockholm, shows how a change in the environment that is of interest to students is used as a task. A new bridge, the Årsta bridge, 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 bridge. Below is a description of the different stages of the project:

a. Formulation of the task

The task is designed with the help of students concerning a question (problem): shape your own vision of a new Årsta bridge.

In this stage of the work, students developed an enormous interest in the task by asking questions, noting similarities and difference, discussing views, defending arguments and being open to the views of others in formulating the task.

b. Analysis

We started with a visit to study the construction, function and shortcomings of the bridge that is currently there. Students also watched a movie showing the history of bridge construction. The movie was supplemented with a tour of Stockholm’s bridges led by staff from the Swedish Museum of Architecture. By studying different bridges from different eras, students collected information about their construction, form, size, function etc. Maps of railroad and road networks in Stockholm were studied and classtime was used to discuss costs involved in the construction of bridges, alternative solutions etc.

In this stage of the work, students developed their ability to look for
information from different sources (library, Internet, city architect), they learned to reconnoiter the planned building site etc.

c. Ideas, sketches
Students divided themselves into groups, with two to four people in a group. Two students chose to work alone. The requirements were set for a model, documentation, presentation and evaluation, as were the timeframe, materials available, scale of the model and content of the technical report.

The groups began drawing different proposals for solutions before eventually choosing the most suitable solution.

In this stage of the work, students developed their inventiveness, the ability to present and evaluate different ideas, proficiency in drawing, and an ability to think about the advantages and disadvantages involved in the impact of the new bridge on the environment and the city.

d. Making models
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 bridge in a different way.

In this stage of the work, students developed their ability to: use the right tools, choose and use the right materials for the model, use scale, construct the model, think three-dimensionally.

The completed models were discussed first in the individual groups together with the teacher. After this, students simulated a local government council meeting discussing the construction of the bridge. Students were given certain roles: city architect, builder, politicians from different parties, representatives of Greenpeace and of local residents. The model was discussed in terms of construction, function, appearance, finance, environmental impact, local residents, traffic, safety, accessibility for disabled persons, potential improvements etc.

In this stage of the work, students developed their ability to: argue, express critical opinions, respect the views of others, participate in a democratic decision-making process, evaluate a technical construction from a number of different perspectives.

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

In this stage of the work, students developed the ability to sort out, structure, supplement and combine the material, write, make drawings and tables, use the computer, reflect on their work and suggest potential improvements.
f. Evaluation – follow-up
Evaluation was done together with the students after the work was completed. They gained an understanding of the importance of bridges as a part of various technological systems, of their importance to people and of how they have developed over time. Students gained an understanding of and familiarity with concepts such as construction, framework, humpback bridge, suspension bridge, and bascule bridge, as well as concepts like social planning and the democratic decision-making process.

Students were very proud of their work but were critical of their own work in making constructions. They were aware of what changes they would make if they were to do the task again.

Students also developed an ability to plan, organise, work systematically, work together and be persistent.

g. Presentation
The groups 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.

In this stage of the work, students showed pride in their work and strong confidence in their ability to argue in favor of their version of the Årsta bridge construction.

Technology as a school subject – a tool for thought

Technical literacy
Technology is influencing our lives and society to an increasing extent. No matter what people may think about this development, it is important that students gain a basic understanding of technology and knowledge about how technology, people and society are interdependent. It is a question of being able to use the technology we meet in our everyday lives, of mastering it in a confident and effective way, and of understanding that technology is more than simply facts and information.

It is to a large degree a question of being able to understand, use and integrate different technical systems. Insights and knowledge about the technological systems we use and are surrounded by are necessary so that individuals can manage their jobs, function as citizens in a democracy and help to achieve ecologically sustainable development.

Technology as a school subject starts out with what is concrete and obvious, and we see four important reasons for technical education in the schools:
1. Technology is culture.
2. Democracy is a central issue.
3. Giving children and young people the chance to speak is an important aspect of democracy but is also a matter of letting young people inspire the adult world. They function as feelers for the future. The needs of children and their dreams for their own environment are a key foundation of technical education.
4. Agenda 21 is the challenge to everyone to create a just planet that is sustainable over the long term. It is predicated on the involvement of everyone, especially the younger generation, in the environment we live in.

**Technical thinking**

Thinking is developed in the shaping process. If this notion serves as the basis of teaching, the goal of technical education will be to develop technical thinking. Edward Franus (1978) argues that technical thinking consists of four types of thinking:

*Practical thinking*
- Simple routine activities – governed by thought, like handling tools, simple production
- Manipulative thinking – assembly and disassembly of technical devices
- Investigative thinking – diagnostics, investigation of new products

*Visual thinking*
- Reproductive thinking – like in the reading of technical drawings
- Creative thinking – in planning, construction work from a simple sketch to drawings, models

*Intuitive thinking*
- Improvement of existing or creation of new constructions as well as well-thought-out construction forms in the world of ideas

*Conceptual thinking*
- Mainly based on thinking operations involving words and descriptions
- Built on systems of concepts or technical categories, occurring in explanations, justifications and in the shaping of actions. An analytical and synthetic way of thinking.

Franus emphasises that these types of thinking do not take place in any chronological order but rather occur simultaneously. In symbolical terms,
it could be said that students have four cups to fill in developing their technical thinking. The cups are gradually filled, and sometimes one cup may be fuller than the others, but it is reasonable to assume that conceptual thinking, an ability to analyse and synthesise, is the kind of thinking that is filled mostly towards the end of elementary school.

Robert Sternberg (2000) analyzes the processes of thinking based on three aspects that work together with our actions – our inner qualities, our previous experiences and the situation we are in.

In Sternberg’s view, intelligence includes an analytic ability (strategies for solving known problems), a creative ability (strategies for new problems, creating and discovering) and a practical ability (strategies for applying and acting).

Gustaf Rosell (1990) distinguishes three types of thinking in engineering which are all needed to achieve the goal: rational thinking, innovative thinking and artistic thinking. The author writes that artistic or intuitive thinking is what is least accepted in engineering, but that there is an aesthetic dimension in technical creativity – an intuitive feeling for the whole, the interplay with people, with function etc. This originates in art, not science. This kind of thinking is closely linked to non-verbal and therefore in particular to visual thinking.

Rosell writes that visual thinking includes, along with thinking in terms of pictures and an ability to draw, an ability to find new ways of seeing problems. There is a Swedish expression, “you think with your pen.” By sketching, both possible and impossible concepts can be investigated, a kind of visual brainstorming.

Sketching is a way of working that is comparable to formulating one’s thoughts in words. As with writing, reworking drafts is an important stage in sketching. Visual language is universal in nature; it can be understood no matter what a person’s nationality is.

We are convinced that in teaching technology as a school subject, the thinking of children is developed by working with the shaping process.

**Developing abilities**

It is the duty of the schools to develop the students’ ability to continually learn and develop their skills so that they can successfully handle situations they will face in the future. In their publication *Företagsamma skolan, SAF* [Entrepreneurial Schools](1997), the Confederation of Swedish Enterprise, a confederation of business interests, gives examples of what abilities they feel are important to develop in students:
– an ability to reflect on their own experiences and impressions, draw conclusions and test these with practical experiments
– confidence in their own thinking, daring to trust their own conclusions while at the same time being open to the views of others and gaining knowledge from research, from different sources of knowledge and traditions
– an ability to communicate, assimilate, study and analyse information from different sources using different means
– an ability to work in groups and take advantage of one another’s resources in development and problem solving
– an ability to work with complex problem solving, that is, identifying, interpreting and solving actual problems both on their own and in groups
– an ability to reflect on their own way of learning, recognizing their own style of learning (meta-learning) and being able to evaluate their real skills and abilities and benefit from their own way of learning
– an appetite for learning (p. 19)

We believe that working with the shaping process in technology in the schools develops these abilities.

**Technical self-confidence**

By working with different tasks, students gradually develop technical self-confidence: I CAN! Perhaps the most important effect is having a personal conviction that, if I confront a problem or am given a task, I have the tools to address the problem or task and an inner conviction that I will fix it in some way. An example of this is Lisa, in Grade 2, who is sitting next to her teacher Berit in early December watching the traditional Swedish Lucia procession pass by. One of the participants is wearing a top with a star on the front with a blinking light-emitting diode. Lisa whispers to the teacher: "Berit, we could easily make a Lucia top like that." This is relevant because the week before, the class had made Christmas decorations using diodes.

Inga-Britt Skogh (2001) shows in her study *Teknikens värld – flickors värld* [The world of technology – a girls’ world] that girls, with few exceptions, express great interest in technology and technological tasks and that technical education in school is an effective way to give girls an opportunity to develop a technical identity through experiences with technology.
Summary of a didactic model for technical education in the compulsory school

In this article, we have tried to describe our didactic model for technology as a school subject as we see it today. The model described is aimed at giving students technical literacy and developing their technical thinking. A further goal is developing their technical self-confidence.

We would like to accomplish these goals through the students’ own work with shaping, completing tasks taken from the society around them (their place). From the formulation of the task to completion (shaping) of the model, documentation and evaluation, learning is focused on technical literacy, on technical thinking and technical self-confidence.

We would like to end this article with a quotation from a report from a UNESCO international symposium held in Beijing in 1989 on Qualities Required of Education Today to Meet Foreseeable Demands in the Twenty-first Century. We think the quote reflects our search for a didactic model, a search that we have described in this article. At the same time, these words also reflect the essential development in technology:

"The future is not some place we are going to, it is one we are creating. The paths to it are not found but made, and the making of these pathways changes both the maker and the destination." (UNESCO, 1989, p. 9)

References


Technology in the Swedish curriculum

Syllabuses for compulsory education

Aim of the subject and its role in education

Human beings have always striven to safeguard and improve their living conditions by changing their physical environment in various ways. The methods used are technological in the broadest sense. Technology as a school subject develops a familiarity with the essential features of technology. The aim is to increase understanding of how conditions of production, society and the physical environment, and thus our living conditions, are changing. Technological activities have a substantial impact on man, society and nature. This becomes particularly evident when technology is undergoing rapid development.

Society and our ways of living are increasingly influenced by the use of technical components, which in their turn are often included in larger technical systems. Making everyday technology as understandable as possible is thus an additional aim. This covers everything from the simplest domestic devices in the home to modern equipment and complicated transport systems. Technical knowledge is increasingly becoming a prerequisite for mastering and using the technology around us. Citizens in a modern society need basic competence in technology, and this competence must also be continuously expanded and adapted. This competence covers not only knowledge about the role of technological development from a historical perspective, but on experience in reflecting over and solving technical problems in practical terms. In addition, it is necessary to be able to analyse and evaluate the interaction between people, technology and the conditions under which we will exist in the future. Exploitation of technology raises a number of intricate issues which affect fundamental values, for example, the impact of technology on the environment. In addition, many other aspects of our existence, such as working life, housing and recreation, are influenced by technology. Opportunities for the group and for individuals to exercise influence and power are largely dependent on how technology is designed and used in society.

The attitudes of girls and boys to technology differ somewhat – as do traditional views on the role of girls as opposed to boys in technological contexts. One aim is to give everyone the opportunity to consciously acquire all-round knowledge in the subject.
**Goals to aim for**

In its teaching of technology the school should aim 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 about the technology which 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 in their own personal views of the world and practical actions,

– develop an interest in technology and their ability and judgement when handling technical issues.

**The structure and nature of the subject**

For thousands of years human technical abilities have been nurtured and developed by women and men in practical activities. This process rests on tradition and praxis, the ability to observe, curiosity, wealth of ideas, initiative, influence from other cultures – and learning from failures. Simple and often ingenious technologies are important features of our lives and thus make up an important part of the teaching in technology. An increasingly larger share of new technology is the result of scientific research and systematic development work.

The culture of technology is largely based on the traditions of knowledge found in practical work. These have been developed in the home and households, handicrafts and industry, as well as in a number of other contexts. By following the historical development of technology, the subject increases the scope for understanding today’s complicated technological phenomena and contexts. In practical activities, being able to test, observe and design is a productive way of becoming more familiar with the primary questions concerning the goals and opportunities provided by technology and of acquiring an understanding which is difficult to achieve in any other way.

Such activities also provide an emotional dimension, which link to other forms of creative activity.

To understand technology and its importance, these must be related to knowledge from other areas, such as the natural and social sciences. However, there are clear differences between these areas. The driving force of the scientist is curiosity in nature, and for the social scientist curiosity in society,
whilst the challenge for technology is the set of unsolved practical problems confronting people. The history of technology enables us not only to gain a deeper understanding of the conditions of technology, sometimes very clearly, but also an understanding of many events in other areas of history. Technology is developed in interaction with the fine arts. In general, technology is a meeting place for ideas and knowledge of the most varied origins, and this has characterised its development since the very earliest times.

Practical and investigatory work provides illustrations of the development process of technology, its identification of problems, ideas, planning, construction, testing and modification, and also shows how the technology around us is linked to different and often interdependent systems.

Some of the central issues and perspectives in the subject focus on what is specific to technology.

Development

Technological development has a number of different driving forces. Changes in nature, such as droughts and floods, and the often unpredictable effects of technology have often presented humans with challenges to surmount. In the same way, societal transformations and needs of different kinds have influenced technological development. This may apply to such things as changes in the population structure, values, economics, politics and environmental requirements. But technological development is driven not only by the effort to innovate, but also by human curiosity and creativity.

What technology does

Technological problems and solutions can be categorised in different ways. How this is done depends on what one wants to accomplish. The following fundamental functions can be identified: transforming, storing, transporting and controlling. By means of clarification and systematisation, pupils acquire their own tools, enabling them to analyse the role and function of technology.

Examples of the transformation functions of technology are the processing of stone into axes, fibres into materials, erection of brick buildings, and the encoding of secret messages. Early examples of ways of storing were earthenware jars with hieroglyphics; significantly later come the refrigerator and the computer hard disk. The technology of transport can be illustrated by vehicles, as well as by power cables and fibre optics. Locks, pacemakers and thermostats are examples of how technology can be used for different kinds of control processes.
Construction and operation
The subject covers the study of different technologies and their solutions in order to build up a technological repertoire, both practically and conceptually. Some examples of fundamental and common solutions in central areas are materials and design, moving parts, electricity and control, which are given special attention.

Components and systems
Objects with technical functions linked to each other in different ways are almost always components in larger systems. Examples of large systems are networks transporting goods, energy or information, whilst engines, power cables and computers are components in these systems. Sometimes it is also meaningful to define sub-systems, i.e. intermediate levels in a hierarchical system. By studying individual technological solutions and their incorporation into larger systems, pupils can obtain important insights into the special character and conditions of technology.

Technology, nature and society
In order to understand the role and importance of technology, the interplay between human needs and technology must be considered. This perspective highlights the consequences and effects on the individual, society and nature of using different technologies. The subject also takes up issues concerning values, conflicts of interest, changing life conditions and economic consequences, which can arise in connection with different types of technological applications.

Goals that pupils should have attained by the end of the fifth year in school
Pupils should
– be able to describe in some areas of technology they are familiar with important aspects of the development and importance of technology for nature, society and the individual,
– be able to use common devices and technical aids and describe their functions,
– be able with assistance to plan and build simple constructions.
Goals that pupils should have attained by the end of their ninth year in school

Pupils should
– be able to describe important factors in technological development, both in the past and present, and give some of the possible driving forces behind this,
– be able to analyse the advantages and disadvantages of the impact of technology on nature, society and the living conditions of individuals,
– be able to build a technical construction using their own sketches, drawings or similar support, and describe how the construction is built up and operates,
– be able to identify, investigate and explain in their own words some technical systems by describing the functions of their components and their relationships.
Why do they do what they do?

The theory of action in practice – using the example of teaching technology

When children (or adults) are faced with a technical task or a technical problem, the actions that follow – what the individual does – are of great importance. The way the person acts – how the individual approaches and deals with the task – leads to consequences for her/his personal experience (the feeling of success or failure) as well as for the concrete result of the action taken (the result is achieved or not). To learn in different ways how to understand why pupils do what they do is, in other words, an especially important task for teachers and educators who teach technology.

How then can we as teachers and educators proceed to attain this knowledge? In social science research there are a number of different examples of explanatory models of the actions of both children and adults. One of many examples in the theoretical field of social psychology is called symbolic interactionism, where the interaction between the individual and the environment is the main focus.

The explanatory model that is presented in this article – a pedagogical application of Georg Henrik von Wright’s theory of the logic of action (von Wright, 1983) – also considers the interaction of the individual with the environment. But von Wright adds a further aspect, namely, the action of the individual in connection with a particular event or situation – e.g. the actions of pupils in “technical” situations.

The rapid development of technology puts demands on schools in teaching this subject. If we want more pupils to be interested in technology then the teaching has to be changed and adjusted to both the individual’s and society’s needs of technical competence. Using analyses of one’s own pupils’ actions as a starting point for obtaining knowledge (and understanding) as to why they “do what they do” could be a way for teachers and educators who teach technology to find ways of adapting their teaching to the pupils situation and environment. Meeting the pupils where they actually “are”, and not where the teacher/educator wants, believes or hopes them to be, should be an important prerequisite when it comes to capturing the pupils’ interest in technology.

After an introductory presentation of von Wright’s theory of the logic of
events and the pedagogical application of this theory, upon which the analysis model is built, I will give examples of how I have used the model as a basis for analysing girls’ actions when faced with technical tasks. The examples are from my dissertation on young girls’ encounters with technology at home and in school (Skogh, 2001).

**Logic of events – a way to understand and explain the actions of individuals**

In his paper *Determinism and the study of man* (1983) Georg Henrik von Wright formulates his theory about the logic of events. According to this theory there is a logical connection between, on the one hand, the individual’s *internal determinants*, that is to say the individual’s intentions and her/his conception about the demands of the situation in relation to the intention (epistemic attitude) and, on the other hand, how the individual reacts.

Von Wright also points out the possibility of explaining an action by seeing it as a result of how the individual perceives external factors (rules, expectations from other people and so on). von Wright calls these factors *external determinants*. The internal and external determinants together constitute the *internal logic* of the action taken by the individual.

Von Wright introduces yet another element in his explanatory model, namely, the need to describe and explain the situation in which the action takes place – the background for the appearance of the internal and external determinants, that is, the event’s historical context. An objective and thorough examination of the situation at hand – the *external logic* – offers a deeper understanding of the individual’s actions. This examination also makes it possible to understand and explain the actors’ internal and external determinants.

Logic-of-events interpretations of the actions of individuals can thus be described as an amalgamation of internal and external determinants (the internal logic) and by the underlying reasons for these determinants (the external logic).

**Logic of events as a point of departure in a pedagogical study**

Logic of events as an explanatory model is not limited to a special scientific situation but can be seen as a general model of analysis for explaining and understanding the actions of individuals, in circumstances and situations that are characterised by a certain stability.

Schools and education have for many years been an established part of society and, in spite of the fact that Swedish school policies are continuous-
ly reviewed, the school as an institution is a permanent element in society. Using the logic-of-events explanatory model in studies about school and education could therefore be said to meet the prerequisites that von Wright lays out in his theoretical model.

According to von Wright there are combinations of determinants that appear with certain regularity, depending on the situation at hand. If we apply this reasoning to a pedagogical situation, it should be possible for a teacher in a given teaching situation to be able to predict, understand and explain with relative certainty the actions of pupils, provided the teacher knows the intentions of the pupils (their needs and wishes, their ability, etc.).

For most active educators this thesis reflects a well-known phenomenon. The teachers’ mission to convey knowledge and experiences can to a large extent be influenced by how well they are able to analyse the teaching situation and identify the conceptual schemata that the pupils, based on their qualifications and intentions, use and act upon. By putting the pupils in a particular situation (during a lesson in technology, for example, letting the pupils build towers that are as high and stable as possible), under certain circumstances and with the help of a number of methodical methods (supplying the pupils with material, inspiring and arousing their curiosity) the pupils will almost certainly act in a predictable way (they start building their towers).

The internal logic of the actions of pupils in a technical teaching situation

The concept of intention

Logic-of-events interpretations are based on the fact that we learn to identify the intentions of individuals (see above). In order to do that, we need to create a picture of the individual. By observing individuals and situations, we can then learn to determine connections between the conditions and the consequences of their intention. However, it should be pointed out that the reliability of such predictions and explanations is to a great extent dependent on the time factor. The longer the time that elapses from the moment an intention is initiated and the longer it takes for the individual to realise the intention, the greater the risk that the individual will have changed his/her intention, which naturally leads to the result that the action the original intention could have been expected to lead to is not fulfilled. Von Wright identifies four intentions; wants, duty, ability and opportunity. Each of these intentions could be described in the following ways:
The intention wants

With the intention wants von Wright describes that which the individual (here the pupil) wants and/or considers him/herself in need of. Since the aim of achieving health, well-being and joy is common to all people, our needs and wishes will in one way or another relate to these feelings. Consequently, it is not surprising that the aim of every pupil is to be liked and appreciated by teachers. The pupil then has to act according to this aim. How he/she succeeds is of vital importance not only in the current educational situation but also in different and future educational situations. The pupil’s action is ruled both by the pupil’s wish to succeed (in his/her own eyes and in the eyes of the teacher) and by the pupil’s desire to avoid unpleasantness (e.g. bad marks, disapproval from teachers, parents and fellow pupils). In the teaching context, the teacher has to convince the pupils that the knowledge and experience the teaching is aiming for is in accordance with the needs and wishes of the pupil. Pupils’ needs and wishes in the teaching context can be labelled as motivation. The motivation of the pupil can be of decisive importance as to how the pupil will act in the teaching situation.

The intention duty

The intention duty should, according to von Wright, be seen as a consequence that the individual is expected to act in accordance with a defined role – behaviour that does not necessarily need to agree with the personal will of the individual. For the pupil this means that he/she is expected to behave in a certain way. This expectation is not a consequence of explicit rules, but instead this expectation is “internalised” – it is so well established in society and in the individual that it is not questioned.

The role as a pupil is not static but changes in relation to the circumstances (and the time) of which it is a part. On a micro level this could mean that a pupil could change his/her interpretation of the pupil role several times a day, for instance with a different teacher and/or subject or because of the pupils around him/her. On a macro level the pupil role is continuously being re-evaluated according to the rules and norms of the surrounding society.

In order to succeed in behaving according to the pupil role, the pupil must be aware of the internalised rules that surround the role. If a pupil lacks this awareness or if he/she diverges for any other reason from the expected pupil role, this will lead to obvious consequences for the pupil (reprisals in the form of bad marks, angry teachers/friends, disappointed parents, etc.). For many pupils these consequences are sufficient reason to
behave in accordance with the intention wants mentioned above, that is, to behave so as to ensure the greatest possible well-being.

*The intention ability*

When pupils are in a classroom situation, the concept ability could be interpreted as an term for the pupil’s individual characteristics in the classroom situation. A pupil’s ability is limited both by inherited (intelligence, memory, health, physical strength) and by acquired (learnt) qualities. If the cultural situation permits, the pupil can improve his/her ability by training and learning.

The possibility to increase one’s ability within a certain area can in certain cases, however, be hindered or limited by different circumstances. Access to equipment and technology is one such limiting circumstance. Another such circumstance is to what degree the individual is given occasion and the opportunity to be engaged in the field in question. The desire to do something is not the same as being able to do it. To try to do something that you do not yet know how to do requires both that you believe that you can do it and that you undertake such measures that in the end you can do what you want. The pupil’s ability changes with time and the question as to what a pupil can achieve can, and should, be connected to the other intentions.

*The intention opportunity*

The possibility of an individual to act is not limited only by his or her ability, but also by whether the individual is given the opportunity to act, as has been mentioned above. The ability is tied to the individual while the intention opportunity is highly dependent on the situation at hand. Von Wright believes that we, by our actions, are both open to and prevent the opportunity to new action. In a teaching situation, the choice by the teacher/educator regarding method, subject content and way of working should make the pupils open to acting in different ways. Strict teaching that is controlled by the teacher leads, not unexpectedly, to a situation where the pupils react in one way, while pupils who are asked to work independently will more than likely act in a different way. What a pupil can achieve in the classroom situation depends on the conditions governing the situation – expectations, resources and the balance of authority. If these conditions change, then opportunities for new actions open up for both the pupil and the teacher. This does not automatically lead to those involved changing their actions. The process of altering a person’s pattern of behaviour is a thorough change for the individual that requires varying amounts of time, depending on the type of change, circumstances and personal disposition.
An extension of von Wright’s concept of intention

The fact that von Wright’s model of thought concerns the behaviour of individuals in general and not the behaviour of pupils in a pedagogical learning situation leads, in my opinion, to a need of extending von Wright’s concept of intention. In addition to the four intentions that von Wright identifies (wants, duty, ability and opportunity) I add two “new” pupil-specific intentions in my pedagogical application of the logic of events. With the help of these intentions it becomes possible to describe and emphasise aspects that influence the behaviour of the pupil (but not that of the teacher) in the school situation. The first of these “new” intentions is concessivity.

The intention concessivity

Concessivity\textsuperscript{10} is an intention tied to the subordinate position of the pupil in the school situation. It is meant to describe to what degree the pupil conforms to and subordinates him/herself (“opens up”) to the teaching – the degree of concession on the part of the pupil.

Being a pupil means in concrete terms conforming to a situation that is not (always) one’s own choice. The will to go to school can be more or less expressed by the pupil, but regardless of the pupil’s view, society orders the pupil to go to school for a minimum of 9 years (in practice, often up to 12 years). Being a pupil means being in a subordinate position in other aspects as well:

– Pupils often know (for obvious reasons) less than their teachers.\textsuperscript{11}
– The teacher (school/society) decides the subject matter, contents of subjects as well as where, when and how the teaching should be done.\textsuperscript{12}
– The teacher (school/society) judges the pupil, which influences evaluations/marks, treatment and prospects for the future, etc.

From his/her subordinate position, the pupil will behave in different ways in the classroom situation. A high degree of concessivity means that the pupil chooses to “be receptive to” the teaching. Showing a high degree of concessivity does not preclude the pupil from questioning the teaching. There might be a number of different motives and considerations behind a pupil’s decision to “play along” and it is not always the case that the pupil is actively aware of these reasons. A low degree of concessivity means that the pupil withdraws from the teaching situation, that is, he/she is not learning what the teacher is trying to convey.

R.S. Peters \textsuperscript{13} (1967) describes this phenomenon in part when he elaborates on the concept of teaching:
As an activity, education must fulfil three conditions – intentionality, voluntariness, and comprehension – for it involves the intentional transmission of something worthwhile, an element of voluntariness on the part of the learner, and some comprehension by the learner both of what is being learned and of the standards the learner is expected to attain.

Peters means that the teaching situation includes a will on the part of the pupil to let him/herself be taught – a voluntariness in the teaching situation. The concepts of concessivity and voluntariness affect an important part of the teaching process and here I would like to explain their relation to each other. Concessivity describes the pupil’s intention (will/ability) to conform and subordinate him/herself to the teaching situation – to what degree the pupil is capable of calling forth “voluntariness”. Voluntariness thus constitutes, in those cases where it does not exist “from the beginning”, a consequence of a high degree of concessivity on the part of the pupil.

For pupils who are interested from the beginning, voluntariness is a “natural consequence” of this interest. For the uninterested pupil (from the beginning), the degree of concessivity constitutes the ability to overcome the pupil’s own resistance – “to deal with” the teaching situation.

Pierre Bourdieu14 (1984) sheds light on this aspect:

In order for the teacher’s normal discourse to work, presented and received as a matter of fact, a certain authority-belief connection is required. A relationship between an authorised sender and a receiver is required in order for the receiver to take in what is said, prepared to believe that what is being said is worth saying. The creation of a receiver who is willing to receive is required, and it is not the pedagogical situation that creates this person.

The word concessivity means the pupil’s will/ability to get ready – the way Bourdieu expresses it “to receive” the teaching. The following example from a lesson in technology shows these combined intentions.

Pupil A comes to the day’s last lesson, which is technology. The teacher introduces the content and activities of the lesson – the pupils are going to make a simple electrical switch. Different degrees of concessivity (concession) make the pupils act in different ways (solidarity, self-assertion, dissociation).

When the teacher looks at the class after a while, he/she sees either A busy working or A not working at all, arguing with a friend, look-
ing out the window or something similar. What the teacher does not see is what is going on inside A’s head. Let us “have a look” in there:

The teaching situation for pupil A means that he/she must decide what attitude to take to the given task. A chooses consciously or unconsciously whether to listen to or just hear what the teacher has to say. The degree of concession in the teaching situation (concessivity) is connected to the pupil’s own will/ability to conquer his/her inner resistance and ability to adapt.

What motives and considerations underlies the pupil’s decision to “play along” with the teaching is something that the pupil is not always aware of. In the example above, the pupil’s behaviour could be derived from one or several background factors.

A, who is tired and hungry, initially has no inclination to do what the teacher says. Besides, A thinks it seems difficult to try to make an electrical switch. At the same time A wants to make a good impression on the teacher (out of solidarity or to get praise) and A is also curious to know how the whole thing works. Inwardly, A also sees how he/she could use the electrical switch in his/her newly built playhouse (Intentions such as wants, duty, curiosity, etc).

If pupil A decides to accept the work and starts making the electrical switch, then A shows a great degree of concessivity – A accepts the situation, adapts and “allows him/herself” to be taught. A pupil who participates in the teaching has, by doing this, “opened up” to the teacher and is willing to accept the knowledge or experience that the teacher presents.

The fact that the teacher and the pupil are “working in unison” in the teaching situation does not mean that the two participants share the same reason for doing so, but both of them think that the teaching serves their individual aims. As mentioned before, a high degree of concessivity does not preclude the possibility that the pupil will question the teaching – what the pupil does is to conform to and subordinate him/herself to the present teaching situation.

A can also choose not to do what the teacher says and instead question and dissociate him/herself from the teacher and/or the teaching situation. The pupil does not want to/can’t for various reasons conform to and subordinate him/herself. The trouble and effort that this would mean to the pupil does not correspond to the usefulness that the pupil sees.

In this situation the teacher could try to force the pupil to do what he/she says. This could possibly lead to the pupil making a half-hearted attempt to
please the teacher. However, the degree of concessivity is nothing the teacher can influence. A pupil who experiences force will distance him/herself from the situation and when the teacher’s sanctions cease, the pupil will stop doing the activity in question.

The intention concessivity is thus not connected to the external demands that rule the teaching situation – instead it is formed within the individual.

A pupil (as well as an employee) who is very ambitious is often willing to conform to and subordinate him/herself in order to get, eventually, good marks (appreciation) that could lead to a desirable position/education (promotion). Concessivity is a combined intention that develops as a synthesis of other intentions (wants, pupil role and ability). This inclination (and ability) to conform to and subordinate him/herself consciously or unconsciously to the teaching situation will have serious consequences for the pupil at the time of the teaching occasion and also in the longer perspective.

The intention curiosity

The other of the two “new” intentions that I have added is the intention curiosity. Curiosity constitutes an important pedagogical force in the teaching situation. Björn Andersson (1996) sees curiosity and thirst for knowledge as an important element in the learning process – as a driving force to make people act in different ways in order to extend their own knowledge and their own world. The inclination to examine and discover one’s own surroundings is a fundamental and untaught ability that all children possess. Already as an infant the child examines its surroundings and the inclination to discover and conquer the world around it follows the child during its growth. The manner in which the child is treated in these matters may affect the way it handles its thirst for knowledge and curiosity in later life.

Children who grow up in environments that are positive to curiosity and encourage the child to explore and find out how things work, or that leave the child “alone” to develop based on its own pleasure in discovery, should react according to this experience. On the other hand, children who are told by people around them not to be so inquisitive, and are told, “You don’t understand that,” could possibly remain more passive. The result of this could be that the child starts doubting its own ability.

Using children’s natural curiosity in teaching situations is a common pedagogical “practice”. It is well known to most people who teach younger pupils that younger children can often be led to read books on their own if the teacher/educator first arouses their curiosity by beginning to read the book aloud and finishing at the most exciting moment. In a similar way, pupils faced with an everyday problem in their technology classes, for
example how a pedal bin works mechanically, usually try to find out from curiosity. In the case of the pedal bin, the pupils usually try different mechanical solutions with the help of models that they make themselves. Few pupils stop before they have discovered how it works – the secret behind such an everyday phenomenon “simply must” be discovered.

According to this reasoning, pupils who are curious will react according to their curiosity. The intention curiosity is introduced now as an intention of its own and not as a part of the intention wants in order to emphasise the fact that the inclination to examine and discover “in itself” leads the individual (here the pupil) to act.\textsuperscript{16}

To sum up, we can thus identify a total of six different intentions among the pupils in a teaching situation:\textsuperscript{17}

1. Wants  
2. Duty  
3. Ability  
4. Opportunity  
5. Concessivity  
6. Curiosity

In addition to the intentions mentioned above, the pupils’ perceptions of the demands of the situation – their epistemic attitude – is also included as an internal determinant, as mentioned previously. The pupil has to decide in what way to handle a situation or a presented task. It is not the formal rules that may exist for the situation at hand that decide how the pupil is going to act. Instead, it is the pupil’s own evaluation of the situation (and the rules) that are the basis for how he/she will act in the end. The way the pupil perceives and handles the “demands of the situation” and his/her role as a pupil are of decisive importance as to how the pupil will “succeed” in the teaching situation.

In connection with the intention duty, von Wright says that individuals are presumed to behave according to the expectations of the people around them. For pupils this means that they are expected by people around them to behave the way a pupil “should”. Since there is no uniform description or set of rules that dictate how the pupils “should” behave, the pupils themselves must form an interpretation of the pupil role, based on their own experiences and perceptions. The way the pupil interprets the pupil role is based on several factors – the pupil’s cultural and social situation and his/her own experiences and personal abilities.\textsuperscript{18}
**About concessivity and epistemic attitude**

It is interesting that the intention concessivity, the individual’s ability to conform to and to subordinate to the situation, is not among the intentions mentioned by von Wright. Parts of this aspect, namely the individual’s ability to conform, are mentioned by von Wright when he introduces the concept epistemic attitude. There is, however, a distinction between the two concepts.

A pupil in a teaching situation could have the perception of demands from the environment to behave in a certain way – for example, “do what the teacher says”. The pupil then acts according to his/her epistemic attitude. The epistemic attitude is connected to (and dependent on) external stimuli or demands.

Acting according to the intention concessivity means that the pupil within him/herself decides on the teaching situation, whether to “play along” with the teaching, conform and “switch on reception”. Thus, the degree of concessivity does not depend on the external demands that surround the situation; the intention concessivity is formed instead within the individual.

In simple terms, concessivity can be seen as a quality/skill and epistemic attitude as the individual’s perception of reality.

**External determinants in a teaching situation**

Deviating to a great extent from current norms has consequences for the individual. Within all systems there are various means of coming to grips with this. For the pupil, school is one such institutionalised practice with similar demands for adaptation. According to von Wright, the institutionalised practice has a social function. The citizens see the demands that society puts on the individual as necessary and for “the benefit of all”. What is beneficial for the collective is also beneficial for the individual. School is an important part of the institutionalised practice and it constitutes “in itself” an institutionalised practice, with its activities controlled in many ways by regulations and rules on both a micro and macro level. In every school/unity there is continuous interplay and reciprocal action between all the different factors in and outside the school that influence the activities of the school.

What external determinants a pupil is going to be exposed to (and consequently affect the way the pupil will act) are dependent on external factors (regulations, social, economic and cultural conditions, the tradition of the school and how it is equipped) and expectations that surround the activities of the institution in question.
In order for an external determinant to be of relevance to a child, the child must have been made aware of the determinant. This means that an expressed expectation of the pupil in the school situation is, in certain cases, of importance for the behaviour of the teacher but not for that of the pupil. We can see this, for example, in the so-called “goals to be reached” in the curriculum. In all curricula there are goals to be reached regarding knowledge and skills that the pupils “should have reached” after the fifth and the ninth year. This must, of course, be seen as an expectation not only on the part of the teacher but also for the pupils. In practice, however, the pupils do not see these goals as real, since few of them are aware of the formulation of the goals. How the pupil then perceives and handles the external determinant is dependent on the pupil’s epistemic attitude.

External logic – explanations for why the determinants appear

A logic-of-events interpretation of an individual’s behaviour requires, apart from knowledge about the situation (the internal logic) experienced by the individual, that we also know as much as possible about the current situation – about the external circumstances that in different ways affect the individual and his/her ability to act.

The more we know about “the world around” the current event – about the conditions of the event – the more accurate our conclusions are in assessing the external logic of an individual’s behaviour, that is, how to explain and understand the presence of the internal and external determinants that are indicative of the individual’s actions.

In order to understand the external logic of a pupil’s behaviour in “technical” situations, we need to know as much as possible about the conditions of the current events – the current “technical climate” (which manifests itself in political decisions, regulations at different levels, the labour market, educational statistics, public debate on problems of modern society and the media, etc.) as well as how people handle the traditionally male image of the subject.

A logic-of-events interpretation can thus be described as the interpretation resulting from putting together our assessment of both the internal and external logic. (Figure 1 shows schematically the different parts and connections of the interpretation process.)

That brings me to the end of my presentation of the structure of the analysis model and the theoretical starting points, and it is time to show how theory can be put into practice.
Figure 1. Overview model of the pedagogical adaptation of von Wright’s logic of events.

Figure 1 shows that a logic of events interpretation/explanation is based on knowledge of both the individual’s “inner life” (internal determinants) and the conditions and circumstances that affect the individual in different ways in the current situation (external determinants). In Figure 1 these are combined under “internal logic” as well as under knowledge of the underlying reasons for the determinants (the event’s historical context) – the external logic.

Examples of logic-of-events analyses and interpretations

**Event – Ulla, Nina and the pedal bin**

In my first example of a practical adaptation of the analysis model, we meet Ulla and Nina in class 4 who, during a technology lesson, are faced with the task of finding out how a pedal bin works. The task is to make a simple paper model of a pedal bin, where the lid opens when a “pedal” is pressed. The girls get their material (cardboard, scissors, paper fasteners and punch pliers) and then they go back to their desks and start working. Those pupils who want help gather around the teacher after a while for a common “brain-storming”.

**INTERNAL DETERMINANTS**
- Girls’ intentions (wants, duties, abilities, opportunities, concissivity, curiosity)
- Girls’ epistemic attitude (understanding of situation demands)

**EXTERNAL DETERMINANTS**
- Relevant circumstances and conditions in girls’ home and school environments

**INTERIOR LOGIC**
Result of intentions, epistemic attitude and external determinants

**EXTERIOR LOGIC**
Reasons for appearance of determinants
“Situation in which action occurs”

Individual’s experience
Description of exterior circumstances
**ULLA**

Ulla gets going quickly. She works in a very concentrated manner and doesn’t seem to care what’s going on around her. From time to time she comments on her own work. Initially she doesn’t think it is a particularly difficult task. “I know exactly what to do,” she says happily. After a while it becomes increasingly difficult – it turns out not to be as easy as she had assumed. Ulla tries and tries – cuts new pieces and tries again. Ulla declines all help and doesn’t want to participate at the whiteboard. “I want to work it out myself!” she says. When the class is over, the girls tidy away their things – except for Ulla. She remains in her seat and when she finally notices that the others have left, she exclaims. “I refuse. I can’t go until I’ve understood how to do it!”

Ulla’s actions show signs of the following intentions:
- **wants** (she seems to be interested, sees the value and wants to solve the problem)
- **duty** (she acts according to her role as “ambitious, clever pupil”)
- **ability** (expresses confidence in her technical ability)
- **opportunity** (she has regular opportunities to spend time on technology)
- **concessivity** (apparent – she plays an active part and thinks positively from the start)
- **curiosity** (highly developed – she has to find out how it all works)

Ulla’s actions – in the fact that she gets going so enthusiastically with the existing task but chooses to remain in the classroom when the bell for break rings (in opposition to the well-established rule that pupils should go out for a break) – could be explained and understood as a result of – the epistemic attitude she shows (primarily as an ambitious, interested pupil) and – the above shown intentions – with particular emphasis on the intention **curiosity**.

**NINA**

When Nina has sat down, she starts by checking that she has the “correct” material, that is to say, that she has the material that those sitting around her have – the right number of paper fasteners, the same size of cardboard, etc. She looks carefully at how her friends are working and tries to emulate them. When the group gathers to work out how to tackle the problem, Nina wants to be included. She doesn’t offer any suggestions but listens to her friends’ arguments. Back in her place she continues, following the advice that has come out of the discussion. She keeps looking around to see if her friends are doing as she is. When the class is over and she is about to go the teacher asks her if the task is too difficult. She then answers: “No, I think it’s easy.”

Nina’s actions show signs of the following intentions:
- **wants** (she wants to do the “right” thing – because at school, one should do the “right” thing; she also has a strong need to “fit in” within the school situation and amongst her friends)
- **duty** (she acts in accordance with her pupil role [as pupil who does the “right” thing] – does what she thinks the teacher wants and does not diverge from her friends)
- **ability** (good faith in her own ability – the task itself is secondary for Nina so she feels it is not important that she does not know/what/how she should do)
- **opportunity** (she has regular opportunities to spend time on technology)
- **concessivity** (not apparent – she seems never to understand the task itself)
- **curiosity** (absent – Nina is here uninterested in solving the problem)

Nina’s actions in the present situation – her seeking support from her friends and lack of involvement in the actual technological task – could be explained and understood as a result of – the epistemic attitude that she shows in different ways (a pupil who does the “right” thing – which in Nina’s case means to do what the teacher wants and deviate as little as possible from friends) and – the above-shown intentions with particular emphasis on **duty** (desire to behave according to the pupil role she has chosen).
Commentary

If we look at the epistemic attitude and what intentions Ulla’s and Nina’s actions express in the current situation, we can establish both similarities and dissimilarities.

Ulla could be said to express the role of an “ambitious and interested” pupil while Nina expresses the role of “schoolgirl who wants to do the right thing”. In spite of the fact that the girls’ choices of pupil role (epistemic attitude) differ from each other, the expression (in the form of behaviour) that results from their respective pupil roles will, in the eyes of an onlooker, seem very similar. Both girls will appear both interested and attentive in the teaching situation – albeit for different reasons.

The interpretations shown here indicate that both girls in the current situation express four of the intentions in the explanatory model (wants, duty, ability and opportunity). These intentions are common to both of them. When it comes to the intentions wants and duty, Ulla’s and Nina’s statements show that they have different motives as far as these intentions are concerned; however, just as in the case of the epistemic attitude, the behaviour that results from these two intentions is similar – the impression of interest and attention is strengthened.

When it comes to the other two common intentions (opportunity and ability) the girls differ very little. The intention opportunity is the same (they have regular lessons of technology at school) and with the intention ability it turns out that both Ulla and Nina see their technical skills as good. To an outsider it could possibly seem that Ulla’s perception of her own ability in this case is nearer to reality, compared to Nina’s perception (considering the fact that Ulla works constructively in different ways with the problem, which Nina does not do at all). But for Nina (and Ulla) the internal experience of technical self-esteem should be seen as equally tangible and relevant.

Based on the available information, it has been possible to show the intention concessivity in Ulla but not in Nina. I build my assessment in Ulla’s case on the fact that she shows at an early stage that she “is playing along” with the teaching – she gets going quickly and is then absorbed in her task.

With Nina on the other hand, we do not see a similar “opening” in relation to the task/teaching. It is true that on a “superficial” level she works with the same task as Ulla – she cuts and makes holes in her cardboard – but to Nina the task itself and the question of how to solve it still does not seem to occupy her. Instead there are other aspects that attract her attention – for example, the importance of having the “right” tools and material and to “fit in”, not to deviate from her friends.
The fact that Ulla and Nina show great similarities in both external (conditions and circumstances) and internal determinants (their epistemic attitude expresses itself in similar ways and the fact that they have four intentions in common) lead to clear similarities in their actions. They both work (albeit in different ways) with their given task; they handle the same material and tools and they listen to the instructions given. In spite of this, their behaviour differs a great deal in reality. We find the reason for this in the intention that Ulla, but not Nina, expresses – that is the intention curiosity. The intention curiosity characterises Ulla’s behaviour throughout. Not only does curiosity propel her forward in her work, but it also makes her nearly forget time and place. Moreover, it nearly makes her ignore the rule that says you have to be outside during breaks (which contradicts her self-image as a “proper” and attentive pupil)...

In the case of Ulla and Nina we can thus see similarities in the “general” behaviour in the teaching situation, but differences in their “specific” behaviour” – that is, their behaviour in relation to the current task.

The question of what this difference in the “specific” behaviour depends on is interesting. In the example of Ulla and Nina, it seems that the intention that was judged in the interpretation as having especially great significance had controlled the girls’ actions in relation to the task. From here on I have chosen to call this particularly significant intention in relation to the task the dominant intention. In Nina’s case the intention duty is the dominant one, and in Ulla’s case it is the intention curiosity. What then do we as teachers and educators gain in trying to identify and reflect about the intentions of the pupils?

In the current example there are a number of possibilities for the teacher/educator. Now that we have increased our knowledge about what is going on “inside the heads” of both girls, it is important when teaching to connect in different ways with what each of the girls considers important.

In light of this knowledge, it would appear unreasonable that a teacher/educator would use a single strategy to reach the teaching target – to recognise and be able to use the current technological solution. In the case of Ulla, who is driven by her curiosity, the ability of the teacher/educator to take advantage in different ways of the power that the intention curiosity offers (support, challenge, encourage) could be of the greatest importance.

In the case of Nina, who is busy “doing the right thing” (what the teacher wants and what her friends do) and who has not taken in the task itself, will probably not be helped by encouragement, new challenges or more general support. If we want to make it easier for Nina to reach the teaching goal, we have to work with and not against her determinants (for example by giving her the possibility to work close to one or several friends and supplying her with firm and concrete guidance).
If we can do this then the prospects are good that both Ulla and Nina can in different ways (and possibly on different “intellectual levels”) achieve the current teaching goal – to succeed in achieving satisfactory functionality (the pedal bin works) and to develop their personal “repertoire” of practical technological solutions (i.e., to learn to recognise this technological solution so as to be able to make use of it in other situations).

**Event 2 – Lena and the room (class 5)**

The pupils in class 5 have been given the task of building a model of a room or a house. The task is not particularly specific and the only “must” is a staircase in connection to (or inside) the room/house and a working light (with a switch constructed by the pupils). An extra bonus is given for a light upstairs that can be turned on/off from the ground floor (a so-called staircase switch). Lena is sitting with Nils and Sven. Beata is normally also there but today she is ill. Nils and Sven decide to build a garage but Lena does not want to, so the boys start on their own.

**Analysis and logic-of-events interpretation of Lena’s actions**

<table>
<thead>
<tr>
<th>LENA</th>
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<tbody>
<tr>
<td><strong>LENA</strong></td>
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<tr>
<td>Lena stares for a long time at Sven and Nils while they work. From time to time she comments on their work but she doesn’t get going herself. When the teacher asks if she needs anything, she seems tired and sighs, “I know, I will fetch the things!” She makes her way unwillingly to the material cupboard. She doesn’t make it all the way however, but instead gets into conversations with several friends, goes to the toilet and even makes a few more small “trips” in the classroom before she and the teacher together gather what she feels she needs. When the teacher leaves her, she is still passive. Some time passes before she is observed again. Now she is working hard! She has temporarily got the room itself together, but has not made a stairway as yet. Instead, it is the lighting that intrigues her. She is eagerly busy trying to figure out how to connect the electric wires to make a functional switch for the stairs. Towards the end of the period, she lets out a triumphant shout: “You see! It can be done!”</td>
<td></td>
</tr>
<tr>
<td><strong>Lena’s actions show traces of the following intentions</strong></td>
<td></td>
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<tr>
<td>wants (“take it easy”, show independence)</td>
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<tr>
<td>duty (she acts in accordance with her pupil role – the uninterested, independent pupil who wants to decide herself)</td>
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<tr>
<td>ability (she can – if she wants to)(^1)</td>
<td></td>
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<tr>
<td>opportunity (she has regular lessons in technology at school)</td>
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<tr>
<td>concessivity (high degree of concessivity – in spite of the fact that Lena does not really want to change her actions and conform to and subordinate herself in the situation, she gets on with (and solves) the task.</td>
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<tr>
<td>curiosity (certain amount of curiosity)</td>
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</table>

Lena’s actions in the situation itself – the fact that, in spite of her expressed lack of interest in the task and in “doing technology”, she becomes active and gets on (successfully) with the task itself – could be understood and explained as a result of – the epistemic attitude which she expresses in different ways (independent pupil, careful about her high status among friends) and – the above-mentioned intentions, of which the intention concessivity has been judged as being dominant. (She conforms and subordinates herself to the teaching situation, overcomes her “inner” resistance and gets on with the task in hand).
Commentary

The term concessivity refers to the individual’s ability to conform and subordinate him/herself to the teaching – to “take in” the teaching that is being offered. One might think it would be easy to detect the presence of this intention – of course we notice if pupils are “playing along” with the teaching and want to learn.

A complication in this situation could be the fact that when we as teachers and educators presume a pupil is interested and receptive, this in fact means only that the pupil is acting in accordance with our conception of how an “interested pupil” should act. Whether the pupil in question is actually as interested and “open” to the teaching as he/she appears is something we can be sure of without studying the pupil carefully (by observing the pupil’s verbal and/or body language, for example).

In my study of girls’ actions when faced with technical tasks, judgements of the presence of the intention concessivity are based mainly on the body language the girls expressed in the situations that I analysed – looks, gestures, motions that in different ways show that the girl in question is “playing along”.

In order to verify the presence of the intention concessivity based on the pupil’s verbal statements, it is necessary for the observed individual to verbally express this. In a study that focuses on young girls at an early school age, the chances are slim of finding a girl whose actions show traces of this intention and who has also reached the intellectual and verbal maturity to analyse and reflect on her own actions. Fortunately, Lena in this example fulfils all of these criteria.

Lena is one of the girls who succeeds best in her school when faced with technical tasks. For everyone who observes her during her lesson in technology, it is obvious that she has a talent for this subject. At the same time she is the girl who expresses the most displeasure in having to “do technology”. In the current situation she is obviously disturbed by having to get on with the given task, but for some reason she changes her mind and becomes very active. After the lesson, when I get the opportunity to ask her why she fulfilled her task in spite of it not being interesting, she answers:

I suppose you can get something out of it and besides it is fun to fight with Nils and Sven – that is, argue for fun. For example, if we [she and Beata] get our thing to work first, then the boys try to find fault with it and complain about it. And if they finish first, we try to find fault with theirs and then we try to make ours better.
Her reasons for getting on with the task (the chance to outsmart her good friends Sven and Nils) do not agree at all with the reasons that the teacher puts forward, but the end result (that she learns to make the correct wire connections) is, of course, completely in line with the teacher’s ambition.

Pupils are in every teaching situation faced with a conscious or unconscious choice of strategy when it comes to handling the situation in hand. A pupil who perceives that the action expected of him/her is in line with the pupil’s own interest will act according to this interest – the pupil conforms to and subordinates him/herself since he/she is (for different reasons) already interested.

In those cases where a pupil is not interested in the teaching presented by the teacher/educator, the intention concessivity could have decisive influence and power. In Lena’s case we know that she tries to avoid being confronted by the given task for as long as she can. Dealing with this task means that she has to act contrary to the intentions she expresses initially. Then, at a particular moment, Lena overcomes/disregards her internal resistance; she “opens up” and “deals” with the current task – the most difficult part of the task – the so-called staircase switch.

It should be noted that it is not the teacher who makes Lena deal with the task. All attempts by the teacher to influence Lena fail. It is not until the moment that Lena has made up her mind that the situation changes. The intention concessivity is thus not influenced by the external demands that surround the current situation, but is instead formed as a mental process within the individual – in this case within Lena.

What Lena does in reality is to reconsider her decision. Instead of getting stuck in her earlier resistance, she mobilises the energy to satisfy new visions and goals that can be combined with the activity that the teacher/educator has initiated. In the current example, Lena sees the opportunity to tease her friends Sven and Nils as a suitable reason to conform to and subordinate herself to the teaching situation. When she later looks back at the event, she notices that she also sees a certain benefit to the task (“I suppose you can get something out of it”).

The intention concessivity is meant to describe this particular ability – the ability to take advantage of the situation in hand for one’s own purposes, possibly to conquer original internal resistance and take in the knowledge and/or the experience that the situation offers. The reason behind a pupil’s decision to conform to and subordinate him/herself to the teaching will thus not (necessarily) coincide with the reasons the teacher/educator responsible had in mind. This, however, does not preclude the actual result of the pupil’s decision from being in accord with the teacher’s ambition.
In this example, the result of Lena’s wish to “argue for fun” with Sven and Nils is that, apart from her having a lark with the two boys for a while, she learns at least two things: one, how a staircase switch works and, two, that she can manage this difficult task – which should be in line with the teacher’s objectives for the lesson.

The fact that teachers/educators have no possibility to directly influence concessivity among their pupils does not mean that this intention is uninteresting in pedagogical work. On the contrary, by trying to identify this intention knowledge increases about one of the factors that have significant impact on the teaching situation for the pupil in question, the teacher and the rest of the class.22

Event 3 – Nadja and electrical couplings (class 3)

Nadja will be in focus in this third and final example of logic-of-events analysis and interpretation. This time the class is working with electrical couplings. The task is to make a bulb light up in a circuit. The lesson starts with the group discussing together how to do this. Then the girls can try to make one bulb light up and then several. After the discussion, everybody starts. The girls chat to each other and everything seems calm and peaceful.

Analysis and logic-of-events interpretation of Nadja’s actions

<table>
<thead>
<tr>
<th>NADJA</th>
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<tr>
<td>Nadja is very active initially (during the oral explanation) in the discussion and it shows that she knows how to do the coupling. The pupils in the class get going with their work. After a while the teacher notices that Nadja has stopped working. She has pushed aside all of the material and tools, and is half-lying on her desk with her face down. When the teacher asks what has happened, she starts to cry and says: “I don’t like these stupid things. I don’t want to! It doesn’t work!”</td>
</tr>
<tr>
<td>Nadja’s actions show traces of the following intentions</td>
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<tr>
<td>wants (she seems – initially – interested in solving the task; she also wants to be “clever”)</td>
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<tr>
<td>duty (she tries but is incapable of acting in accordance with the pupil role of a clever schoolgirl)</td>
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<tr>
<td>ability (lack of ability – she is incapable of making use of the necessary tools)</td>
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<tr>
<td>opportunity (she has regular lessons in technology at school)</td>
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<tr>
<td>concessivity (low degree of concessivity – she does not conform to and subordinate herself to the teaching)</td>
</tr>
<tr>
<td>curiosity (low degree of curiosity)</td>
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<tr>
<td>Nadja’s actions in the current situation – that she gives up, gets sad and doesn’t want to continue – could be understood and explained as a result of</td>
</tr>
<tr>
<td>– a lack of agreement between the epistemic attitude she has chosen (to appear to be a clever schoolgirl) and her actual ability in the current situation and</td>
</tr>
<tr>
<td>– the above-shown intentions, of which the intention ability has been judged to be dominant (in this case, the lack of ability to make use of the necessary tools).</td>
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</tbody>
</table>
Commentary

The “coupling problem” is not a problem for Nadja; her difficulties are on a completely different level. A requirement for making the connection is that the wire is “peeled” at both ends. The group has practised this work on several occasions and most pupils have become quite proficient. During some of the time that was spent practicing peeling, Nadja had a problem with one of her hands and a friend helped her. When her hand got better she still had help from the friend (of which the teacher was unaware). At the time of the current task, Nadja and her friend had fallen out with each other and Nadja did not receive any help. The fact that Nadja knows what to do but is not capable of practically carrying it out makes her very frustrated.

In accordance with von Wright, the intention ability can thus be described as a limiting intention. Wanting something is not enough in itself – in order for an intention to be fulfilled the individual must have (or acquire) the ability to do what the intention means.

Lacking practical/manual ability in technical situations leads to immediate and obvious consequences. For Nadja in this example, the fact that she knows how to connect the circuit but cannot do it in practice makes the situation intolerable to her. She gets both sad and angry and gives up all attempts. What long-term consequences this failure leads to for Nadja can be said to depend on how she normally perceives her technical ability (degree of technical self-confidence) and the motivation this feeling gives rise to. If she sees this event as a one-time failure, then it is very likely that she will “swallow the bitter pill” and learn to handle the tool in question. However, if due to poor technical self-confidence she sees this event as further confirmation of her own incompetence in practical/technical tasks, then it is very likely that she will try to avoid similar situations.

In Nadja’s case her technical self-esteem was bruised slightly – she had not thought that it was very important to be able to “peel”, but she recovered and eventually the “peeling” ceased to be a problem.

**Logic-of-events interpretations – a pedagogical tool in the teaching of technology**

As has been pointed out previously, when it comes to technology behaviour is of vital importance and the way one behaves results in consequences for both the concrete result and the personal experience – a situation which, when it comes to the teaching of technology in school, is not only of importance to the pupils, but also leads to consequences for teachers and educators whose task it is to convey knowledge in technology.

With the three examples of logic-of-events analyses and interpretations
that I have shown here, I have attempted to point out how we teachers and educators, by systematically analysing pupils’ actions, acquire deeper knowledge about the pupils we teach, which makes it possible to relate the teaching of technology to the pupils’ experiences. The analysis model also gives us the possibility to discern more general and recurring patterns of behaviour among the pupils – a knowledge that constitutes a valuable help when it comes to dealing with future pupils in similar teaching situations.

**But how does one know that a logic-of-events interpretation is “correct” – who decides?**

As in all interpretations, the picture of the course of events analysed or the behaviour that is presented is in many ways a reflection of the observer (= the interpreter) him/herself. Interpreting pupils’ actions based on logic of events includes a number of subjective considerations. The fact that intentions do not appear in a form of their own but appear only in the actions they initiate gives room for more than one interpretation; moreover, this room for interpretation applies to the entire process of interpretation – from the choice of the analysis situation, the question of “labelling” the pupils’ epistemic attitude and the question of choosing what external circumstances could be considered relevant to how we judge which intentions are suggested by the behaviour of the pupil. It is inevitable that there will be variation among different observers – the intentions credited to a pupil by teacher A in a certain situation will not necessarily be the same as by teacher B.

I believe that the great advantage of logic-of-events interpretation is not only in the individual pupil interpretation. (It is possible to deal with, for example, erroneously interpreting Greta’s behaviour in an imagined situation as a consequence of the intention wants rather than the intention curiosity.) The advantage has more to do with the fact that the logic-of-events interpretation model supplies concepts that put words to both the pupil’s “internal life” and the pedagogical situation in question – we become aware not only of the effects of the pupils’ actions but also of possible reasons for these actions.

The systematic structure of the model brings to the attention of the teacher/educator aspects of the pupils (which are of possible pedagogical significance to the teacher/educator) that might otherwise remain undiscovered and unexploited. Furthermore, every logic-of-events interpretation includes the fact that the teacher/educator must decide how the pupil’s behaviour relates to all “categories of intention” – not only those that the teacher him/herself considers to be the most likely, but also other possible interpretations. The intellectual and mental preparedness that this leads to opens up
the mind not only to the particular pupil in the current situation but also to other pupils in similar situations.

Logic-of-events interpretations of students’ actions can thus be said to increase awareness of the pupil as an individual and of the pupil as part of a greater context – of the complexity that surrounds every teaching situation. Knowledge and insight about this complexity should be valuable to every teacher and educator – especially in formulating successful strategies for the future of teaching technology.

**References**


**Notes**

1. The terms internal and external logic have been coined by the school researcher Sverker Lindblad (1994).
3. In the past 40 years four different curricula have been implemented (Lgr 62, Lgr 69, Lgr 80 and Lpo 94). The fact that each curriculum is preceded (and followed) by extensive changes on the national and regional levels means that changes in Swedish schools could be described as a continuously ongoing process.
5. Such didactic considerations constitute, in my experience, an important part of pedagogical activities.
6. The question of how the municipalities spend money on computers has often been taken up in general discussions. What happens to children who live in municipalities that do not spend money on computers and the Internet, and furthermore do not have access to this technology at home? Will they be helplessly left behind or can (should) such skills be learnt later in life?
7. A person who seldom or never reads a book will, not surprisingly, quite likely face greater difficulties with reading compared to a person who reads a lot daily.
8. Consequently, it is both reasonable and explicable that pupils who, for various reasons, never had the opportunity to engage in technical activities are not particularly interested in this subject.

9. One could argue that since an individual’s opportunity to act seems to depend on external factors it would be logical to consider this factor as an external determinant. *Opportunity* is nevertheless regarded as an intention due to the fact that the individual decides “internally” what an opportunity is. It does not help that we as onlookers believe that we see that an individual is exposed to a number of opportunities, since these opportunities become real to the individual only if he/she perceives these opportunities.

10. The term concessivity is chosen with reference to the term concessive, which means expressing concession (compare concessive conjunctions = subordinate conjunctions are characteristic of concession). The *Swedish Academy’s Dictionary* (1995) Publisher, Norstedts Förlag, Stockholm.

11. Of course there are pupils who know more than their teachers (who has not heard of pupils with more knowledge than their teachers when it comes to using computers?) But when discussing basic teaching, the teacher as a rule is more competent than the pupils.

12. Not unexpectedly it is society and the adult world that set the rules. From time to time suggestions are put forward to increase the pupils’ influence, but all such initiatives depend on the extent to which adults in society allow that.


16. Among von Wright’s intentions, the intention curiosity could be assigned to the intention wants since the need to satisfy curiosity leads to well-being.

17. It is worth pointing out that it is not possible to observe the intentions “per se”. It is, on the other hand, quite possible to observe the acts that follow the individual’s intentions. See Näslund (1991) p. 40.

18. In the same way a pupil makes his/her own interpretation of the role as a pupil, the teacher will also make his/her interpretation of the role as a teacher. To analyse his/her role as a teacher and then change his/her behaviour based upon this analysis is probably very difficult for most teachers (as well as for the pupils).

19. The girls could estimate their own technical skills.

20. The aim in this case then is not that each pupil at any cost “find” the “right” solution, but instead that the pupils achieve *in different ways* satisfactory functionality, that they recognise and can use this technological solution in different situations.

21. It is interesting to see how Lena values her technical ability. In spite of the fact that Lena is very successful in doing what she does during the technology lessons, her statements show that she does not see herself as particularly technically successful.

22. The fact that pupils with a high level of concessivity are active and interested affects, in different ways, everyone involved (the pupil him/herself, the classmates and the teacher/educator). This applies equally well to aspects such as the atmosphere in the classroom, exchange of knowledge, teaching strategies and working methods..
Artistic and practical aspects. Experiences and visions

When I was hired for the NyIng project, I was given these words by the management group as the basis for my work. These served as inspiration for a presentation at a NyIng conference and for the writing that followed. They provide several interesting approaches to my task. I have chosen to take a few somewhat different approaches in my work. The two more extensive sections below deal with related critical concepts and a few ways of thinking about important aspects of the training of engineers for the 21st century. Before I finish this article, I will summarise my findings and formulate in the final lines a new title – a title that better reflects the ideas I am developing.

Experiences

Many people who begin their training as engineers have what can be called in somewhat imprecise terms ”creative” or ”cultural” interests. I find many musically-minded students in particular at Linköping Institute of Technology. At the same time, there is something else in the background interests of young people that has evidently convinced them that pursuing extensive technical studies is worth many years of hard work for a career in advanced technology, which offers them something interesting that is worth aiming for. By adding a cultural term to these words, it would also be easy to attribute this ”something” in their background interests to what is represented by culture.

Higher technical education, represented by our universities of technology, cultivates a field of knowledge that has grown and taken on its technological form in a relatively short period of time. It has been characterised by modernism’s faith in change. It was shaped in the 20th century by positivism’s quantitative ideal, thinking in measurable units in terms of cause and effect. The preoccupation of technology – ”getting the thing to work” – which was often linked to personal knowledge – has meant a superstructure of technological theories, impersonal knowledge articulated according to the scientific tradition. At the same time, the distance between the producer’s large-scale manufacturing process and product complexity, on the one hand, and the consumer’s user situation, on the other, has increased. We have greater
proximity to more and more technological products, while at the same time we often lack knowledge about these items that are so close at hand. We have more and more of these "black boxes" in our everyday lives to deal with. The need for higher technical education has increased in both scope and depth. What was initially thought to be a quantitative change turns out to have generated a need for qualitative change.

The content, forms of teaching and forms of examination in the first two years of education have been critical in shaping the knowledge, skills and attitudes of graduates with a technical degree. The introductory building blocks in this education, what they have looked like until now (or did until yesterday?), reflect to a large degree the 20th century approach to technical education. More and more knowledge requires more extensive studies, a growing number of important courses. First, all the important basic courses, and then … even more of them. In particular, the implicitly conveyed conception of the role of engineers, the view of society and the view of individuals, influences what students will get from, as well as take from, their education. "The hidden education agenda," the university’s/faculty’s not clearly explicit codes, underpins this construction. Perhaps it is in these often unarticulated and undiscussed attitudes that we can find a new, inspiring area of development if higher education is to produce 21st century engineers. However, attitudes are not learned in a "course on attitudes” but in stimulating physical environments together with teachers, students and visitors from life beyond the university, in work with relevant problems which generate a need for knowledge in students.

**Visions**

The statement above reflects some of my experiences from teaching in the last fifteen years. The description below should mainly be seen as a personal contribution whose aim is to stimulate thoughts about changes in the education of engineers. The reader should understand the difficulties of fully adapting these ideas to the whole of this vast area of education. In reality, it is not a question of the role or the training of engineers. There is a spectrum of roles and of training. I am talking mainly about product, bearing in mind what is to be developed in professional engineers. In some cases, this way of reasoning is also applicable to other areas like services, processes and workplace environments.

I would really like to formulate some thoughts in the hope of taking part in some kind of remodeling. A change in education should be able to give us even better engineers. They should thus, based on the following description, be called "human-technology-skilled,” which unites a career-related
concentration on technology with an interest in people, in people’s knowledge and their representation of knowledge. The foundation should then consist of a constructive, creative and scientific approach to technology, which takes people into account. With a humanist technical approach as the basis of discussion, I see technology as a tool for promoting people’s opportunities to create a better life. Technological progress is thus always changes that enhance people’s opportunities to develop physically, intellectually, aesthetically, morally, and in a pleasing environment. By clearly shifting the focus from technology in its narrow sense to the relation between technology and people, technology will be an important subject not just for technical education in the spirit of the 20th century but with a view to the 21st century. There is good reason to further develop technology as a concern of faculties of arts and science in Sweden as well as the country’s medical schools and law schools.

Key terms

In this section, I will present my perspective on a few terms because I think that a discussion of them could generate ideas about education and clarify what are dangerously ambiguous terms. These brief lines of reasoning can also provide a map that the reader can use to become oriented in dealing with the areas of interest suggested in the title of this article.

A discussion should not be stifled by defining terms to the extreme, which is what happens if people think that the meaning of a term can be determined conclusively. At the same time, it has been demonstrated that some discussions can make significant progress if people are agreed about what is being dealt with.

Ideas about key concepts can also stimulate new thoughts. This is the main reason for the following survey of terms – a change in education, yes, but based on what fundamental thoughts about people, technology and people-technology?

Technology

When one of the ombudsmen for the Swedish Association of Graduate Engineers (Sten O Andersson) spoke about the role of engineers, he quoted the technology historian Fergusson, who prefers to link artist and engineer rather than engineer and scientist. A slogan could then be formulated – ”Technology and art”. As far as can be judged from this, he wants to highlight what is not always formally articulated knowledge which is needed for creative activity and which also involves technology. At the same time, I would like to quote the motto of the Royal Institute of Technology,”Science
and art.” Perhaps there is an interesting triangle, “Technology, science and art.”

The meaning of a term can be explored in many ways. One way is as illustrated above, to try to get at its meaning through its association with neighboring terms that are to be defined. An etymological derivation can be an inspiring start, but it hardly provides any good up-to-date definition. When we look for the etymology of ’technology’, we find ’techné,’ which means art, handicraft. A dictionary can be consulted for a dictionary definition, which in my experience gives a rather general explanation, which does not always correspond to general language use. For instance, in one dictionary, ’technology’ is defined as ”1. system of advanced production and extraction methods, 2. practical procedure in the exercise of something.” (Nor should we forget that the meaning of the term changes in the contemporary language environment. ’Art’ in KTH’s emblem today was introduced in the 1820’s.)

It is interesting to try to get at people’s active and passive understanding of the word, which certainly gives an important definition to the term nowadays: let us call this an everyday meaning of the term. People can also give their own stipulative meaning of the term, which is subjected to testing. I will try both paths.

“Under orderly scientific conditions,” I investigated the different senses of the term ’technology’ in my dissertation Teknik – genomskinlig eller svart låda? Att bruka, se och förstå – en fråga om kunskap [Technology – transparent or black box? Using, seeing and understanding – a question of knowledge] (1997). I interviewed eight-year-old, fifteen-year-old and adult Swedes. How do people understand the term ’technology’? Based on these interviews, the meanings can be arranged into groups as follows.

A. Artefacts, objects made by humans. A traditional picture of technology is clearly discernible in the informants’ initial spontaneous utterances. 1. Hard technology is most visible in its associations with metal, oil, machines and workshops and thus a man’s sphere. 2. ”Computer machinery” is often mentioned as being near this sphere. 3. In every age group there is also an awareness that there is soft technology which is associated with textiles, food, the home and implements that traditionally belong to the world of women.
B. Procedure, practical skill. 'Technology' is also understood as an action, a process. Then it is a question of an ability, a practical skill, which results in the manufacture of physical objects. It can also involve achieving an effect, playing a computer game, playing soccer, cleaning and ironing shirts.

C. Competence, knowledge, which is expressed as an ability to explain and evaluate production, objects and actions. It is the understanding of many informants that the knowledge that a person has shifts between invention and production to objects. Technology, technical knowledge, is thus found in the object. Technology as knowledge – only one of the eight-year-olds identified this category. For several fifteen-year-olds, but especially for the adults, technology is also the same as what people know and make visible in their actions and evaluations.

D. Mentality, thought patterns articulated to various degrees, that constitutes a more or less conscious basis for thoughts and actions. The majority of informants, when they think in terms of the history of technology, think that every culture has some form of technology that is an essential part of it. Some also believed that different technologies result in different ways of thinking. The technological development of a society affects the way people think. This is expressed most clearly by the adults, who see this not just as a positive phenomenon.

These categories can be seen as one of the results obtained in this study. It shows the various understandings of the term 'technology' and the order in which these different understandings often appear when someone thinks about the meaning of technology; it is also represented as a set of stairs up which we advance as we expand our concept of technology with age and experience.

My own stipulative and condensed definition of the term in a discussion relating to education would look like this: "Technology is the term for people’s different abilities and facilities – of thinking, knowledge and objects – focused on solving practical functional (physical and intellectual) problems."

This means a more extensive conception of technology than what is given in dictionaries, which corresponds well with the view of philosophers of technology in the late 20th century. The concept of technology has been expanded to include people’s abilities and understandings. With technology having this kind of meaning, education for engineers will also change.
As with technology, we can look at the etymology or a dictionary definition of 'art.' It is striking how similar the etymologies and definitions are for 'technology' and 'art.' When we looked for the etymology of 'technology,' we found the Greek *techné*, meaning *art, handicraft*. The Latin *ars* has a similar meaning, *skill, innate or acquired ability in terms of scientific, artistic or handicraft ability*; it represents both an ability (activity) and a product. The English word *art* has this connection to Latin whereas in Swedish, we use the word *konst*, which is related to the German *Kunst*, in the sense of *art and skill*. This explains the technical sense of the Swedish word *konstgjord* ['artificial'], as well as the Swedish word ‘konstfull’, which means ”done well as” ”done by a skillful artist or craftsman.” The changes that occur in the meaning of words reflect different language cultures and the cultural changes that have taken place over hundreds of years.

The last hundred years in particular, with the breakthrough of modern art, have influenced our understanding of the meaning of the term 'art.' Theories about ”l’art pour l’art” vindicated products that were to be seen mainly as expression without needing to have a practical function. Art took on a positive value, as in ”good art.” Our perspective changed in particular when decisions about quality in a work of art shifted from being based on a *quality that could be identified in the artefact* to something decided by the *observer*. This does not prevent us from retaining alongside one another the various meanings of art in the sense of skill, as in the art of engineering, the art of speaking, the art of food and the art of solving problems. The debate in the 20th century made the concept ambiguous and difficult to identify, almost unusable without stipulative definitions that hold in only a limited context. As a result, the term ”artistic” has also been discredited. Perhaps because of this, a discussion about a new educational program for engineers is better served by using other terms to get at a creative ability that should be developed.

If I were to investigate what *art* means to people today in general language use, I would probably find that there is a set of stairs which is quite reminiscent of that for the meaning of *technology*, but with different senses.

My own stipulative definition would look like this: *Art is the term for people’s ability and products – thinking, knowledge and objects – usually focused on describing and formulating understandings mainly about people in their life context, to create (emotional and intellectual) understanding of ”reality” in a broad sense.*
Technology and art

What then is of interest in this link between technology and art? Engineers are not supposed to become artists in their training. I will be very concrete. As a teacher, I have had experience with the work in two-dimensional and three-dimensional forms, color and construction in civil engineering training that serves as a gateway to a designer’s way of thinking (this mainly concerns education in machine construction and industrial economics). When those of us who initiated and taught the courses began this work, we brought with us content and teaching methods from education in the arts and in handicrafts. There were considerable positive effects in the new teaching environment. In confronting design problems, it is a question of working like an artist (and a researcher) with a mix of intuition and articulated knowledge. It is a question of developing an openness to opportunities, solving a problem thinking in a way where there is no correct answer. It is a question of having an ability to think in different ways. In addition, there are opportunities to combine theoretical knowledge and immediate sensory experiences in a teaching situation where handling two or three dimensions is important (this involves both construction work in material reality and virtual reality). Actually, then, it is not "artistic" knowledge and experience that are the focus. I would instead prefer to talk about "aesthetic" knowledge and experience.

Aesthetic

The etymology of the word "aesthetic" can be traced to the Greek word ai’sthesis, ta aisthetai, the sensual, the perceptual. This is a good beginning for understanding the term. In the 1820’s, the term took on another sense, in part through Hegel, and was linked to the narrower meaning "the science of what is beautiful," an antiquated limitation that we still suffer from in certain contexts. Many different meanings have given rise to various theories. There is research being done in such concepts as depiction, symbol, meaning, expression and value as well as in factors that influence experiences of appreciation and dissociation.

After the Second World War, there was discussion about an aesthetic upbringing, which then took on the meaning of "education of the senses" and the name of "education through art". Analogous to this, we can translate 'aesthetic experience' as experience gained through the senses, which has its basis in the original meaning of the word. In education, we can then talk about a physically experimental way of working as an aesthetic way of working. The different senses are involved in both the acquisition and the presentation of knowledge. But as is always the case when we talk about learning situations, it is important to pay attention to the whole and not
limit our sights. Obviously it is important to see the combination of common sense and feelings, non-verbal and verbalised knowledge, as useful partners in achieving an aesthetic means of expression.

Society today is rapidly changing our contact with physical reality, for instance, raw materials and products. This is largely because we are dealing with industrial manufacturing. Few people today have experience and thus knowledge of how a piece of furniture is made, how the clothes they are wearing have been produced, how the food we eat has "grown" to be transformed into raw materials for the food industry and its packaged "groceries." A related reason is that places of work involved in the production chain are isolated from what our children come into contact with and from the everyday lives of adults. Moreover, food, for instance, is purchased so that we do not have a chance to touch, see or smell "this object," because it is vacuum-packed or frozen into a frosty whole. Perhaps we could talk about an "obscuring of the senses" or a "confusion of the senses." The picture on the front of the package can replace the other sense-based contacts. In the same way, the raw material is invisible or difficult to identify in the case of furniture, because the bearing matter is concealed by sheeting, which is also sometimes a clever way of giving the illusion of a material that is not present. Another opportunity would be to replace contact with the sensual reality we have developed from the picture of it, through our ability to create a virtual reality.

My own stipulative definition would look like this: Aesthetic is the term for people's ability to use their sensory experiences to understand "reality" in the broad sense of the word and create sense-stimulating artefacts. Aesthetic can also be used as a term for things that clearly give rise to sensory experiences.

Insufficient experience with materials and a lack of knowledge about materials can cause concern for people who plan constructions in physical materials. In the society of tomorrow, too, the development of our technological environment will depend to a large degree on engineers with intimate knowledge of relevant constructions in three dimensions. The lack of reflective experience with form and changes in forms can also result in banal thinking about products. The aesthetic experience is of importance for both the development of the efficient, practical, functional use of products and for a dimension of experience that can be called an aesthetic function. We are thus also concerned with issues relating to design in the sense of the conscious construction and form of objects manufactured by humans.
Design

Design is a key term for engineers. From the focus of activity in the US, which was coloured by the economic troubles of the 1930’s, people in Sweden adopted a superficial definition after World War II: design involves making a beautiful exterior for something that is already constructed. In the worst case, it meant that the job of the artist was to jazz up the construction of an engineer.

Design is used internationally as a term for the giving of form, which in a broad sense means the forming of products produced industrially or by hand. In compound expressions, the word takes on a meaning that is more suggestive of industrial manufacturing: design management, engineering design, industrial design. In this article, I am talking about design in the sense of industrial design, which is a specific sense that is common in Sweden. Design can be used both as a word for the activity and for its result.

My stipulative definition would look like this: Design is the term for a goal-driven activity that forms new products, usually for mass production, and coordinates requirements for such products for practical, aesthetic and social functions with regard to technical and economic factors of relevance to consumers and manufacturers, taking into consideration resource and environmental aspects.

Many product developers, in a broad sense, are involved in an activity that falls under this notion of design. There is good reason to think about what knowledge this very large group of people should have if we want to develop products that are well-adapted to people in today’s society while maintaining competitiveness in an international context. If design is seen as an important field of knowledge and not as a narrow professional category, questions arise concerning education for all groups of people who fall under the category of ”product developers,” even though responsibility for overseeing design matters can be divided differently in various projects. To make progress, major demands will be placed on the ability of companies to handle design, on the buyer’s knowledge and on the design process.

Creativity

Creativity was supposedly used in its modern sense for the first time in 1950 by the researcher on human intelligence Guilford. The effect of Sputnik in the US in 1957 is called an earth-shattering experience with regard to the ”space race”. ”Why aren’t we best?” was the question, which was answered with ”More creativity and more science!” There are many questions that must be considered in order to make the term meaningful. With good reason, interest can shift between the person, the process and the product in an attempt to define the term, and this has been the case in the abundant
research on creativity. There is also the question of whether a valuable result must be supplied or whether it is enough that the product be distinguished as being "new, not seen before." The term "new" would likewise need a longer explanation.

What I think is essential in the context of basic education is our knowledge about the creative process. Modern literature, particularly that in the US, nowadays uses the term "problem solving." Part of the debate has shifted to "flow," which concerns the aspect of experience.

Experiences in this area are of great importance to everyone who works with creative activity, like artists, designers and engineers. A number of studies show that creativity is not synonymous with intelligence in its usual sense. An easy way to begin a discussion would be, for instance, to describe convergent and divergent thinking. It would also give nuance to the picture. But we must then also emphasise that we need both these ways of solving problems if we are to take action.

My own stipulative definition in such a discussion would look like this: *Creativity is the term for people’s ability, based on experience of existing objects, to create "new" unique artefacts that are expressed as objects, knowledge and thinking. We are working with the individual’s ability to solve problems of different types by liberating ourselves from existing patterns.*

**Knowledge**

Knowledge is an especially key term in the training of engineers. The implicit and explicit understandings of technology, which are expressed as research results, in teacher instruction, in course material and in curricula, largely determine the results of education. Similarly, it should be pointed out that the predominant view of knowledge, which is not always clearly expressed, affects education in its entirety. Discussions about basic terms can be useful and play a clearer role in the debate about a new education program for engineers – not to lock in but rather open up reflections on important issues about learning, teaching and examination – and even extending product development and the evaluation of technology.

There are several models that describe the way people acquire and use knowledge. The view of knowledge that I will give a short summary of is based on a person’s own experiences in artistic creativity and on the practical and theoretical knowledge of others in different activities. I will briefly describe a model which is based in part on experience and on an analysis of people’s interaction with everyday technology. The empirical and theoretical background can be found in Sjögren (1997) (see above under "Technology"). What is most important about the description below is not
its construction in detail but rather its potential for regarding knowledge as a broader concept than it is understood to be by engineers in past training programs. There is a risk that students will view knowledge as the same thing as what is tested in formal exams.

I consider there to be four categories (or aspects) of knowledge in the model, which can be expressed as follows. Two dichotomies can be used for the construction of a four-field diagram. In the first case, verbalising action is opposite physical action. Similarly, reflective action is opposite non-reflective action. I place stipulative knowledge, critical knowledge, skill-based knowledge and knowledge based on familiarity with an object in the four fields. But knowledge is not of itself verbalising or physical. Nor is it possible to understand reflective or non-reflective knowledge by definition as having some kind of invariable form. These forms should instead be seen as what can be understood when we use the knowledge we have acquired or as visible forms of knowledge when we acquire it. From this perspective, we can only observe knowledge when it is used in some way.

A person’s collective experiences, an individual’s knowledge, could be visualised as the contents at the bottom of a box. This knowledge is tacit, in the sense of having no form. All of our experiences and interpretations of our reality contribute to this tacit reserve of knowledge. We use knowledge, we take it out of the bottom of the box when it is needed. Only when it is in contact with the outside world does the knowledge become visible and specific. All knowledge that we can account for is knowledge in context, and the context influences the form of the knowledge.

My own stipulative definition could be formulated as follows: Knowledge is the term for the individual’s collective ability – basically tacit, in the sense of non-verbalised – which can be used and thus observed, which is focused on establishing contact with and dealing with reality.

**The concreteness of vision**

The demands on higher technical education are increasing as society becomes more complex and more difficult to grasp, as artefacts become more complex and elaborate and as the quantity of information available expands without limits. The world that we experience and are dependent on is growing. At the same time, it is possible to argue that the world is shrinking into the global village – which may be the same thing, expressed in different terms. Our possibilities for coming into contact with people now alive in this big/small world are expanding. A lot of the contact between people is made at a distance in faceless anonymity. In terms of production, both in small and large companies, we likewise note the growing emphasis in the
business world on the need for social competence in its workers. Many of what were once considered obvious connections are changing in this game of contrasts in a changing world.

**Creativity and stimulation of the senses**

The 20th century was marked by industrialism, materialism and modernism. Many of the basic values remain even though we are trying to use new terms for our “society in change” by adding the prefix “post-” in front of these three established words. What we have found is a more or less informal and less hierarchical structure, increased mobility, internationalism, a lack of interest in issues concerning the economic systems previously labeled socialism and capitalism, and the prioritising of creativity over productivity. Perhaps we can interpret this as an increased interest in qualitative questions formulated in a different way than they were by the positivism and scientific optimism of the early 20th century.

The role of engineers has been subject to scrutiny in the light of this new society. There have always been creative activities in the field of technology. When the term creativity was “invented” and drew attention, it was originally in a narrow context, where renewal was experienced as a politically urgent need in the US. Even though the word has been worn out with so much use, particularly in popular journalism, the term has lived on as a research field and as a challenge to a shift in perspectives. A change in attitude of this kind is praised as being the way to development in every respect.

Research in the last forty years has provided us with knowledge about what happens in a process of ”new thinking” of this type. We have also found that this kind of thinking can be cultivated in many areas. If we want to develop education for greater creativeness in the technical field, there are several ways of doing this. I see considerable potential for the training of engineers in presenting this perspective early on in their training in a combined practical-theoretical activity. Obviously theories about creativity should be presented to develop a base of knowledge, but if it is done in a lecture format or only by studying literature, it will result in knowledge about creativity, but not in creativity. We need to look for situations that develop both understanding of and experience with concrete practical laboratory work. There are pedagogical reasons for such a change. But there are also compelling reasons for making this a matter of developing the professional competence of engineers in 21st century society.

After many years of experience at the university level with different student groups working toward different careers and who need to develop their individual creativeness, I would like to emphasise the following. First of
all, it is important to work with problems that are simple and clearly formulated. Exercises should also be completed relatively quickly so that links and theoretical associations can be made at relatively short intervals. In the beginning, it is helpful if the material that people work with is physically tangible (stimulating multiple senses) and quickly yields results that can be recorded as a visible result of the process and thus be a subject for discussions. These aesthetic experiences are both educational content that is important in future productions and a pedagogical means of instruction for greater creativity.

There is no creativity without content. For the prospective engineer, basic knowledge about form and colour is important for everyone employed in the production of technical artefacts. This is said bearing in mind both people who work with computer-based information displayed on screens and people who will develop products in three dimensions, that is, more obviously sense-stimulating objects. Laboratory work in this phase is best based on work with two and three dimensions, pattern and movable constructions. Computer programs can also provide work material in this initial phase for these "exercises in creativity." Among the advantages is the speed in presenting solutions in such programs; among the disadvantages is the limited range of sensory experiences.

It is useful to have students undergo some of the basic experiences described here in creative activities using different materials, which provide sense-stimulating experiences. At the same time, this experimentation is linked with a reflective activity, often in the form of seminars. With this kind of arrangement, we have a fruitful combination of theory and practice. These work forms are critical for the development of this kind of knowledge.

There is also reason in this context to draw attention to the broader significance of these experiences. There are great similarities between the process that we can identify in these types of exercises and the chain of events involved when someone invents an industrial product, when a researcher formulates and works with a scientific problem and when an artist solves an artistic problem. Among other things, a student must make discoveries related to dynamics. This is a process that can not be formalised in a step-by-step schedule. Experience, judgement, imagination, and intuition are united in different ways to describe and visualise the problem/task.

There is the view that creativity is a question of innate talent; a person either is or is not creative. My extensive experience in different environments, in various university programs for technology and art, in teaching handicrafts for various occupational positions, is that creativity can be developed in everyone. It is essential that individuals undergo their own concrete experiences of the creative dynamic process, while at the same time
intellectual activity creates an awareness of the chain of events. What results from this kind of experience is a mental change. We will also most likely see a change in attitude toward the possibilities of the creative process.

Aesthetic impressions and expressions, to the same degree as creativity, involve a person’s innate assets, which can be expanded and developed. The abilities that we possess through our five senses can be developed or inhibited with resulting consequences, which have been scientifically investigated in several contexts. Experiences in the realm of aesthetics clearly involve more than the very concrete suggestions that were put forward in the text above. Perhaps the broad experience from a person’s own creative activity in music, drama, pictures or handicrafts is a factor that opens up new capabilities in the individual, which is also beneficial to the role of engineer. Creativity in the areas that fall under art – with an emphasis on personal expression – does not belong among the basic subjects in the training of engineers but can contribute, with its human development, to “the new engineers,” people who create technology for people.

Creative activity entails choices – choosing to add or take away. To take a central area in higher technical education, questions about quality also involve creative activity. Even in the most dangerous experiments and in the adjustment to qualitative norms, it is a question of in some way combining some of the traditional knowledge about people and things with a new way of thinking, which changes what are perilously obvious structures. Creativity is not a new phenomenon, but rather a human capability that was made visible in the latter part of the 20th century in a critical way by using this word. Nowadays we can also see it as a concrete realisation of the ideal of modernism, a person in the state of continual renewal.

Design and communication

Swedish economic well-being is predicated largely on a successful manufacturing industry. The international market is changing; new technology, changing production patterns, new players and tougher competition place greater demands on the products we manufacture and plan to manufacture. This suggests that there will be changes as a result of studying every phase in manufacturing. One key term is product development. In this area, there is one factor that has attracted insufficient attention, the role of the designer.

Among the steps that need to be taken in this kind of situation is a change in education. Industrial design is a field of knowledge that requires greater attention in a number of educational contexts if companies are to acquire the skills needed for product development. Professional designers who have extensive university training play a specific role but, for a number of rea-
sons, can not fulfill all the needs for design work in the near future. The tasks in the area of design are so large-scale and so integrated in the development of basically every product that we must try to find other paths for the development of Swedish design instead of depending on “the designer.” One of the professional categories that may play a vital role in the work with design is that of civil engineer/constructor (in the broad sense), on condition that their education has provided adequate knowledge about design. I will comment on a few aspects of this kind of knowledge.

Design can be considered to be a question of communication. Communication is thus defined as the exchange or interaction of something (artefacts) between groups or individuals involved. These artefacts can thus be considered messages. Seeing people as manufacturers and consumers of technology can thus be considered as an indispensable double perspective, both in terms of consumer and producer products.

The traditional model of communication could then be seen as in the illustration below:

<table>
<thead>
<tr>
<th>sender:</th>
<th>receiver:</th>
</tr>
</thead>
<tbody>
<tr>
<td>producer —&gt; product —&gt; consumer</td>
<td></td>
</tr>
<tr>
<td>intention</td>
<td>interpretation</td>
</tr>
<tr>
<td>&lt;-&gt; product</td>
<td>&lt;-&gt; interpretation</td>
</tr>
<tr>
<td>&lt;-&gt; interpretation</td>
<td>intention</td>
</tr>
</tbody>
</table>

In this kind of model, the dialectic sender – receiver (producer – consumer) is of vital interest. As a result, it is also important how we see the role of people, technology being manufactured by people for people. What knowledge and values are central in these roles if we are to work for optimal solutions?

To help answer this, I would like to present some ideas about the concept of function. (These thoughts are applicable in certain cases depending on the product in question. This line of thinking largely concerns product design.) This presentation is made bearing in mind the simplified model of communication given above. We are working with one party who by definition often functions as the person judging quality, the receiver. Sometimes, in fact, the quality of a product or service is defined as ”the ability to meet the customer’s needs.” A more general definition of quality (in accordance with SS-EN ISO 8420) expands this perspective, as I see it, by not identifying any subject that is to do the judging. Accordingly, the sender is also given a role.

We will restrict our argument to artefacts that we ”socialise with” in many ways. They can be manufactured to fill a number of different functions, not just practical functions. They should perhaps be manufactured to
fill a number of different functions, but the manufacturer has missed one of these. We use them in the way they were planned or for other purposes for which they were not originally intended. We can justify talking about *their multiple functions*.

The things around us help us manage difficulties of various sorts while at the same time creating new difficulties for us. There is often a physical problem to be dealt with, where the object can help us find a solution. The object fills a *practical function*. In order for me to store my papers and laptop easily, I put them in a briefcase. In order for me to quickly saw off boards when I redo the roof of my summer cottage, I have purchased an electric circular saw. It is easy to find other objects as examples of these kinds of solutions to problems. Often it is a case of extending the different abilities of my own body. For instance, I need to move my body quickly and get out my bicycle, an extension of my legs. I want to retain the memory of an event I have been a part of and purchase a camera, an extension of my pictorial memory.

At the same time, for millennia we humans have shown that there is another role that we willingly assign to the objects around us. They are to stimulate our senses. It is partly a question of wanting to amuse ourselves. On weekdays and for parties, we let objects make us happy. With variations in form, in colour, in texture and in the treatment of materials, we create this influence on our senses. From the Greek word *ai’sthesis* we have created the term aesthetic. This word fits well with the meaning of the role we assign to objects, *the aesthetic function*. This can also be usefully combined with the practical function, something it is easy to find proof of. This possibility of combining different functions also applies to what is presented below.

But it can also be a question of objects that are given a symbolic purpose, meaning that they are supposed to influence people’s understanding in some context. We have the Swedish flag and the combination of yellow and blue, a red heart and many other symbols, often originating in the peasant society and kingdom of Sweden. But there are also many sophisticated varieties. These things can make us think of something, which is not immediately present but which is nonetheless important. We speak then of a *symbolic function*. We also use things to outwardly define our personality (or company profile or organisational profile). The message is supposed to clarify who the person (company, organisation) is in a given context. It is also a question of making ourselves aware of our own existence and distinctive character, through things, for our own selves.

Often the feeling of solidarity is created if several people interpret a symbol in the same way. We can also talk about the broader role of influence
that we assign the object and are thus also subject to – when things create solidarity among people: candlelight, a fireplace, the television set, photo albums, but also objects and traditions associated with Christmas and Midsummer (this can also be transferred to the organisation level). We can then identify a social function of the object. This function and the symbolic function work as important messages between individuals, in order to somehow bring them together or communicate. It is thus never a case of a completely private experience.

I can also think of several other functions. I would like to identify one of these because it plays an important role for individuals. If we look around our homes, we find many objects that have or have had a practical, perhaps an aesthetic function, but which are really there for another crucial reason. Things endure over the course of the years because they remind us of a person, an event or a place. This reminder of something can be very private, and the power of this function is sometimes difficult to explain. It concerns something else, and something more complicated than the souvenir we bought on our summer vacation. It concerns emotions; we can call this an emotional or an affective function.

With these thoughts about functions, we gain tools for part of what we call, in educational contexts, object-oriented analysis (or to extend the term beyond objects, artefact-oriented analysis, where artefacts comprise both physical things and mental/organizational constructions). It is worth pointing out that it is actually people who are at the center of these issues, not things. Other aspects that are important for an incisive analysis include the manufacture of things, their material and technology, and of course economics. But even here the role of people is interesting. Behind all the critical decisions involved in manufacture, we find the knowledge, skills and values of people.

Functions are always an expression of people’s ways of interacting with things. If we want to get at the quality of products, we must expand our knowledge about people and their basic needs. We need both consumer-oriented and producer-oriented design. For this, knowledge about people and knowledge about technology are needed, along with an awareness of how these can interact. This can also constitute a productive basis for a critique of technology, in the sense of broad reflection about technical artefacts.

As a result of what is presented above, it is possible to express the desire that students acquire basic knowledge about the importance of the interplay between people and product. A key term in this context is interface, which highlights the face technology presents to the consumer. Education in this context is aimed at increasing the ability of students to independently eva-
luate and make decisions about products. Included in this ability is the in-
tellectual preparedness to shift between the perspective of the sender and
the user of technology. There are also elements here of empathy, the ability
to experience other people’s needs, ideas and reactions. Technology is a
question of producing “technical constructions” that work. In the begin-
nning, technology was a theoretical superstructure for “technology that
works.” Today we see more and more clearly that we are involved in tech-
nological systems. Extending the meaning of the term, technology in sys-
tems involves social questions, which are consequently part of the responsi-
bility of engineers. Curriculum plans for education should thus indicate that
students are to pursue knowledge about people’s needs, their thoughts and
reactions, and about the interplay between people and product and the link
between technology and society.

**Representational forms of knowledge**

Knowledge is the term for the total experience associated with a person. It
can be observed in several guises. These are visible when we acquire or
give expression to knowledge. A great deal of our success as creators of
culture depends on our way of giving form to and using what is in itself
invisible knowledge. Such transformations are made in many different con-
texts. I will call attention to a few of these. They all include an enduring
question: in what way can we give prospective engineers a broad register of
representational forms and the ability to shift between them? It may be tempt-
ing to talk about linguistic competence, if language is given a broad defini-
tion. We must respect non-verbal thinking, which has deep roots in technolo-
ogy and still helps us solve problems in the field of technology.

One context involves our ability to transform in various ways our senso-
ry experiences of the surrounding three-dimensional reality into different
representations. Knowledge about a three-dimensional box in the form of a
parallelepiped can be expressed verbally but also in a **two-dimensional pic-
ture**. When more complex forms are involved, it soon becomes clear that
verbal language comes up short. The two-dimensional picture can be a **hand-
made perspective drawing** or a **sketch drawn in views/projections**. It can
also take the form of a **compute-drawn perspective drawing** or be illustra-
ted as **computer drawn views**. Here is where some of the keys to much of
our product planning are found. Here is also an educational task which can
not simply stop at the teaching of a few three-dimensional graphic compu-
ter programs. The physical handling of forms provides a basis for under-
standing form, which in turn provides opportunities for insightful work with
both hand-drawn and computer-drawn languages. At the same time, the
work is with representational forms, seen as language, a way to greater knowledge about our three-dimensional reality.

Our understanding of three-dimensional reality as experienced through the senses is dependent on previous experiences recording reality and our ability to do so. With knowledge about drawing views, people will learn to describe three-dimensional forms differently than if they have never had contact with this language. This can be taken further: a person who has worked with the cross sections or surface spread of projection theory clearly has a different understanding about three-dimensional reality than does someone who has not been taught. This follows from past experience: you see what you know. In the cases given here, representational forms are what make us understand and handle reality in a more advanced way than without representations. Extending this argument, I would also dare to claim that people will have difficulty forming and constructing free forms (beyond the basic simple stereometric bodies) if they have not incorporated a broader register of their active store of forms and created a representation in some form for this knowledge. With their passive store of forms (similar to passive vocabulary), they can manage tolerably well in the everyday world of forms. However, in this article, we are dealing with professional constructors in a number of specialties in the various engineering programs. There is then reason to contemplate the importance of acquiring the capability of handling three dimensions in material and in representation. Developing an active store of forms is one task of education.

There is also an extension of the discussion above going on today. It concerns the relationship between the reality of pictorial graphics, especially VR (virtual reality), and MR (material reality). In order to create virtual space and be able to develop the often limited forms of VR today, people must have experience with the material world which has been subject to reflection and to which an active register of forms has been added. An argument can be made for working with form workshops, where sculpture and movable constructions develop their form. This kind of work will have the greatest impact if there is an exchange between the graphic representation of computers, the volumes and space of quickly-sketched pencil drawings and experimental work in cellular plastic, plaster, wood, textile material and metal. There is to some extent a connection between this and the work with form that has been proposed which would serve as an introduction to the various domains of creativity.

We are now experiencing a great deal of enthusiasm about the possibilities of VR. There is every reason to be curious and take advantage of the opportunities created by this technology, just as we did with past inventions. At the same time, there is reason to take a critical look at the medium
and its consequences. There are opportunities here to establish links with the discussion concerning our need for sensory experiences and the stimulation that multi-sensual impressions give us. Many museums are currently creating presentations in virtual space. You can sit at your computer and visit the Louvre or the Musée de l’Homme. You can zoom in on the paintings and objects you would like to examine. The world has opened up as VR. Wearing gloves and a helmet, you can, with great illusion, turn the virtual objects around. At a later phase, when this is considered a ”normal” museum visit, museums will provide visits where you can see the real objects and touch the items, MR. Not just researchers but people visiting a museum will be surprised by how ”real” things ”appear” to all of our senses.

As a direct continuation of what was presented above, which concerns the view of reality and the qualities of reality, it is reasonable to discuss the growing distance between the constructor and the materials used. For instance, wood, metal and textiles are still used as materials in industrial production. It makes sense that people planning for production in wood should have what is called a feel for the material. ”Feel” here is meant as physical experience with the material, which gives that person familiarity in evaluating it. If instruction is needed in sculpture to maintain this contact between form as experienced reality and as a representation of reality, we should, given these basic comments, think about whether it may be advantageous for some training programs to develop activities that provide experience with materials through experimentation and processing. Textile materials, wood, ceramics and metal have unique qualities that can not simply be studied in textbooks.

Another aspect of the discussion concerning the relationship between representational forms is our experience of how the representation of knowledge directly controls knowledge. Examination is a crucial part of the learning process. If people are ”studying for a test,” the form of examination will to a large degree influence what they consider to be knowledge: problem solving of real problems, analysis, synthesis and evaluation. If the test is only in written form with questions that emphasise shallow knowledge, students will quickly form a shallow concept of knowledge. The same holds for deep knowledge. The representational forms of knowledge as established through courses control the students’ understanding of what knowledge is in a course. A key question then is whether we are unaware of this or whether we have the pedagogical knowledge and ability to vary the forms of examination in order to be able to control this knowledge consciously, in a positive sense.

The representational forms of knowledge and their effect on thought and product, verbal and non-verbal representation, are of critical importance in higher education.
There is no reason to believe that industrialism is the final economic and technological phase of development. Manufacturing still plays a dominant role in the social structure, but it is not the labor-intensive manufacturing of the last hundred years. Knowledge has always been the core of human cultures, but the amounts of available information that can be conveniently stored and communicated have never been as great as now. The struggle continues, since Daniel Bell published a book about the post-industrial society in 1973, to name the change and thus influence our view of the ongoing change. Post-industrial society, the information society, post-materialism society, the IT society...

From a Swedish perspective, we can talk about how we are in the midst of two crises of expectations. A century of "obvious" economic progress became less obvious when growth collapsed in the 1970's. This view took on a new dimension when we realised that Sweden was changing as a politically independent nation, given the globalisation of business and financial markets. A positive interpretation of this is that, in this structural uncertainty, there are fundamental conditions for a major structural change with new opportunities for a different welfare society and an exciting life for people. One thing that we can be sure of: the next generation will be characterised by dynamic change. "All that is solid melts into air," to quote a view of modernism by Marshall Berman (1982).

Are we taking part in change or are we at its mercy? A large part of the answer depends on our own attitude to the actual phenomenon of change. An important concept in the debate on education is reflection. Of central importance then are our ability to be aware of what we do, of what the result of various actions can be, and thus a comprehensive view. Education is to be based on a scientific foundation, which has at its core this reflection. Without this, we risk winding up in what can ironically be called university-educated banality. The internal critique of technology is an important part of the professional responsibility of engineers.

Unreflective knowledge is close to an immediate sensory experience or action, which are in themselves essential. What is characteristic of reflective knowledge is evaluating alternatives, both in terms of an action and the result of an action. What is then in focus is our ability to construct different perspectives, see different alternatives, see what is selected and what is eliminated. This is done by the individual through advanced learning. One form of education that clearly promotes this kind of dialogue is the seminar. If those of us involved in higher education want to increase the impact of these dialogues in individuals and in groups, we should give prospective
engineers some knowledge of scientific theory early on. This includes an awareness of what distinguishes a quantitative and a qualitative perspective as well as what consequences these different approaches have, which is a solid basis for the development of a human technology.

It is time to give this article a title as was promised in the introduction. A subtitle would emphasise the idea that we are producing artefacts, and through these human constructions, we communicate: **Reflective people who produce and consume artefacts.**

I would like my main title to capture all these key terms: design and functions, aesthetic and sensory experiences, art and technology, creativity and knowledge, practical and theoretical, and experience and vision. But a title is not supposed to be complete; it should capture the attention of browsers. I will thus title this article:

**Creating knowledge for human technology**
Jan Åke Granath

A Design-Theoretical Approach to Learning in Technology

Introduction

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

Our economy is less and less dependent on manufacturing things and hardware. Our future lies in the production of soft goods like advanced services, systems design and management as well as innovation and research in areas where vast intellectual and economic resources are needed to compete. These new areas require an advanced education in engineering but also a new kind of engineer that can handle new types of problems that were out of reach for the traditionally trained 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 paper differs, at least from the everyday Swedish meaning of the word. Design could be a noun, meaning e.g. the style, form and other properties an object has been given, and a verb, meaning e.g. to give form.


Professions in transition

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

My empirical foundation for the discussion is almost three decades of very inspiring practice in design, research and education with architects and engineers with different specialties. As a genuine believer in design as a learning method, 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.

With this text I would like to contribute to a discussion on how the learning situation in elementary and high school might be designed in a way that prepares students for a future career in engineering and other professions based on technical understanding. I will also suggest that a design-theoretical view of technology shows that technology is closely connected to questions of importance to young people today of both genders. To do this I will use the training and professional practice of architects and engineers to illustrate the possibilities of future technological professions.

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 will also describe some obvious differences between and within each profession. In his book

The Reflective Practitioner, the American design theorist Donald Schön distinguishes 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 that engineers are taught to treat knowledge in a technical rational way while architects mostly depend on reflective behaviour in their practice. I will come back to this later in the paper.

I am drawn to Herbert Simon’s view that “Everybody designs who devises courses of action aimed at changing existing situations into preferred ones”. In this paper, however I will, 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 therefore always have an intended or so-
sometimes unintended effect on human beings and society. Both architectural and engineering practices are design professions in this sense.

**Artisticness and architectural design**

Many professionals have an urge to artisticness. By this I mean an urge to express themselves through professional performance beyond what most others can do. This urge is mostly an ambition resulting from the personality and the talent of the professional. In the training of architects, however, this is a central aspect of the curriculum like in the training of performing or fine artists. For some architects this becomes the paramount driving force in their work. Even if the purpose of artisticness in architecture, in most cases, is to make something pleasing, I do not connect this only to aesthetic dimensions for two reasons. The first reason is that my experience from working with engineers, and other professionals, has convinced me that any serious professional has an aesthetic dimension in the way they design or perform. Nonetheless, this is often implicit and often even denied by them. Their 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 aimed at communicate with society and individuals.

In this sense I think of artisticness 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 absolutely necessary condition. The driving force could be merely introverted. Some philosophers would argue that this urge to fulfil one’s own dreams or express oneself is the only valid driving force among human beings. Research done in the US by Robert Gutman, the sociologist and professor of architecture at Princeton, shows that the main goal of practising architects is to be appreciated by their fellow architects rather than by users and society as a whole.

**Engineering construction and engineering design**

On the other hand, we have what I call engineering construction. I am not talking here about construction in the sense of erecting or manufacturing something but the activity of giving the artefact its normative qualities, properties and dimensions following good professional standards. This is reminiscent of a common definition of design, but in this case, I will suggest engineering construction as a more restricted view of 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 in the outcome to be. What I call *engineering construction*, which is different from *engineering design*, lacks to a large extent this uncertainty and ambiguity. I consider engineering construction to be a design situation where the engineer knows very clearly 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 in solving the problem and that an acceptable result will be achieved in the end.5

Therefore, on one hand I have distinguished *artisticness* in terms of *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 are favoured. It is however important to point out that we find very few professionals, if any, who fit completely into these two categories. When we discuss education in engineering and architectural design, however, I find it useful to make these somewhat “artificial” distinctions 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 problems*.6 In these cases ambiguity and uncertainty are always present concerning the problem definition, the relevance of theories and methods and often even the actual conceptual context of the solution. In these cases design can be described as a simultaneous and iterative process of i) decision-making, ii) problem solving, iii) communication and iv) considerations of aesthetic and ethic values.

The *decision making* process involves *rational logic*.7 This involves the ability to master professional methods for collecting and structuring data, setting up and evaluating alternative actions and being familiar with concepts, rules and regulations of the profession and finally having the professional skills to follow them. These skills depend mainly on what Schön calls *technical rationality* in its view of knowledge and professional design behaviour.
Problem solving, on the other hand, involves a more intuitive logic\(^8\) where questioning rules, bending and breaking rules and developing new rules are essential aspects of design. The problem solving process involves to a great extent 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, 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 recognise this from everyday design situations. We only have to think about one way to solve a problem to immediately realise 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 users 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.\(^7\) Simon’s claim above that everybody is a designer indicates a collective design process\(^9\) as something that does not just involve professional designers like engineers or architects.

The problem solving and communication dimensions of design could, in Schön’s terms, be described as reflective behaviour. Reflective behaviour is well suited to situations 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 upon 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 is a part of reflective design behaviour.

Because of Schön, every designer uses a combination of technical rational behaviour and reflective behaviour in their professional practice. A technical rational way of thinking is however more predominant and regarded as the norm in engineering education whereas reflective behaviour is considered so in architect education. As a result, those engineers occupied mainly with engineering construction often feel less professional when they “degenerate” into what they feel is “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 as uncreative and an obstacle to artistic quality. As detailed data and normative methods are crucial to the traditional engineer, too much knowledge and information sometimes make the design too complicated for those architects merely seeking the artistically consistent solution.
Dealing with uncertainty

Reflective behaviour is essential for solving poorly defined problems and for innovating, and technical rational behaviour is needed to take advantage of expertise and scientific knowledge and above all as controlling behaviour for intuitive suggestions. Reflective and technical rational designers have different strategies to deal with an overflow of information and ambiguity in the design situation. Technical rational behaviour delimits the problem to a safe area where the methods and theories at hand are relevant to the simplified problem. This makes it difficult to deal with actual real life problems that are not easily reduced to fit into single professional areas. This restriction is not a 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 are more general in the form of rules and regulations set up by authorities or taken from handbooks and manuals. The presence of such normative data however is controversial among architects. It is argued, on one hand, that such norms are a help in guaranteeing certain qualities that are essential to users and society and still give architects great freedom to concentrate on the artistic aspects of the design. Another view however is 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 for taking advantage of scientific knowledge and previous personal experiences could make many of these normative regulations obsolete and entrust the design to reflection and creative thinking. The situation however is far from ideal in architectural practice when it comes to feedback from previous design situations, procedures and methods that enhance the ability of reflection-on-action. This is an area where engineering practice has a lot to offer.

The importance of context and values

The last aspect of design I mentioned above was considerations of aesthetic and ethical values. For this purpose I would like to 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 Roman architect Vitruvius8 (last decades B.C).10 Ehn used the model
to describe properties of artefacts in general. I have modified the model to discuss the education of architects and engineers.

The technical rational point of view, according to Schön, is that knowledge based on science is the sole basis to build design practice on. Skills are something that comes after knowledge and are 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 discussions on practice-generated theory and hermeneutic sciences, on the other hand, have called this into question as the sole basis for professional education.

**Two education traditions**

**Engineering education**

Engineering education is for natural reasons based on structural knowledge (see figure above). Structural knowledge is defined here as scientific knowledge, independent of the context; i.e. rules for how to calculate a concrete beam are the same regardless of whether it supports a church or a football stadium.

Relating professional knowledge to the context has traditionally been left until after one’s professional degree. In practice, the engineer has acquired true engineering design skills, including reflective behaviour in his/her design practice. With growing awareness among engineers of the need to deal with poorly defined and wicked real life problems without delimiting them to abstract pieces of a problem field, contextually-related training has become 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 were made at the School of Architecture at Chalmers University of Technology in the late 1960s, and this method is still an important part of teaching in the school. Unlike some modern problem-based courses, the basis here has always been
real real-life problems, where the students have intervened in situations and co-operated with people in their everyday world, whether it involve workplaces, housing projects or redesigning public facilities or communities. Several projects have been realised or contributed ideas that were later realised.

Engineering education still has its basis in structural knowledge but increasingly adopts the ideas of using real-life contexts or at least simulated ones as a basis for professional training.\textsuperscript{12}

Aspects of ethical or aesthetic values were long “off limits” in engineering education. A strong standpoint has been that scientific knowledge is neutral and stands above political or moral considerations. 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 emerged. This has also meant that the scientific truths of the natural sciences have been subject to discussion and considerations based on values among individuals and society.

\section*{Architectural education}

We can find two main lines of development in architectural education. One is the “académie des beaux-arts”, where the architect’s education is mainly artistic. This tradition was always and is still strong in some countries. In other countries, architectural training is part of an engineering school. The education of Swedish architects was traditionally more similar to engineering education and had a larger part of its curriculum than today in the area of structural knowledge. The contextual aspects and training in real-life problems however have always been important. Before the change in the late 1960s, real-life projects 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 a real-life situation or fantasy problems simply formulated to stimulate creativity or challenge the students without feeding any useful solutions back to those who lent their reality to the students’ exercise, if they at all existed. This latter use of real life or fantasy in architectural training still exists and has a value, but the importance of interaction and usefulness is predominant today. It is interesting to note that in schools of the “académie des beaux-arts” tradition, real-life problems and communication with laymen often are regarded not preferable. The argument is that reality will restrict creativity, and the need to adjust to users’ demands and wishes, other than those determined by the architect’s own interpretation, will harm the artistic quality of the result. Real-life restrictions will come soon enough in real practice anyway.
Values have always been present as an important factor in architectural education and practice when it comes to aesthetics. In education, values in other areas such as social, humanist and environmental issues are also important. Those who see architecture mainly as an artistic profession put aesthetic values among designers, tutors and fellow professionals 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 ethical values of the designer, on the other hand, changes over time both in education and practice. So does the focus on the interest in aesthetic and ethical values.

It is interesting to observe how traditional engineering education is based on structural knowledge but increasingly tends to involve contextual and value-based aspects in education. Architectural 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 efforts under way, at least at Chalmers University of Technology, to marry structural knowledge in technology with the context of human life and the built environment.13

**A few reflections**

In this text, I want to suggest that a design-theoretical approach to education in technology could broaden young people’s conception of technology. Introducing techniques for accepting and solving fuzzier problem definition might make technology more demanding and interesting. Discussing 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. Approaching technology in a multi-disciplinary way that bridges humanities, art and the social and behavioural sciences might make it more interesting and meaningful. I also use the engineering construction tradition in engineering practice and the excessive focus on artisticness among architects to illustrate different kinds of professional traditions that might be obstacles for adopting and handling real-life problems.

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

1 This is described in more details in my doctoral thesis from 1991, *Architecture, Technology and Human Factors: Design in a Socio-Technical Context.*

2 The traditional definition of *artefact* is closely connected to *physical things.* It is something *manufactured* by man. My view however is that this definition is not sufficient in modern society, where 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 phenomena. My definition of *artefacts* therefore includes anything created by man, including those that originally lack a physical form like ideas, theories and mental models.

3 I use the expression *the real world* to distinguish it from the Cartesian division into disciplines that is the tradition in engineering and the natural sciences, and other sciences too for that matter. The real world means a more holistic approach to the problems at hand, where we can bridge 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 Wictor Papanek in his book *Design for the Real World* as early as 1985. He however focused more on the appropriation of artefacts rather than on the knowledge behind its design.


5 The Swedish professor in Informatics Bo Dahlbom suggests 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 1990s. I have elaborated on this suggestion in my own way since then.

6 The 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 continually forced 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. Furthermore, you cannot be certain you have found a solution. Rowe, Peter H. 1987. *Design Thinking.* Cambridge, MA: The MIT Press: 39-41. Rowe’s points of departure are: Churchman, 1967, Rittel, 1972 and Bazjanac, 1974. Cited from Granath, J =. 1991. Architecture, Technology and Human Factors: Design in a Socio-Technical Context. Diss. Chalmers University of Technology, Gothenburg.

7 I allow myself to use an expression here that, using a special meaning of *rational,* could be a tautology. I use the term *rational logic* to distinguish it from *intuitive logic,* used below. Intuitive logic would be regarded by some as 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.*
By intuition, I mean the ability to recall earlier experiences that are understood by the designer. Referring to Simon and to discussions with Rudolf Arnheim (Ann Arbor, MI, 1988), I see intuition as something individuals who have experience from certain situations can use to solve problems in similar situations.

Inspired by Schön, I suggested that the concept collective design is a reflection of 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 designers like assembly workers, engineers, architects etc.

This is an interpretation of the original Latin text in De architectura libri decem, in which Vitruvius presents his ideas about the elements of architecture; originally from an English translation by Sir Henry Wotton (1568 - 1639)

This is reported in Kjellgren K, Ahlner J, Dahlgren LO, Haglund L (eds) Problembaserad inlärning – erfarenheter från Hälsouniversitetet. 1993, Lund: Studentlitteratur.

I distinguish between real real-life problems, which involve the solution of an existing problem together with people affected by the problem setting, and simulated real-life problems, where the situation is realistic but not real.

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. Strategic programs in Facilities Management and Design also try to bridge engineering, architecture and other disciplines outside the technical university.

References

Lars Lindström

Creativity:
What is it? Can teachers assess it? Can it be taught?

Abstract
Lars Lindström takes the subject of visual arts as the point of departure in a discussion of how, with the help of portfolios, assessments may extend to include both the unpredictable and the ambiguous. In the author’s view, the notion that assessments of learning outcomes must be either limited to superficial knowledge or completely arbitrary is a misconception. Lindström has made a study of the progression of young people’s creativity in the visual arts from preschool to upper secondary school. The assessment was based on both product criteria and process criteria (investigative work, inventiveness, ability to use models, capacity for self-assessment). The materials assessed were portfolios of work containing sketches, drafts and finished works, log books, sources of inspiration and videotaped interviews with the students. Is there any progression in students’ visual design, in their ability to work independently and assess their work? What is the degree of correlation in the assessments of different judges of student portfolios? These are some of the questions that Lindström attempts to answer in this article, which concludes with a discussion of how schools can build a culture of learning that fosters the creative powers of young people.

“The school is responsible for ensuring that all pupils completing compulsory school have developed their ability to express themselves creatively,” says the 1994 Swedish Compulsory School Curriculum (Lpo 94, p. 12). The broader statements in curricula about the kind of person, the kind of knowledge and the kind of society that school is supposed to promote are often referred to in the educational debate as “the poetry section”. It has been generally accepted that these are high ideals that are diffuse by nature and difficult to translate into the everyday reality of school. What, then, is creative ability? Can it be expressed in words? Can it be assessed? Does any development take place? What part does the student’s background play? And can creativity be taught? These questions served as the guiding principles for a study entitled Portfolio Assessment of Creativ-
ty in the Visual Arts carried out by the author with two colleagues from the Stockholm Institute of Education: Leif Ulriksson and Catharina Elsner (Lindström, Ulriksson & Elsner, 1999). This was one of five studies that made up the National Agency for Education’s “Evaluation of the Swedish Educational System, 1998, with regard to the New Curricula (US98)”.

Earlier national studies were based on random samples of about 9,000 students in a particular year, who completed questionnaires, attitude forms and written tests in a range of subjects. The 1998 Evaluation tested a new approach, which consisted of a number of in-depth studies of comprehensive, cross-curricular competencies in the latest curricula (Lpo 94/Lpf 94). Of particular interest to the National Agency for Education were competencies that required methodological development and innovative thinking to make them assessable. The researchers involved in the project were encouraged to apply “innovative and open thinking, without giving too much consideration to the structure of traditional evaluations of education” (National Agency for Education, 1995).

The study of creativity produced a number of unexpected results. Or, to put it another way, it suggested that some of the prevailing views about children and the visual arts owe more to preconceived notions than to facts. Readers who are interested in these sections of the study are referred to the research report (Lindström et al. 1999) and the article, “Sju fördomar om barn och bild” (Seven Myths about Children and the Visual Arts) (Lindström, 1999). Here, I shall focus instead on the methodological development that took place in the project, and on how portfolio assessment, criterion-referenced judgement and grading may be used to nurture creative ability.

What is creativity?

While a visiting scholar at Harvard Project Zero in 1991, I had the opportunity to study Arts PROPEL, a programme of curriculum development in the areas of the visual arts, music and imaginative writing (Gardner, 1989; Winner, 1991). This programme encourages students to reflect and to make their own observations about their work. Students reflect on the purpose of their work, on decisions they have made, or on their strengths, weaknesses and positive achievements. Norman Brown, a visual arts teacher, took part in the project; Ella Macklin was one of his students. At the end of Ella’s second year in high school, Norman and Ella went through her voluminous portfolio (Wolf & Pistone, 1991). It contained a book of sketches and notes and close to twenty works, accompanied by accounts of the way they had progressed. They discussed what Ella had learned while working on her “family series”. She leafs through her file and pulls out an early drawing of
her father, who is holding her (Fig. 1). In working on this picture she had to decide which was most important: expression or a naturalistic depiction of reality. Ella remembers: “I felt that I didn’t draw the arm right. But I changed my opinion of it when we talked about Matisse in class, and I saw pictures in art magazines where the arms are somewhat distorted. My dad is just like that arm. I mean, he is really protective.”

Ella now began to recognise that she had the right to develop and alter the actual content of her family photographs. The portfolio contains a portrait of Ella and her grandmother. “In my family photo album at home she’s sitting on the couch in the living room, and the photo shows the whole living room. But I just wanted my grandmother and myself, so I decided to put the picture in an outdoor setting.” Norman comments on the way the open, airy landscape brings Ella and her grandmother into focus. He turns the attention towards the visual design of her drawing, and Ella remarks on the way the soft, rounded shapes convey a sense of shared intimacy. “I think there is more to this picture,” she says. “You see the way my grandmother’s body hugs me. It is strength; it’s warmth; it’s caring. I think pastels help achieve that – they can be blended and they can be smoothed even. Or they can be left rough in certain areas, where you want it to be highlighted.”
Ella pursued what she called “this family quality,” that is, the intimacy she has captured with the help of soft shades in pastel oils - a surrounding, embracing intimacy. A catalogue from a Harlem Renaissance exhibition and a visit to the Carnegie Museum sparked her imagination. Ella found other artists there, among them Giacometti, who had confronted similar problems of visual design. The visit to the museum made her question the individualisation that had hitherto been a characteristic of her family portraits: “One of the things that I noticed,” she says, “was that the paintings, and even some of the sculptures, didn’t have a face … So I could interpret it; I could put myself into the picture; I could put in my own feelings … This began the universal series that I later developed in which you have an adult holding a child, a mother holding a daughter, whoever.”

Ella began to draw more of her figures with less detail. One was a mother holding her child on a swing, a theme that culminated in Ella’s plaster sculpture of a parent lifting a child (Fig. 2): “I liked the way the quality of Giacometti’s Walking Man was rough; it was a very rough bronze statue. I attempted to create that same roughness. Even though you have good relationships with your parents, you still have arguments. You have rough edges in a relationship. So I left that rough quality. Because to smooth everything would be very unrealistic.” Later, she returned to the theme of parents with children, and produced a simple line drawing and a series of prints in different colours.
This is an illustration of the kind of learning that occurs in creative activity, provided the students are given the opportunity to constantly make new observations and reflect on what they have done. Ella’s description of her work process confirms the findings of other case studies, not only of artists (e.g. Arnheim, 1962; Josephson, 1984; Lindström, 1993a) but also of children and young people (Taylor, 1986; Wolf, 1988; Lindström, 1993b-c). These studies show that creative work has a number of dimensions, among them the ability to adopt a number of different stances or perspectives, to harness both cultural and social resources, and to pursue ideas for a period of time long enough to allow the sources of problems to be identified, and ways of solving them to be found. These performance or process qualities can scarcely be measured objectively. Neither can we measure the “beauty” or similar qualities of the finished product. Nevertheless, as John Dewey points out in *Art as Experience* (1934, p. 298 ff.), this does not prevent us from employing various criteria to judge the qualities we appreciate in a painting or, for that matter, in an essay, a scientific experiment or a historical study.

In evaluating creative performance for Sweden’s National Agency for Education in 1998, we tested seven criteria. Three of these concern finished products, while four concern the work process. The selection is based on objectives formulated in the national curricula, on qualities that are appreciated in the art world, and on research into the creative process (for a different, inductive method for defining criteria, see Lindström, 2001). The product criteria comprise: (1) the visibility of the intention behind the picture or pictures (the student’s visual work communicates what he or she intended); (2) colour, form, and composition (the student achieves desired effects with the aid of visual elements and principles); (3) craftsmanship (the student masters materials and techniques). Process criteria describe: (4) investigative work (the student pursues a problem across several works or experiments, feels challenged rather than discouraged by difficulties); (5) inventiveness (the student sets up problems, tries new solutions, is willing to take risks); (6) the ability to use models (the student actively searches out models to emulate); (7) capacity for self-assessment (the student describes and reflects on different qualities in his or her work). In addition, we included (8) an overall judgement in which the teacher takes into account what degree of difficulty the student masters, his or her capacity to work independently and other factors of significance.
Can creativity be expressed in words?

Approximately 500 children took part in our study of creativity in the visual arts, from preschool (5-year-olds), through the second, fifth and ninth grades (8-, 11-, and 15-year-olds) of the compulsory comprehensive nine-year school, to the final year (19-year-olds) or concluding courses in the arts programme of the upper secondary school. The study was carried out in Stockholm and Jönköping (one of the ten largest cities in Sweden. It is located in the southern region of the country, which is known for its many successful small and medium-sized enterprises) from 1997 to 1999. The material studied consisted of portfolios whose contents, in addition to a final product, included sketches and drafts, reflections in logbooks, models used as sources of inspiration and a 10-15 minute videotape interview with each student. The portfolios documented the students’ work over a period of 10 hours (nine-year comprehensive school) or 30 hours (upper secondary school). During this time, the students worked within a visual arts theme of a divergent nature, that is, a theme that could be approached in a variety of ways, which was selected by the teacher.

All of the students’ portfolios were independently assessed by both the student’s own teacher and a teacher at the same grade level from another school. A general definition of what was to be assessed was formulated for each of the seven criteria. The following quotation is an extract from our description of “capacity for self-assessment” (Lindström et al. 1999, p. 79):

“Creative people often possess an ability to adopt a number of different stances or perspectives. When they look at their own work, they focus alternately on the technical aspects, the visual design, the ideas, and so on. They develop a set of standards or a checklist that directs their attention and helps them to monitor the creative process. In addition, they master a vocabulary that enables them to assess their work in multiple dimensions, so that they can pass more qualified judgements than just ‘good’ or ‘bad.’ (…)

A capacity for self-assessment is not innate, it is something that students can develop and refine. A student with a high ability to evaluate his own work can leaf through his portfolio and reflect upon the content, on both the themes addressed and the materials and techniques, and also upon colour, form, and composition. He can point out works or parts of works that are successful or that require continued work, and he can give reasons why. He can point to decisions taken in the course of the work and explain why he chose to do something in a particular way (for example, why he chose a particular colour or arrangement). He may also be able to say how the choices he made affected his pictures and reflect upon how his future work may benefit from the experience he has gained.”
For each criterion the assessors had to choose between four rubrics, each with “plus,” “medium” and “minus” (that is, a twelve-grade scale), presented in a teacher’s manual. These rubrics describe levels of performance on an ascending scale. They correspond to the development from novice to expert outlined by the Dreyfus brothers in *Mind over Machine* (1986) and thoughts about rubrics design put forward by Goodrich (1996), Wiggins (1998, p. 153 ff.), and others. The development proceeds from solving simple tasks with assistance to tackling complicated problems in an independent and confident way. The progression on our process criteria corresponds particularly well to this description (*Table 1*). The lowest level (novice) is characterised by expressions such as: the student “does only what the teacher requires.” Descriptors at the next level include the student being able to assess his or her work “with some help” and “take a problem the teacher has set and change it slightly.” At the highest level, students develop the work on their own, set themselves problems to solve, actively search out models, can justify their preferences, and so on.

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<tr>
<th>Process criteria</th>
<th>Expert</th>
<th>Novice</th>
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<tbody>
<tr>
<td>Investigative Work</td>
<td>Takes considerable pains approaches themes and problems in several different drafts, sketches or text work to develop the work.</td>
<td>The student does not give up in the face of difficulties, preferring to concentrate on a particular approach that she begins to develop and refine.</td>
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<td>Inventiveness</td>
<td>Often sets up problems or reformulates the problems set by the teacher. Makes consistent progress and experiments regularly, is willing to take risks and often finds unexpected solutions to problems.</td>
<td>The student sometimes sets herself problems. She develops her knowledge, experiments fairly often and sometimes finds unexpected solutions to problems.</td>
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<tr>
<td>Ability to Use Models</td>
<td>Actively searches out models to emulate and can use them in her work in a multifaceted, independent and well-integrated way.</td>
<td>Can take a problem the teacher has set and change it slightly. Shows tendencies to experiment and play with colour, form and composition, or materials and techniques.</td>
</tr>
<tr>
<td>Capacity for Self-Assessment</td>
<td>Clearly identifies merits and shortcomings in her own work and can select sketches, drafts and works that illustrate her progress. Can justify opinions and explain why a particular result was obtained. Can produce qualified judgements of peers’ work and contribute constructive criticism.</td>
<td>The student shows an interest in other people’s pictures that she or the teacher has found, but she confines herself to copying them.</td>
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<td></td>
<td>As a rule, manages to see for herself the merits and shortcomings in her work, and can select sketches, drafts and works that illustrate her progress. Is beginning to produce qualified judgements of peers’ work.</td>
<td>With some assistance, can identify her strengths and weaknesses and differentiate between good and less successful work. Her views about her peers’ work are limited to subjective preferences (good/bad, like/dislike).</td>
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<td></td>
<td>Demonstrates a degree of patience, tries out her own solutions and approaches, but does not develop them.</td>
<td>Shows no interest in other people’s pictures and cannot benefit from them even when the teacher has helped find them.</td>
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<tr>
<td></td>
<td>Makes active efforts to find pictures for her own work. Demonstrates an ability to select images that suit her intentions.</td>
<td>Cannot identify strengths and weaknesses in her own work or differentiate between good and less successful work. Has no views about the work of her peers.</td>
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Good descriptive rubrics, supported by examples of both high quality and less satisfactory work, help students to assess their own work and to understand what qualities of performance the teaching aims to achieve. The rubrics should satisfy the following requirements:

- **They should be sufficiently general so that their connection with the overall goals is evident.** Rubrics that apply only to a particular assignment are, no doubt, more concrete and easier to apply. However, such rubrics may obscure the broader educational objective for which the assignment was designed, and may unnecessarily limit the freedom of students and teachers to demonstrate knowledge and skills by various means.

- **They should be descriptive.** That is, they should describe unique and typical characteristics of performance at different levels. To be informative, they should refrain from using purely comparative and evaluative language, such as “unusually good composition” or “unimaginative composition”.

- **They should be described in equivalent terms.** Descriptors should make it clear that the assessment is based on the same criterion; new dimensions, explicit or implicit, should not be introduced in the transition from one level to another.

- **Rubrics should be neither too many nor too few.** There should be enough levels to separate and identify important qualities, but there should not be so many that they become impossible to distinguish one from another. From the educative viewpoint, three levels are perfectly adequate, says Peter Elbow (1997), who considers the important factor to be that the assessment is multidimensional, and not that it differentiates many levels.

**Can creativity be evaluated?**

All student portfolios in our study were assessed independently by both the student’s own teacher (the class teacher) and by a teacher who taught students of the same age at a different school (the co-assessor). The assessors used a teacher’s manual containing our descriptions of the seven criteria of creative ability and the four levels of performance for each of these criteria (Lindström et al. 1999, Chap. 5). They also judged, at each level on a criterion, whether the portfolio demonstrated performance that was slightly below, on a par with, or slightly above the average described in the manual. As a result, the level on each criterion was assessed on a twelve-grade scale. Such a finely-graded scale was essential for research purposes, because we wanted to make statistical comparisons of students between the ages of five and nineteen.
We compared the assessments of the class teachers and the co-assessors, applying all criteria on 458 portfolios gathered from 22 classes in 17 schools (later on, another set of 32 portfolios from six preschools were similarly collected and assessed). If there had been major discrepancies in the judgements, with considerable differences between assessors, the criteria and levels described above would not have been accepted as a reliable instrument to assess and judge students’ creativity. Possible causes would be imprecise definitions of the criteria, inconsistencies in the criteria, the quality of the material gathered (the portfolios) being inadequate, highly idiosyncratic preferences among assessors, or irrelevant circumstances affecting the assessment.

One of the methods we used to study the reliability of assessments was to calculate the frequency with which the judgements of the class teacher and the co-assessor differed by two steps or less. We considered a difference of two steps on a twelve-grade scale to be acceptable, particularly as the teacher’s manual contained verbal descriptions of only four levels of performance. Assume that Leif’s portfolio was assessed by applying the “Inventiveness” criterion. The class teacher gave him a score of six while the co-assessor scored his performance as being no better than four. Both judgements are compatible with the following rubric: “The student can take a problem that the teacher has set and change it slightly. He shows tendencies to experiment and play with colour, form, and composition, or with materials and techniques.” Even in cases where a difference of two gives a different standard, we regard this outcome as fully acceptable. After all, judgements contain a subjective element that defies precise verbal description; they presuppose that the teacher uses his professional judgement in interpreting criteria, levels and the content of portfolios.

We found high agreement between class teachers and co-assessors in ratings of both the students’ visual results (product criteria) and their approach to work (process criteria). In almost 3,100 comparisons between class teachers and the co-assessors from another school, there was 78 per cent agreement (≤ 2 steps on a twelve-grade scale). Given that other discrepancies between the two assessors were small and indicate an approximately normal distribution, this may be regarded as a satisfactory result. Were we to consider the differences of three steps or fewer as negligible, which would not seem unreasonable, then the level of inter-assessor agreement would be as high as 90 per cent. Thus, the study effectively refutes the idea that only superficial knowledge and skills can be assessed and evaluated. By using criteria related to visual design and students’ work habits, we managed to evade the assessor’s Scylla and Charybdis, that is, a tendency to place undue emphasis on students’ skills in the use of materials and tech-
niques on the one hand, and a judgement based solely on arbitrary preferences on the other.

The results of our study are in conflict with the view that process criteria are intrinsically difficult or impossible to assess. They suggest, however, that assessment of processes of learning requires the students’ thoughts to be made accessible in a more explicit way than normally happens. It was not until we supplemented the students’ logbooks with the videotaped interviews that different assessors arrived at similar results. The interviews addressed the students’ capacity for self-assessment and their work processes step-by-step. The appropriate criterion, that is, what dimension of performance a question is primarily intended to highlight, is given in brackets below.

What task have you worked on? (Criterion 1: Visibility of the intention)
Choose a picture that you like. Explain why. (7: Capacity for self-assessment – quality)
Choose a picture you are less satisfied with. Why don’t you like it so much? (7: Capacity for self-assessment – quality)
Choose a picture that says something about your way of expressing yourself. How can one see that it is your work? (7: Capacity for self-assessment – personal style)
What did you want your pictures to state or express? (1: Visibility of the intention – can the picture stand by itself or does it require an explanation?)
What inspired or suggested your pictures? (6: Ability to use models – how actively and independently did the student use models and cultural resources?)
What problems and difficulties did you encounter during the work? How did you go about resolving them? (Criteria 4, 5, and 6 – information about the work process)
Have you attempted something you have never done before? How did you get on? (5: Inventiveness – the courage to try something new and the ability to learn from experience)
Choose a picture from which you learned something new about making pictures. What did you learn? (5: Inventiveness)
Choose a picture that you would like to change or redo. What would you do with it? (7: Capacity for self-assessment; 4: Investigative work – the ability to develop an idea)
How much help did you get? Who helped you and how? (This question is relevant for assessment with reference to all the criteria.)
Extracts lasting about five minutes each, from 46 videotaped interviews, were converted to digital format. Together with the students’ portfolios, these were put on a CD-ROM as illustrations that we produced as an appendix to the final report (Lindström et al. 1999). These interviews serve not only as illustrations of various dimensions of performance, and as a demonstration of the kind of evidence on which students’ portfolios were assessed. They also have an intrinsic value as a source of knowledge about the way Swedish children and young people at different ages and in different types of school approach creative work.

**Does any development occur?**

A high correlation between independent judges is a necessary but not sufficient condition for assessment outcomes to be accepted as valid. Another condition is that the ratings on different criteria are independent. Everyday experience, as well as empirical evidence from a few similar studies (Hargreaves et al. 1996; Kárpáti et al. 1997), directed our attention to the risk that both the class teacher and the co-assessor form a general impression of a student’s work, which then influences their assessment on each individual criterion. It is still interesting that the class teacher and the co-assessor often had a similar general impression of a portfolio. However, a tendency to over-generalise would make ratings on individual criteria less valid.

To examine this source of error, we recruited 30 students who were close to completing their training as art teachers. Each of them was asked to assess a large number of portfolios, including videotapes, using a single criterion. They were to ignore other aspects of the portfolios than those defined by that criterion. Thus a student art teacher judging pupils’ “inventiveness” had to examine all portfolios from that viewpoint alone, and ignore, for example, how successful the final product was. The portfolios were anonymous, and were sorted in random order to make it more difficult to estimate the sex and age of the pupils.

Although this procedure took several days, it proved to be a good investment. A factor analysis (i.e., a statistical technique that allows for the reduction of variables representing a particular construct) supported the assumption that teachers’ judgements were strongly influenced by their overall impression of a portfolio. However, with the more independent judgements that the student art teachers made, we obtained two main factors: “product criteria” and “process criteria”. All the process criteria were loaded on a common factor, as were the product criteria. None of the seven process and product criteria appeared to be multidimensional, that is, to be a manifestation of qualities in both process and product. This outcome sup-
ports the hypothesis, on which this present study is based, that creativity in the visual arts contains two main dimensions that must be considered separately when assessing students’ work. At the same time, the results show that teachers need training in applying one criterion at a time, if they are to evaluate various qualities in their own teaching and give useful feedback to their students.

The outcome of the student art teachers’ assessments indicates that pupils in the comprehensive school improve their visual design and artistic skills. That is, they make progress on two of the product criteria, one which describes elements and principles of design, such as colour, form and composition, and the other the use of materials and techniques (craftsmanship). However, with regard to process criteria, referring to their capacity to work independently, evaluate their work, and so on, students in ordinary comprehensive school classes appeared to stagnate or show only insignificant improvement (Table 2).

Visi- Colour, Crafts- Investig- Inven- Ability Capacity Overall bility of Colour, man- tive- tive- to use for Self- Overall
the form, ship ness ness models assessment judgment
inten- composition

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<th>Visi-</th>
<th>Colour, Crafts-</th>
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<td>bility</td>
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<td>Grade 9</td>
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<td>Grade 5</td>
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<td>Grade 2</td>
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Table 2. Median values on criteria for creative skills in the visual arts in comprehensive school. Assessors: student art teachers (individual criteria) and class teachers (overall judgement).

Since it is ultimately the products of the creative process that count in society, there may be reason to question the relevance of the process criteria. If the art works steadily improve, does it matter how the improvement comes about? To answer that question, we must examine the content of the process criteria. The result for investigative work shows that the average student at the junior and intermediate grades “tries out her own solutions and approaches, but does not develop them” (Level 2 in the transition from “novice” to “expert,” see Table 1). The same applies to boys in the final grades of comprehensive school, whereas girls at that age begin to develop the approaches they have chosen (Level 3). As regards inventiveness, most students, irrespective of grade and sex, can “take a problem that the teacher has set and
change it slightly”; they also show “tendencies to experiment” (Level 2). On the other hand, they do not set up problems of their own, and they have not begun to experiment regularly (Level 3).

Most students in the comprehensive school lack an advanced *ability to use models*. They show an interest in other people’s pictures that they or their teacher have found, but they confine themselves to copying them (Level 2); they do not actively look for pictures or genres to get ideas, and they are unable to select what can be of particular use to them (Level 3). The ratings on *capacity for self-assessment* show that most students in the comprehensive school can, “with some assistance,” point out strengths, weaknesses and other characteristics of their work (Level 2); on the other hand, they do not achieve this on their own, nor can they select sketches, drafts, and works that demonstrate their own progress over time.

This examination of what the process criteria refer to testifies that these criteria are significant in their own right. They show how well the school has achieved one of its overall goals: the development of students’ creative skills from solving simple tasks with support to tackling complicated problems in an independent and confident way. This is the very core of the development from apprentice to master, from novice to expert in a domain. Using a terminology that underpinned the latest Swedish curricula, we can say that the students in our study acquired *knowledge* and *skills* as regards how to make art. However, they did not develop the *understanding* and *familiarity* that is required to apply what they have learned to new situations or to rely on their own judgement.

Criterion-referenced assessment, applied by teachers and students, can draw attention to the processual dimensions of creative work and articulate the “tacit” knowledge (Polanyi, 1962) or “dispositional” characteristics (Winner & Hetland, 2001) that these criteria refer to. To that end, guidelines for what should go into the portfolio must take into account not only the quality of the product or performance, but also the student’s ability to reflect upon her work and choose appropriate materials, techniques, and content. A student with sophisticated reasoning and an appropriate approach may still hand in flawed or careless work, while a less sophisticated student can produce painstaking and well executed, albeit simple, work. With a multidimensional assessment, each of these students will be both acknowledged for her achievements and encouraged to progress.

**Can creativity be taught?**

A multidimensional assessment gives students *feedback*, which helps them discover their strengths and identify areas in which they need to improve.
The scores on such assessments can also help an educational programme to review its results, consider its position and modify the course if necessary. The 1998 evaluation of the latest Swedish curricula indicates that both students and teachers need to be more aware of the processual dimensions of creative work and to reflect upon the “dispositional” qualities that are involved. The students made progress in terms of visual design, it is true, but they did not improve on those dimensions of creativity that we have summarised under the rubrics of investigative work, inventiveness, ability to use models and capacity for self-assessment.

However, there was one exception. In the very area of the process criteria, students in the final year of the comprehensive school who attended Stockholms Bild och Formklasser (The Stockholm Visual Arts and Craft Classes) completely outdistanced students of the same age in ordinary classes. Most of this difference is probably attributable to the culture of learning that Stockholms Bild och Formklasser offer. “Children are given the opportunity to get deeply involved in and complete their various projects,” and the art and craft teachers, whose classes are half the size of regular classes, “are in constant dialogue with the students about their work as it evolves” (from teacher interviews). These and other observations have been documented on a video film produced as part of the 1998 evaluation (Härlin, Lindström & Zetterberg, 2000). They substantiate what has been found in research on contexts and dispositions that foster creativity (e.g., Weisberg, 1993; Jay & Perkins, 1997; Nickerson, 1999; Cropley, 2001) as well as experience from the Arts PROPEL (Gardner, 1989; Winner, 1991) and other attempts to promote creativity.

On the basis of these observations, I propose the following hypotheses about how schools can attain the prescribed target of helping students to develop their creative ability:

Investigative work

fostered if students are given assignments that extend over a significant period of time and address central themes in the domain.

The proliferation of subject matter and materials that schools are supposed to deal with and offer causes major problems. In general, it is easier to add new subject matter and extra materials, techniques and teaching materials than to remove something. The underlying assumption appears to be that the more information the school provides and the more activities the students carry out, the better. It is easy to forget that if too much is crowded into the syllabus, teaching breaks down into small segments and knowledge becomes fragmented. Research on the psychology of learning lends sup-
port to a motto that the school reformer Theodor Sizer (1992) took from the Bauhaus School: “Less is more” (see also Dempster, 1993). The concepts, principles and perspectives addressed in schools should be central to a domain of knowledge and skills. They should be exercised in different contexts over an extended period of time to allow the students to understand their interrelationships and implications (Wiske, 1998). In order to further creativity, students should be given enough time to investigate, test and revise, to reflect and speak to peers, and to make critical assessments of their own work.

*Inventiveness* fostered if the teacher emphasises the process as well as the product and provides ample opportunity for research, experimentation, and revision.

Creative people have been characterised as problem-finders, since they often discover new challenges when working on a project (Csíkszentmihályi & Getzels, 1989; Jay & Perkins, 1997). They try out new solutions, often by combining ideas and suggested solutions in unanticipated ways. There is a close association between these distinctive features and what has been mentioned above, since one must get deeply involved with a work over time to discover where the interesting challenges reside, and to find ways of pursuing them. Discovery through mistakes or serendipity requires a “prepared mind” (Merton, 1957, p. 12). Yet this mental readiness is not sufficient for a creative leap to take place. To reformulate problems and try new solutions, one also needs a certain degree of courage and a willingness to take risks. Experiments and risk-taking do not always bring successful results. This is inherently true. Experiments that always succeed involve no risk; they teach us nothing that we did not know already. If a student is to be adventurous and willing to take risks, the teacher must show appreciation and approval of her courage to take further something she did not already know or master, even if the outcome is not always the intended one.

*The ability to use models* fostered if students are encouraged to integrate production with perception and reflection.

Without exception, studies of creativity show the importance of other people’s works and ways of thinking (Weisberg, 1993). Creativity is not as private and individual a process as we often imagine. It is always part of a social and cultural context. Looking for models to emulate, and finding links between them and one’s own work, is a highly active and complex process. This type of cultural influence should not be counteracted in school, as often used to be the case. On the contrary, it should be encouraged and appreciated, since the conditions for creative work are considerably im-
proved if the student constantly intersperses her own work with observations of other people’s works, and reflection upon what can be learned from them. Making active use of models means choosing what corresponds to one’s own intentions and making something of one’s own from it. One borrows what is useful from one or more works that have captured one’s interest. This interaction between the student’s pictures and those of other people is facilitated if pictures are discussed in class, if the students have ample access to pictures of various kinds, and if they get help in finding the cultural resources they need.

Capacity for self-assessment fostered if the students are given many opportunities to assess their own performance and to get feedback from peers and teachers; the most informative feedback originates from explicit criteria that tap the important keys to good performance.

The creative work of students, if taken seriously, can and must be assessed and evaluated. Refusal to assess student work is a concession to those who maintain that no learning is taking place. If we accept the assumption that visual design is related to thinking and learning, and that students can develop their ability to appreciate aesthetic qualities, then it is also important to establish what they have learned. A teacher who fails to assess what the students do cannot decide whether or not she is contributing to or impeding their progress. If everything, however trivial it may be, receives the response, “That’s good. Would you like to tell me something about it?” then the student probably will conclude that what she is doing is not particularly important. In his classic paper on “myths” in art education, Elliot Eisner (1974) maintained that children respect considered assessments and criticism, because they indicate that the teacher cares for them and is paying attention to their work.

In Arts PROPEL, it is not simply the finished product that is assessed, but consideration is given to the work process and the students’ ability to make more subtle observations and reflect on what they have done in a wider context. Assessment has an important part to play in the learning process. It should not simply be a matter between teacher and student; it is at least as important that students are given the opportunity to assess what they themselves and their peers achieve. Criteria and scoring rubrics can serve to focus students’ attention on qualities of performance that are otherwise easily neglected; they give them instruments with which to reflect on and communicate about their own learning processes.
References


Technical Thinking as a Psychological Category

Introduction

Technical thinking is a specific category in present-day psychology. Its great importance, which is the result of the development of a new model of information civilisation, requires that profound thought be given to what its contents are. The development of a civilisation is determined by the creative participation of more and more people in various forms of activity, i.e. work, study, leisure activities and rest. Hence, many research workers are interested in the concept of creative thinking. A question thus arises about the characteristic features of creative thinking with respect to thinking and, furthermore, to technical thinking.

At the present time, no thorough studies have been carried out on the issues mentioned above. As a matter of fact, among Polish psychologists, only Edward Franus1 has focused his research on this subject. His work has been continued by Witold Dobro_Bowicz2

Waldemar Furmanek & Wojciech Walat

Problems in defining the essence of technical thinking

As Franus rightly noted, in psychology there are still at least four reasons for the failure to perceive technical thinking as a separate category:

1. The supposition that it is a popular expression;
2. The conviction that a concept is the same cognitive process as any other kind of thinking;
3. The opinion that separating technical thinking is not sufficiently justified because the notion relates to technology;
4. The view that in the classifications of thinking used so far there is no place for technical thinking.

Let us discuss each of these reasons separately.

The first reason also shows indirectly that psychology lacks a special theory of technical thinking. However, such a theory could be developed
once psychologists have conducted sufficiently thorough and precise studies of the specificity of the phenomenon. It has been thought, as can be frequently attested at present, that there was no reason to define such a category since there is only one type of thinking as a psychological process.

The second reason is actually the result of a mistake in methodology. Only common features in thinking have been perceived, while different qualities have been ignored. To date, psychological research carried out on the matter has, in fact, aimed at generalisation. This has resulted in the definition of such common qualities as: a conceptual and notional structure, a catalogue of basic mental operations, a dialectic relation between recognition and activity. However, they are not sufficient to show the specificity of individual kinds (forms, types) of thinking. It seems necessary here to emphasise the catalogue of different qualities. This may be done even today on the basis of the findings obtained so far. An explication of the phenomena of interest to us requires abandoning the methodological tradition that still generally prevails in psychological studies. Adopting a systematic approach is the only way to modify existing research procedures with respect to technical thinking.

To help in the analysis and create a new situation for research, let us introduce a simple cybernetic model made up of the following three components: an information (signal) input block, a data (information) processing block, and a processing result (reception) output block. In each of the components, activity is controlled by the processes of thinking. We can distinguish cognitive processes, found in the input as well as the processing block, and executive processes, which are developed in the processing of information and its application. Is the character of thinking the same in both instances? Certainly not. Then, what does the specificity of these processes consist in?

A similar problem is mentioned by Franus. He notes that in the processes of acquiring knowledge and applying knowledge, designations are represented by distinct processes. Students think in a different manner when they are acquiring knowledge than when they are applying it to solve problems. There is clearly technical thinking when students use their knowledge to solve problems. And there is cognitive thinking – when a process of acquiring knowledge takes place.

The third reason mentioned above is of great importance since it refers to the fact that technical thinking is a two-attribute concept. It should take into consideration that aspects of both components of the contents have a bearing on the scope and character of the approach in question. And here the concept of technology is very important. Here, we are confronted with an extremely difficult question concerning the essence of modern tech-
Technology, a question about its constitutive features and the dissimilarity of its character with respect to the past. *Technology as the objectification of thinking cannot be understood in its narrow meaning as a concrete object or discipline (such as biology, astronomy, etc.), but as a specific style of thinking different from that of cognitive thinking.* As was noted by Heidegger, *the essence of technology lies in discovering truthfulness.*

In the analyses we have carried out regarding this point – which are presented in the book titled *Zrozumie_technik_ (Trying to Understand Technology)* – we have emphasised the necessity of formulating the concept of technology in a multi-dimensional perspective. Its global meaning leads us to the concept of *metatechnology.*

Let us say, that present-day technology does not resemble the technology of the past by any means; it is a history-making phenomenon which generates a new model of information civilisation; it has a global character and it affects each person completely; it introduces changes in the present axiological system and alters the character of modern culture.

All this makes it necessary to perceive each form of human activity in a different way. It requires that people think in different situations, which are increasingly influenced by technology. All the elements that are decisive with respect to the structure and functions and, consequently, the position of humans in a situation (which is, by nature, of a technical character), represent for humans the area of their activity. It also represents for humans a system of sources of differentiated information, which is the basic material for psychological processes (including thinking). Technical thinking processes depend on the character.

The fourth reason listed above is the least comprehensible. This is because it could be argued that it is based on research results on the essence of technical thinking which have not been disseminated widely as yet. Those who support this view may also produce evidence showing that the number of studies carried out is not impressive and does not reflect the importance of this category. And finally, one key observation is that there is a substantial role played here by a *system of prejudices, myths and controversies* which has consolidated into society’s views on the essence of technology, its role in the lives and activities of people. Is it not true that we come across too often as having a contemptuous attitude towards technology? Are technology and technical activity not identified too often with manual work, physical labour, etc.? Although present-day technology is being developed by only a few people, everyone can take advantage of it. And in spite of the fact that no one is willing to give up its benefits and return to the spinning wheel, prejudices tend to persist and often result in a negative attitude towards technology. It is difficult to become involved in any polemics with such views.
Sources of technical thinking

Taking a historical approach to the issue, it could be said that thinking has grown from a practice into the processes of human work. In fact, it involves recognising reality, understanding and converting it, according to one’s needs. **A disposition to recognition and a disposition to action** constitute two different models and two directions of thinking which control the action of human beings. In the first instance, information is gathered, compared and generalised in the form of different judgements. In the second, the information acquired is used in processes related to technological activities. What is obvious here is that the experience gained in subsequent human activities is used for further recognition of reality. The process is followed in a complementary and continuous way.

In the 19th century, with technological development, it was necessary to separate the technical sciences, determine their subject of study and build their substantial and methodological identity. In fact, the technical sciences were characteristic of the dominance of tasks resulting from the practical function of scientific research. They were mainly aimed at inventing scientific methods for converting matter into products used in everyday life and products used for the further recognition of nature. These tasks are still characteristic of the technical sciences. The catalogue of tasks has been supplemented with new tasks resulting from functions for explaining, estimating and forecasting.

Modern technological disciplines have assimilated a great deal – which is in their nature – and disseminated it to other branches of science. There are many reasons for this. Nevertheless, the scope of interest of the technical sciences (as well as that of all-technology) has expanded greatly. Today, production technologies have become merely a segment of modern technology. Research, which answers the questions what, what, how, is undergoing change. With a shift in their focus from materials to energy, modern production technologies are concentrating on information. Nowadays, information technologies have become the ones that define the present-day information civilisation. Knowledge, information and human competence have become production factors which can often replace materials, technical resources and capital, which used to be production factors in the era of the industrial society.

This has resulted in a change in the scope of research being conducted in the technical sciences. In technical studies, the main emphasis had been placed less on recognition that on the application of science to technology. Cognition focused on practical tests of materials, energy and information; on processing methods on utilising science – for the purpose of production and exploitation. The technical sciences have never been concerned with
the study of nature itself for the sake of its recognition but with the study of artificial creations (artefacts). The objective of the study has always been further improvement of production (means, methods, organisation) and its results. But it has also been the study of phenomena related to their dissemination, their exploitation or the cancellation of the results achieved (with the results being continuously differentiated).

It is obvious that both the character and objective of studies, and the transformations in studying the technical sciences as a subject, have created and are creating a new style of recognition and new standards of thinking, methods and strategies of solving problems. All this represents the basic contents of technical thinking. This has also resulted, as Franus so rightly notes, in a transformation of the essence of the relation: recognition-action:

- Development of cognitive sciences
- Development of technical sciences
- Development of studies with the help of technology
- Development of technology with the help of science
- Development of scientific knowledge about laws of nature
- Development of technical knowledge about rules of technical operations
- Development of cognitive thinking
- Development of technical thinking
- Development of theories
- Development of technology

The isolation of the basic sciences from the technical sciences was broken during World War II. The new phase was called a scientific and technical revolution.

After World War II, the psychology of thinking was influenced by the scientific and technical revolution. Closely linked to this, the revolution in information science (and in the whole panoply of related sciences) contributed to significant transformations in people’s opinions about technical thinking, and in methodological disciplines, which underwent intensive development. This resulted in the formation of a relatively stable theory of technical thinking.

**Selected theses of technical thinking according to Franus**

In Poland, J. Kozielecki³, in his concept of thinking, admitted that it is an intellectual activity which was created in the process of development as a result of internalisation of motorial actions or interiorisation of these actions and which takes place in problem situations. Problem situations are such forms of situations where people cannot solve a problem with the knowledge they possess. They must find (devise) a way to solve the problem. We sometimes call this productive or creative thinking. Thinking, in Kozielecki’s view, is not only a process of processing but also of producing and selecting information. Producing information consists in using various
intellectual processes, including processing, apprehending, comparing and selecting.

Any information produced is subject to verification in the process of thinking itself and in practice.

Making use of the views of others, Franus worked out a Polish theory of technical thinking. He provided documents to prove that technical thinking is a component of a technical aptitude; it is developed in the process of forming a technical concept and it is phasal in nature. The process includes the following four main phases:

• perceiving a technical disharmony
• thinking heuristically
• accepting the first good concept
• designing the technical form of a project.

Franus credits a special role in technical thinking to technical imagination. He defines it as follows: imagination is a mental process subjected to verbal and notional thinking which lies in the reproduction of images from memory and their transformation and combination into new systems, in compliance with the requirements of a task and in the course of thinking.

Franus distinguished the following types of technical imagination: spatiial, constructional, kinetic and operational imagination. In his latest paper, he adds to the imagination list material substances, operation duration, graphical language in technology as well as aesthetic presentation of creations.

In his work, Franus has carried out a detailed analysis of various theories concerning thinking and he relates it to specific technical situations and human thinking in each type of situation. As a result of such an analysis, he draws the following conclusion:

The most universal notion in the field of technology is creative thinking, which includes different forms of creation: composing, devising, sketching, finding, testing, describing, establishing principles, standards, determinants, designing, reconstructing, reproducing, manufacturing and modeling.

The most typical and exclusive type of thinking in technology is constructional thinking. What various types of thinking have in common is their characteristic psychological structure, which includes two mutually interlaced phases: cognitive and constructively creative phases which represent their dual nature.

In the objective characteristics of technical thinking (type of material, determined by substance), there appears to be a differentiation of this type of thinking with respect to other processes of thinking, which take place in scientific, literary, musical and artistic creation.
Objectifying means that thinking is combined with a certain type of substance, the properties of which are of fundamental significance with respect to production technology and the qualities of the results of technical activity. The substance of technical thinking belongs to the following:

- theories and scientific laws, technical concepts;
- ideas and understanding of knowledge;
- production technology operations, principles, rules, standards and patterns.

The course of technical thinking is especially influenced by the following four production technology categories:

1) what is to be made?
2) out of what?
3) how?
4) with the use of what means?

In the conclusion of the analyses concerning the specificity of technical thinking, Franus proposes the following definition:

Technical thinking is a process of solving through an understanding of technical problems which is distinguishable by: 1) a dual processual analytical and synthetical (i.e. cognitive and creative) structure with a two- or multi-phase course filled with microsyntheses or a final creative microsynthesis and 2) a binomial objective structure including a) a subsystem of laws of nature scientifically discovered together with requirements of ergonomics and ecology and b) a subsystem of technical categories, concepts, notions, graphical language, standards and principles of production technology used in designing or studies of new technical objects.

With reference to the definition above, Franus precisely states the qualities of technical thinking as an intellectual process:

1) phasic manipulating of analysis and synthesis operations in designing and studies of new technical objects;
2) understanding as a warranty of efficiency;
3) making use of engineering drawings;
4) using specific conceptual and notional categories as well as terminological categories;
5) applying the laws of nature;
6) implementing the humanistic principles of ergonomics and ecology;
7) following the principles of production technology.
In his monograph, *My _lenie techniczne (Technical thinking)*, Franus put great emphasis on the question of sources of technical information. This established a basis for distinguishing the following types of technical thinking:

- **practical technical thinking** (thinking in action), *for which the source of information is:* sensorimotor activity – using tools, operating equipment; *manipulating activity* (disassembly and assembly of equipment); *recognition activity* (technical diagnostics, recognising equipment and technical structures). *The source of information representing the substance of technical thinking is practice;*

- **graphical technical thinking**, of a drawing-technical type and a reproductive character (reading engineering drawings) or of a creative character (design engineering, drawing records). *The source of information is graphical records of technical structures;*

- **notional technical thinking** (devising technical solutions in one’s imagination). *The source of information is resources of conceptions;*

- **conceptual or theoretical technical thinking** based on the system of technical concepts which is employed in planning, explaining and justifying the essence of actions which is the source of information.

The types of technical thinking presented above are only a formal differentiation of intellectual actions involved in the course of solving concrete technical problems. In reality, they interlace one another to create a complex intellectual process. However, the fact that they are distinguished is important from a didactic point of view, since it enables us to set in order the systems of technical problems designated for individual stages of technical education.

**Bibliography**


**Notes**


14 Franus E.: *Wielkie ..., op. cit.*, 2000, p. 46.

15 Franus E.: *Wielkie ..., op. cit.*, 2000, p. 68.

The Dual Nature of Technical Thinking

Summary of a Chapter from

WIELKIE FUNKCJE TECHNICZNEGO INTELEKTU
(Great Functions of Technical Intellect)

1. Cognitive thinking is always of an analytical character, while creative thinking (of a constructional type) is always of a synthetic character.

2. In solving problems, cognitive thinking always performs an auxiliary function, preparing the intellect for a creative synthesis. Therefore, creative thinking finalises the course of cognitive thinking. Both processes play a role in solving a problem; however they are not identical.

3. If the operation of analysis is an essential feature of cognitive processes, both in science and technology, and synthesis is an essential feature of creative (constructional) processes, it means that there is a psychological border line between cognitive and creative processes that runs in the thinking itself, between an analysis and synthesis both in scientific thinking and technical thinking. It is a transgressive border which divides the process of thinking into two parts: a cognitive and analytical part and a synthetic and creative (constructional) part.

4. The transgressive border is a kind of Rubicon, which is to be crossed by a thinking process (in the state of consciousness or unconsciousness, latency) in order to become a new quality. It occurs when the mind has collected enough information and reflections, i.e. productive contents which, in accordance with the dialectic principle, makes it possible to change quantity into quality. This new quality still requires the furnishing of some details, but it already constitutes an outline for a solution of the problem. Therefore, the transgressive border is at the same time a symbol of transition from analysis to synthesis, from quantity to quality, from the cognitive to the creative process, from recognition to action. Thus, a question about transgression is a question about conditions which are to be satisfied in order to solve a problem.

5. Thinking as a cognitive process ceases only when it finishes in effectively. Therefore, definitions which describe thinking en bloc as a cognitive process are wrong and deceptive; they set up a barrier to research on creative thinking in all disciplines of science and technology.

Edward Franus
6. Thinking for the purpose of solving problems can be of a dual structure:
   a) a **homogeneous** structure, of a cognitive type only, if it is an ineffect-
      tive process, limited to being acquainted with the contents of the pro-
      blem and not resulting in the problem being solved;
   b) a **dual** structure, i.e. a cognitive, creative and effective one.

7. With simple and easy problems, thinking always has a dual structure
   and the simplest course: being acquainted with the contents of a problem
   and solving it.

8. With complex and difficult but effective problems, thinking also has a
   dual structure but its course is complex and consists of many attempts or
   bad solutions, corrections, breaks – until “revelation” and acceptance of
   a correct solution in the synthesis have taken place.

9. Also, penetrating analyses show that mental work on a difficult problem
   does not follow a simple model from stage to stage, but includes many
   synthetic microparticles, **microsyntheses**, which as links in a chain make
   up the complex final creative **macrosynthesis**. Furthermore, in cases of
   a multicomponent problem, the mental cognitive and constructional
   structure develops in the form of a mosaic composed of many microsyn-
   thenic particles.

10. Technical thinking, like any other kind of creative thinking, is not only
    cognitive thinking (as some authors will have it), but a complex process
    of a dual nature both with respect to simple and complex problems, and
    both with respect to the structure of microsyntheses and the structure of
    macrosyntheses.

11. Nowadays, Science and Technology represent two equipolent, mutually
    co-operating and supplementing systems in our civilisation. An archetyp-
    e of these links can be the unity of **homo cogitans** and **homo technicus**
    to be found in the primitive man who under the harsh conditions of his
    environment developed into **homo sapiens**. A primitive club, flint or a
    flint axe as a tool was no less a creation of transgression for the pithecan-
    trophus than a lightbulb invented by Edison or even the design of a nu-
    clear power plant by Fermi.

12. A creative synthesis in scientific thinking is the heart of the matter in a
    concept of a theory?? in a scientific discovery, whereas in technology it
    is the heart of a matter of a concept of an invention or a structure of a
    technical object. In both cases, we deal with objectified processes of
    creative thinking, albeit processes very much different in terms of qual-
    ity. Both develop in the sphere of concept and the imagination, but the
    first processes always assume the shape of words and sentences, while
    the others assume a drawing design and concrete material substance.
13. Cognitive thinking performs various functions for the purpose of creative and non-creative processes. In scientific creation, it serves as a research process to prepare information sets to be used in forming a theory or as a recognition process in getting acquainted with the contents of problems to be solved.

In non-creative situations, it performs different functions in everyday life: indicatory functions in the environment, steering functions when driving a car using tools etc., observational and control functions as well.

In technical creation, it works in at least four major instances: getting acquainted with the contents of problems, getting to know scientific theories, principles of production technology, formulae, etc.; controlling the course of manufacturing processes; controlling the operation of a completed object. In each of these instances, cognitive effects (decisions, choices) are acts of a creative synthesis, key elements to complete the creative process.

14. Technical thinking as an objectified process differs from other objectified processes in that it deals with building an artificial world (artificialite), designing objects and production technologies in the widest scope of usefulness.

However, with respect to processual, psychological aspects, it is characterised, as are other objectified (musical, artistic, literary) processes, by a typically dual cognitive and creative (constructional) structure.

15. In complex sciences (e.g. in ergonomics), the dual nature of mental processes has remained unchanged. There has been an enrichment in the empirical method, which enables multi-aspect recognition of reality and multi-aspect adaptation of the creations of technology to the expectations of humans.

16. In light of the discussions carried out so far, primarily the analyses of problem solving processes, the view according to which technical thinking is supposedly cognitive thinking alone cannot be maintained. Already the very comparison with reality sounds irrational.

One cannot say that all mental processes are only cognitive, since this is not true. Also, one cannot maintain that creation lies only in objectifying, since this is not true either. The secret of both recognition and creation resides in the processual structure of thinking which includes a cognitive phase in the form of analysis and a creative phase in the form of synthesis. In the case of difficult and complex problems, the structure becomes more complicated and adopts a multiplied form which consists in cognitive and creative phases that occur alternatively, something like a chain made up of microsyntheses and a final macrosynthesis.
In contrast, objectifying thinking, i.e. its contents, is based on a relation with a certain form of matter and production technology. Various forms of matter and different production technologies, operations and methods, as well as results, creations and works of human intellect arising from them each represent specificity of objectified thinking. The same matter, but in different forms and using various methods (production technologies), is subject to research and described in theories, used in design engineering, in agricultural and horticultural production, in architecture, sculpture and instrumental music, and pictured in literature and poetry. Specifically-oriented objectified thinking manifests itself in all these extremely varied forms of creative activity.

However, the processual, cognitive and creative structure of thinking always remains the same, as it is made up of the two basic operations, that is, (cognitive) analysis and (creative) synthesis. Impulses reaching the brain indeed provide it with cognitive information about the substance, but they are synthetically transformed in the brain into a new quality and “returned” in action already as a creative result. Thus, the secret of creation lies in a synthetic act of thinking and not in the magical reflection of the peculiar stamp of matter.

There may be some reasons why thinking is narrowed down to a cognitive process:
1) the relicts of philosophical speculations deprived of any empirical studies;
2) the domination of reflection theory;
3) the mysterious nature of a synthesis process;
4) the influence of the splendour of research in comparison with the survival of prepossession against manual work with which handicraft and technology have been associated since the times of ancient Greece.
Practical assumptions about the technical education system in elementary schools and upper secondary schools in Poland

Education is conventionally considered to entail phenomena and pedagogical problems related to school practice. In this paper, I will attempt to present practical assumptions about the technical education system being modelled in Poland by using samples from a syllabus, textbook and workbook for technology and informatics at the upper secondary level.

1. Model of a technical education system for elementary school and upper secondary school

The construction of a model of the technical education system or of the learning and teaching of a given school subject (block) provides a grid of notions of practical solutions that are to be considered in any methodological paper needed to examine didactic processes. A syllabus is the basic methodological document for a teacher. Here a presentation is given of detailed teaching objectives, teaching material for the subject, procedures for achieving objectives, standards of achievement for students as well as didactic means to reach these, and sample sets of exercises and experiments to be used with students. The model of a didactic system is coloured by the philosophical and psychological approaches (metaorientations) adopted by the creator of the syllabus and contained in the theoretical assumptions of the system for a given field of education – in this case, technical education.

In our case, the metaorientation (attempt) of the model being developed is based on the introduction of a paradigm which reflects the notion of humanist technology. The notion of technology is designated by some peculiar history-creating phenomena in civilisation. Technology is manifested – through its results – in the way it helps people in various types of activity for which they use their own potential abilities; they aim to improve the world and any activities in order to change the quality of their own lives and of the other people’s lives as well. In today’s world, one of the basic ways of improvement is the informatisation of any domain of human activity.
Four basic planes can be distinguished for formulating the assumptions in the model of the system for learning and teaching technology and informatics used in elementary schools and upper secondary schools in Poland:

- an educational plane – which assumes the sustainable psychophysical development of students as based on the multi-faceted and complex activation of students;
- a psychological plane – which assumes development of technical thinking in students through technical activities undertaken by them;
- a substantial plane – which assumes a phasal character of human technical activity;
- a methodological plane – which assumes that the learning process of students is organised on the basis of consciously finding solutions to technical problems.

2. Development of key competencies – the educational plane of the technical education system

It is assumed in the educational plane that the basic function of technical and informatics education is to prepare people to live in a dynamically changing technical environment. Given this assumption, a system (not a random collection) of technical skills must be developed which includes informatics skills which manifest themselves in key competencies determining the quality of human life (Fig. 1). We can recognise the following as determinants of quality:

- the variety of individual experiences of values;
- participation in the construction of a system of values;
- awareness of participation in activities;
- self-reliance in initiating and performing actions;
- technical creation
- use of self-development capabilities².
In our case, we can identify two main dimensions (directions) describing the development of students in the educational plane (Fig.1):

– **the horizontal direction** (multi-faceted and complex activity of students at each educational stage);

– **the vertical direction** (initially non-directed activity which gradually turns into organised forms of activity and later into conscious technical activity – creation – in the students’ adult lives).3

This assumption is reflected in the modelling of objectives in technical education. The ultimate objective in this field of education – at each stage – is to help pupils come to an understanding and accept the truth about themselves and prepare them to develop their humanity based on accepted ethical values by participating in various technical, didactic-educational situations organised in secondary schools.
In other words, we can say that the objective is to develop the humanity in humans, who realise their vocation (living, acting and working) in a dynamically changeable technical environment and who take advantage of technology in accordance with the system of values they have adopted.

Pursuing this objective requires that students know themselves, other people and the world; understand the main rules to be observed in the phenomena of interest to them, and evaluate each rule and include it in the system of their own rational behaviour (or conduct).

An analysis of this objective presented in a descriptive way enables us to formulate the ultimate (main) objectives of technical education as the recognition and understanding of:

A) **ONESELF** – as a subject acting creatively in the technical and informatics environment and taking advantage of the results of actions taken by other people and past generations;

B) the place and role of OTHER people in the world of technology, in the social distribution of responsibilities and work, who are destined to live an active life under the pressure of up-to-dateness;

C) the human living ENVIRONMENT, including the technical and informatics environment and its connections with the natural and social environment;

D) the VALUES embracing the whole of mankind, their stability and changeability caused by the developing civilisation.

3. **Development of the students’ technical thinking – a psychological plane of the technical education system**

3.1. **The structure of technical thinking**

Technical thinking is of a dual nature. It refers, on the one hand, to a recognition of reality (through a number of analyses carried out) and, on the other hand, to its transformation (through creation or a synthesis of microsyntheses, building up to a macrosynthesis, depending on the degree of complexity of a problem). This duality results from the well-established practice of taking the two notions in opposition related to the spheres of human activity, i.e. **science** and **technology**. Science plays a cognitive role here and hence thinking in science is credited with a cognitive function. In contrast, technology plays a creative, productive role, and this is why (technical) thinking serves the purpose of formulating new solutions. Since the latter half of the 20th century, it has become evident that marking a distinct division between science and technology is not that sensible and that further development in civilisation must be based on a simple equation: **S+T** (called the second technical revolution).
Hence, it is assumed that thinking has a dual nature: cognitive and creative (analytic and synthetic).

The dual structure is a universal feature of all thinking processes. In addition, thinking processes have specific characteristics, connected with special qualities of the activity in a given field. In this respect, the processes of theoretical scientific thinking, technical thinking, artistic thinking, musical thinking etc., are different from one another. However, the definitions of the processes of objectified thinking (e.g. technical thinking) should contain both characteristics (processual and objective characteristics).

The process of thinking in modern human technical activity is phasal and indirect in nature. A designer communicates with a manufacturer (a contractor) with the use of technical drawings (generally speaking: information technologies). Will the manufacturer be replaced entirely by information and informatics technologies (CAM – Computer Aided Manufacturing) in future?

![Fig. 2. A model of creative technical activity in modern industrial production](image)

An expansion of the model described above is represented by the following model, which consists of three subsystems:

![Fig. 3. A model of the structure of technical thinking](image)
Subsystem **A** constitutes a processual structure of thinking, which includes two universal and basic operations of analysis and synthesis, which make up the cognitive and creative process which leads to the constructive solution of a problem.

Subsystem **B** constitutes a scientific basis of thinking, which includes the achievements of the theoretical sciences; it also includes principles of the latest complex sciences, i.e. ergonomics and ecology.

Subsystem **C** constitutes a technical basis, which includes theoretical and practical achievements with respect to means related to contents in the form of categorial notions and conceptions, standards, graphical language etc., as well as principles of production technology necessary to find substantial solutions to problems.

Subsystems **B** and **C** constitute a basis for subsystem **A**. This way, both the processual features and objective features represent an essential centre of technical thinking. In the functioning of the centre, which combines universal and special features, bonds are maintained between all the elements taking part in thinking, based on understanding, without which the entire process of technical thinking would collapse.

The following are the most important features of thinking as an intellectual and objectified process:

a) phase manipulation of the analysis and synthesis operations in designing and recognising new artefacts;

b) understanding as a warranty of effectiveness;

c) the use of a technical drawing as a graphical language;

d) the use of specific conceptual, notional and terminological categories;

e) application of the laws of nature;

f) observance of the humanist principles of ergonomics and ecology;

g) adoption of the principles of production technology.  

3.2. Development of students’ technical thinking

Technical education in its psychological plane is aimed at a situation in which desirable changes, with respect to knowledge, skills and a system of values, have occurred in the pupils’ mind. The changes consist in one superordinate cognitive ability, which is technical thinking. This means that the learning of technology must be carried out by developing technical thinking (practical, graphical, notional and conceptual thinking) as well as the students’ other cognitive abilities on the basis of characteristic forms of technical activities (Fig. 3).
Technical thinking is in essence a process of recognising and applying the laws on nature and the principles of technology in human technical activity (in an analysis of needs, designing, constructing, programming actions, manufacturing, operation and liquidation).

3.3. Technical problems – a methodological basis for the development of technical thinking (cf. a methodological plane)

In praxeology, as well as in theories of organisation, the notion of a “problem” is connected with the notion of an objective, and the objective defines the anticipated state of affairs and events which a person wants to achieve. This means that states of affairs are for some reason very valuable to people, and they can be achieved through a person’s own activity.

W. Oko_ in his Sownik pedagogizny (Pedagogical Dictionary)\textsuperscript{11} says: a problem is a situation where a certain need or necessity to overcome difficulties arises which causes a certain action to be taken, the result of which are achievements in the material sphere or in the field of values.

Technical problems will be determined by various forms of technical activities occurring in the course of transforming motivational situations into problem ones. A person acting in a technical situation understands the scope and character of the emerging difficulties, so he or she knows what the order of actions is and is aware of the expected results of the individual stages of action. The nature of a problem is changed, and some elements go missing or are modified.

Taking these comments into consideration, we can assume that a technical problem is a divergence observed (a technical discordance) between the actual state of creations and technical phenomena (the results of technical actions), the methods for taking advantage of them and the application of the laws of nature in order to satisfy different human needs and enrich the mental and physical properties of humans and the states they desire given the values they have accepted\textsuperscript{12}.

3.4. Types of technical thinking and types of technical problems

As regards technical thinking presented in the form of a model (Fig. 2, 3), technical problems can be arranged not only by assigning them to individual types of thinking, but by constructing for them their own hierarchy (Fig. 4).
We can present the development of technical thinking in this model as a four-level hierarchical system. This division of technical thinking was introduced by Franus.13

The first level – **practical thinking** – is developed through the technical actions of students on technical creations. Students carry out technological operations (they shape materials), assemble and disassemble as well as diagnose the potential inapplicability of the equipment.

The second level – **graphical thinking** – is where technical activities are pursued on the basis of technical drawings (methods of recording a construction). Students read and make technical drawings.

The third level – **notional thinking** – involves technical activities which consist in creating conceptions (projects) of technical creations and activities. Students analyse the characteristics of the creations being designed (using notional schemes and then transforming them) and plan actions to be taken.

The fourth level – **conceptual thinking** – is developed through technical activities which consist in analysing the functions of technical creations, analysing values and making calculations, e.g. constructional calculations. Students solve problems related to analysis, classification and calculation – in a general way – and they use notions on the categorial level.

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**Fig. 4.** In a psychological plane, development of the students’ technical thinking is assumed to be based on a series of technical problems selected by design.
It is worth mentioning that technical problems which develop technical thinking on the first level are based on technical activities with respect to technical creations, whereas technical problems developing technical thinking on the second, third and fourth levels are based on technical activities with respect to technical productions.

Modern technology necessitates that, in modelling the processes of technical education, the technical problems of a productive character, which are clearly aimed at preparing only makers and users of technical goods, are no longer predominant. It is always forgotten that in each class there are future creators of technology among the students, and therefore emphasis should be given to the need to differentiate technical problems from the point of view of developing the technical thinking of students.

4. Model of technical activity – a plane of the contents of technical education

4.1. Functional approach to the contents of technical education

The way of selecting and then arranging the contents of a given field of education, i.e. the structure they form, is decisive with respect to the didactic processes taking place in a given school subject. The contents of teaching are defined – to put it most simply – as what is being taught\(^\text{14}\); we can say more precisely that the contents of education are a set of actions planned to be taken by the student which are fixed by the teaching material and the mental change planned\(^\text{15}\).

Assuming that the contents are anything the teacher wants to teach the student by organising didactic processes for this purpose, we can identify the following two concepts of teaching:

– the information concept, based on knowledge, which is focussed on memorisation and reproduction of knowledge; it is a concept rich in information but poor in functions;

– the functional concept, based on skills, which is focussed on the application of knowledge; it is a concept rich in functions but poor in information\(^\text{16}\).

4.2. A model of technical activity

In a substantial plane, it is assumed that studying individual, distinct, fields of technology and informatics should be abandoned in favour of studying and using methods of an interdisciplinary (universal) character and potential. This means they have to be set in order and arranged in accordance with the characteristic actions taken by people. The model of technical activity (Fig. 5) best serves this purpose.
Fig. 5. A model of technical activity – a plane of technical education contents

The description of subsequent phases of technical activity shown in the model has been illustrated with some sample pages from a textbook on technology and informatics designed for the first year of upper secondary school17.

- **Recognising** a technical situation is connected with getting to know and assessing all the components contributing to the situation and thus the technical environment of people at a given time; programs used for gathering and managing information resources are carried out here (e.g. data bases).

Fig. 6. Recognising in a textbook for the first year of upper secondary school
Designing leads to the development of a conception of solutions to technical problems being developed using computer-aided visualisation programs.

Fig. 7. Designing in a textbook for the first year of upper secondary school

Constructing involves formulating solutions to detailed technical problems in the form of technical documentation; CAD (Computer Aided Design) programs are used here.

Fig. 8. Constructing in a textbook for the first year of upper secondary school.
– **Programming** of activities includes actions of an organisational character which result in the drawing up of a plan of activities, for instance in the form of a schedule, including computer programs for activity planning.

![Programming](image)

**Fig. 9.** Programming in a textbook for the first year of upper secondary school.

– **Manufacturing** involves implementation of projects in a material and the result is a ready technical creation, including CAM (Computer Aided Manufacturing) methods.

![Manufacturing](image)

**Fig. 10.** Manufacturing in a textbook for the first year of upper secondary school.
Operating covers any actions related to using of technical creations (here, actions connected with operation, adjustment and maintenance take place), including software and hardware.

Fig. 11. Operating in a textbook for the first class of a gymnasium.

5. Liquidation of the negative results of technical activity and also of worn out machinery and equipment; here, technical activity related to data protection takes place.

Fig. 12. Liquidation in a textbook for the first class of a gymnasium.
With these characteristic phases of technical activity adopted as the basis of the structuralisation of the contents of technical and informatics education, it is possible to eliminate the need to continuously add knowledge (information) from newer and newer fields of technology in favour of learning skills related to technology and informatics based on these methods.

4.3. A spiral system of the contents of technical education

The logic and arrangement of the contents of human technical activity alone cannot decide the arrangement of the contents for the teaching and learning of technology. To implement this, students should be prepared on the basis of the actual level of their psychophysical development and a system of motivation.

The arrangement of the contents can be as follows: a linear arrangement (taking into consideration the basic criteria of logical coherence and regularity); a concentric arrangement (taking into consideration the postulate that the contents of education are focussed on a common leading idea) and a spiral arrangement (where the ideas that the contents are to concentrate on form a system of leading lines in the vertical arrangement of the contents for individual classes).

Given the dynamic character of technological development, the modelling of a syllabus should be based on students learning the system of technological methods over time, learning elementary methods of technical activity in elementary school and systems of technical activity at the upper secondary school level. With such an assumption, the only acceptable model for the structuralisation of the contents of technical education is the spiral arrangement (Fig. 6).

The model for arranging the contents proposed here is made up in essence of a core of contents around which there are complementary, supplementary and extensional contents. The arrangement as a whole resembles a truncated cone with its base upside down, thus suggesting the idea of a spiral arrangement of contents.

If we cut the cone into imaginary planes parallel to the base, we obtain a number of truncated cones which symbolise individual stages of education. The first two represent elementary school, the third lower secondary school, and the fourth upper secondary school (cf. the educational plane). Mental changes that take place as a result of technical actions taken by students at each stage of education can be described as follows:

– the first stage represents a level of technical knowledge;
– the second stage determines the level of observation and interpretation of technical phenomena in the human environment;
– the third stage is a stage of technical analogies;
– the fourth stage is a stage of subsystems of technical actions (of full competence).

**Fig. 13.** A spiral model of the arrangement of the contents of technical education

### 4.4. Information technologies in the contents of technical education

One of the basic assumptions of modern technical education is that its contents include forms of student activity that are characteristic of technical activity at its present stage of advancement\(^{18}\).

The present stage of technological advancement means, primarily, multi-faceted acquisition, passing on and recording of information. A characteristic feature of the present time is the development of *information technology*, or informatics, coupled with other types of technologies – especially those related to communication – which contribute to its applications\(^{19}\). It is no longer computers alone but the whole infrastructure, in combination with them (called multimedia computers, or more correctly, information technologies), that determines civilisation at the beginning of the 21\(^{st}\) century. Information technology has placed humans on the verge of progress. We are thus standing on the edge of a precipice and do not seem to perceive the dangers of the world, which exist only in the memory of computers. A fundamental question then arises about whether people are able to spread their wings wide enough so that they do not fall into the depths of the digital mental illusion.
Seeing the absolute truth constitutes a basis for the building and functioning of not just technical education, but the entire system of general education as well. Our future and that of coming generations depend to a great extent on whether there are technical activities organised for students at school that correspond with the activities of mankind as we enter the 21st century: people who are creative and have an open attitude to life, who can use multimedia not only to satisfy their momentary whims, but for the sake of their own good as well as others’ – people who can see the beauty behind the equipment’s casing which seems dead, but within which one can feel the pulse of information being processed.

There have already been attempts made to find a way out of the difficult situation that humans are placed in by information technologies. This is what Michael L. Dertouzos\(^2\) says about the future of informatics:

Enough of such designing! It is high time one changed one’s approach and stopped focusing on the hardware – we must find informatics’ equivalents of a steering wheel, brake and accelerator pedals. This analogy leads directly to my idea for the near future: people should use the latest informatics technologies so that they can achieve more with less effort.

When I say ”achieve more with less effort”, I mean three things. First of all, we must adapt new technologies to our style of life, and not the other way round. We are not going to achieve this objective when we put on special goggles and a spacesuit and submerge ourselves in some metallic cyberspace where gigabytes are at large. In the era of the industrial revolution we did not move into a motor space after all. It was the motors that came to us hidden in a fridge where we keep our food or in a car which we use to drive in. I expect that exactly the same thing will happen with computers and telecommunication equipment: they will become a part of our everyday life and we will begin to associate them with useful actions they perform for us.

Information technologies are to be found in two basic functions in technical education – first, as a means of assisting students in their learning and teachers in their teaching (computers linked up in a local area network and connected to an external network - the Internet) – then we talk about information technologies. The second function of multimedia is to play the role of an object to be recognised (students learn the structure and functioning of computers) – then they create information technologies. In modelling the contents of technology and informatics programmes, the idea should be abandoned of teaching students individual and mutually distinct fields of
technology in favour of applying interdisciplinary (universal) methods of technology. That is why we must assume that multimedia are one of the symptoms of intensively developing technology and as such they must find their place in the educational system.

Currently, we also observe attempts to create multimedia textbooks. The same textbook would be a didactic means of assisting learning processes. Using information technologies in this material realisation, it would be a subject of recognition in a natural way. That is why these two functions of information technologies should be seen as being integrated. This is the future; it is difficult to say how far away it is right now.

1. Students solving technical problems – a methodological plane of technical education

5.1. The notion of a problem, a technical problem

Praxeology, as well as organisation theory, associates the notion of a problem with the notion of an objective. An objective is defined as an anticipated states's of affairs or events (desirable in future) which people want to reach.

This means that people assume, with respect to these state of affairs, that they are for some reason of great value and importance to them and that it is worth achieving them through their own activity.

The basic characteristics of objectives are manifest given that:

a) they always refer to future states of affairs or phenomena;

b) they can be built first in a person’s imagination; and as notions they are schematic, fragmentary and foggy;

c) it is possible to make them more detailed through the processes of thinking that depend on a person’s cognitive abilities, volume of knowledge and experiences;

d) they always refer to essential, important matters for a given person so that they have a stimulating character which motivates that person to act;

e) they are connected with a system of values of a given person and are evaluated and assessed by him or her; formulating objectives means pronouncing postulate (evaluative) judgements.

In general, we assume that: a set problem or objective also refers to future (anticipated) events or states of affairs which are described by one person and delegated to another person in order for them to be solved.
5.2. Technical problems from a psychological point of view
According to a psychological point of view, problems have the following characteristics:
a) they are a divergence between the actual and anticipated states of affairs perceived;
b) they have an explicitly specified objective which they control; they direct actions;
c) they are always connected with the description of a problem field;
d) the experience and knowledge of an individual play a particular role in them;
e) individual functions of the awareness of the objective are fully expressed in them;
f) imagination plays an important role in them with respect to the description of an anticipated state;
g) they activate different acts of motivation, conditioned by objects, depending on a person’s knowledge and experience;
h) the action of a person in a problem situation lies in drawing up plans.

Taking into consideration the characteristics of problems identified above as well as earlier definitions of technology, we can say that: technical problems are divergences perceived (called technical discordance) between the actual state of affairs of material objects (creations) and ideal objects (the results of technical activity).

In other words, we can say that solving technical problems requires methods of recognising and applying the laws of nature to be mastered in the creations being formed in order to satisfy different human needs and enrich the mental and physical characteristics of the individual. The point of departure is a comparison of actual states with desirable states on account of the values accepted by that person.

5.3. Elementary technical problems
The technical education process is a well-ordered sequence of didactic and educational situations of a technical character. We understand the notion of ”a technical didactic and educational situation” to be an arrangement of the conditions of the technical environment accompanying an educational interaction which enables it (among various forms of student activities) to realise such forms of technical activity that have been assigned by the operational objectives of technical education.

We will call this type of technical problem, in which the problem field with respect to the structure and function constitutes a matrix for one or one
type of educational situation, Elementary Technical Problems (ETPs) or Minor Technical Problems.

The technical education process is connected with sequences of elementary technical problems that reflect those forms of student technical activity that are required by the operational objectives adopted by the teacher.

The structure of an ETP sequence should be subordinated to the regularities of transformations in the personality of an individual under the influence of technical activity. However, ETP sequences must be also subordinated to the technical activity of logic, as purposeful, rational activities related to satisfying the changing and different human needs.

From a technical point of view, Elementary Technical Problems are connected with clearly distinguished phases of technical activity: e.g. in a manufacturing process, such an activity is one part of a manufacturing technological process; it is a technological operation. Here it is a continuous action performed at one work station by one operator on one subject of work.

5.4. A methodological model of the system of learning and teaching technology

The structure of the system as a whole, prepared by design, can be seen in the methodological arrangement that has been accepted, given that teachers mainly express ideas which characterise the entire contents of education.

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**Fig. 14. A model of the methodological structure of textbooks for learning technology and informatics**
One basis for the sequences of technical problems that are treated as basic elements in the structure of textbooks is the notion that a methodological plane (axis) of teaching technology and informatics is the solution of technical problems by students using information technologies.

Fig. 15. Combining technical problems related to recognising technical situations – an example from a textbook for the first year of upper secondary school.

Individual phases distinguished in this model of technical activity constitute structural blocks made up of a system of elements – Elementary Technical Problems (ETPs). Being properly selected and connected with ETPs, they compose Technical Problem Sequences (TPSs) which are equivalent to a corresponding phase of technical activity (e.g. designing), and TPSs in turn make up Complex Technical Problems (CTPs) (Fig. 14, 15).

The need to ”combine” technical problems into sequences was noted long ago by various authors. For example, H. Pochanke justifies this with certain substantial and didactic considerations. He mentions requirements concerning the contents (the need, resulting from the programme, to present the organisational cycle to students) as well as formal requirements (indirect combining) resulting from the structure of a syllabus. Furthermore, the principles of connecting elementary technical problems have been defined in a complex and creative way by W. Furmanek.
Combining technical problems into sequences creates a foundation for the multi-stimulus and directed process of learning technology and informatics which is to be differentiated in its functional aspects. This is in accordance with the assumptions of the theory of education through technology that is expressed in the statement concerning the praxial character of technology.

2. Exemplary solutions of practical assumptions adopted in the technology and informatics syllabus in an upper secondary school

It appears from the model assumptions that the learning of technology and informatics in a secondary school means recognising, understanding, internalising and adapting the systems of values in human behaviour in technical situations, the carrier of which is modern technology.

The basic way to employ the cognitive processes described above is in a multi-faceted and complex student activity expressed in didactic and educational situations organised (created) by the teacher. This assumption explicitly identifies the functions of the teacher and students in the processes of learning technology and informatics. They become evident in the systems of actions (behaviour) of people in the course of technical activities they undertake at school.

In elementary school, we emphasise the need for students to understand that technology is created by people to serve human needs. It is very important to get pupils to understand that modern technology is different from technology in the past. Nowadays, technology is connected with anything that is done by people; it is omnipresent in various forms of everyday human activity and is based on the advancement of information technologies.

Modern technology can effectively serve people when people – even within an elementary scope – have learned and understood its fundamental principles and have become familiar with its relations with the results of scientific research. This requires the development of the ability of students to assess and evaluate technical phenomena which surround them.

The following extract from a syllabus has been prepared on the basis of one author’s programme (Item 3, titled Procedures for achieving objectives) Technology – Informatics in One Upper Secondary School. The extracts have been compiled in such a way as to make it possible for them to be analysed in a vertical arrangement from Class One through Class Three. Actions and activities to be undertaken by students have been rendered in capital letters.
Class One
Procedures for achieving objectives related to:
c) constructing: students PREPARE methods of testing and changing properties of materials (with the example of metals); they COMPARE the results obtained with the parameters for other materials; they READ and PREPARE an elementary design documentation; they TAKE ADVANTAGE of computer graphics programs; they DEFINE the principles behind the development of material engineering (on the basis of their own observations and analysis of literature); they BUILD and ANALYSE physical MODELS of machinery from the past (flat, three-dimensional and experimental) out of various materials: paper, plaster, clay, timber, metals, plastics, etc.; they ASSEMBLE constructional and functional units of machinery out of ready-made mechanical and electric sets; they DISASSEMBLE and ASSEMBLE machinery intended for the purpose (typewriters, sewing machines, drilling machines).

Class Two
Procedures for achieving objectives related to:
c) constructing: students DEVELOP their own designs for sensors and converters of various signals (dusk sensor, temperature sensor, motion sensor, moisture sensor, smoke sensor, etc.); they READ OUT the values of electronic elements in the form of codes (bars, dots, shapes); they SELECT elements of the sensors being constructed in accordance with design and construction assumptions; they ASSEMBLE (out of ready elements) protection systems, e.g. doors, windows, a courtyard, a room, etc.; they DRAW blocks and structure diagrams of the systems being created; they MAKE TRIAL start-ups and adjust the systems being assembled; they TEST radio sets with different operational parameters.

Class Three
Procedures for achieving objectives related to:
c) engineering constructing: students ANALYSE different technical drawings that illustrate constructional designs of various types of equipment with built-in microprocessors (e.g. household appliances: washing machine, refrigerator, TV set, microwave oven); they DEVELOP graphical models of household appliances with microprocessor systems; they CARRY OUT a computer simulation of the operation of equipment used for the reception, transmission and processing of information; they PREPARE sample service manuals; they MODEL utility robots: industrial robots (e.g. a robot placing glasses, plates, electric bulbs on the assembly line), household robots (e.g. a robot placing tableware on the table, cleaning the floor, etc.)
Summary

The problem of modelling technology and informatics syllabuses is a very complex process both from the point of view of pedagogical theories and didactic and educational actions taken by teachers, often based on their own educational experience. Modern technology is completely different from what was found even ten years ago. Should this not be reflected at least in the selection and modelling of the contents? Many researchers dealing with this field of education perceived the problem as early as the 1970’s and 1980’s. However, it was not before the end of 1990’s that changes took place. A new model of technical education is slowly being introduced in the schools.

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Notes


A New Model of Technical Education

Introduction

The complicated nature of the problems discussed in this paper forces us to confine ourselves to the questions of greatest importance. Therefore, I would like to adopt the terminological conventions adhered to in the field to describe the research subject of the theory of education through technical activity and the theory of technical education; I would also like to point out the basic research considerations of the problems in question. However, I would first like to pose the most important questions concerning such studies which require deeper reflection.

The catalogue of assumptions included in the completed model of Polish technical education currently being implemented - and which is presented in this paper - is, out of stern necessity, of an introductory nature. It requires further development and, above all, arrangement. This will be possible once this paper has been revised by wider circles of research workers and above all by those who adopt different theoretical and methodological standpoints with respect to the questions raised.

Terminological Conventions

1. An analysis of selected phenomena in terms of the assumptions of the pedagogical sciences usually leads – sooner or later – to a pedagogical theory. Depending on the basic subject of research, they assume their peculiar character.

The subject of interest to us is pedagogical phenomena as a whole which relate to the development of the humanity of humans by making use of pedagogical values purposely introduced into the processes of education through technical activity. In this case, we are then dealing with the theory of education through technical activity.

When we try to analyse the problems generated by this theory from the point of view of educational practice, we are then dealing with technical education and, in connection with this, modern technology didactics. Adopting these as the basic subject of pedagogical studies, we can talk about the theory of education through technical activity or the theory of technical education.

In this paper, we fix our attention on the presentation of the basic as-
sumptions of this theory, while treating technical education as a component of compulsory general education.

2. Also of some importance for the explicitness of our standpoint is the question of defining a grid of notions, which provides the meanings we will use to carry out our analysis.

The adoption of a chosen current – or trend, or simply a few ideas about modern pedagogy – as our foundation greatly determines the direction of the analysis and the structure of the pedagogical theory of interest to us.

The grid of notions is of fundamental significance not only for unification and communication of the problems discussed. It serves to prove that a given discipline is mature in terms of its methodology and that its level of identity is sufficiently high. However, as I like to say in such circumstances, let us not start with ABC. We cannot always start from the very beginning. Adopting such a position, we focus only on fundamental issues in this paper, the explanation of which seems to be necessary for the consistency of discourse. We discuss other questions in the context of papers already published and refer the reader to the footnotes.

3. The notions which occur in the context of our analysis of basic problems for the theories mentioned above require some explanation. I include the following among such notions: education, education through technology, technical education, teaching of technology.

It is also important to explain some notions which are subsumed in other notions, i.e.

technology, technical activity.

4. However, the analysis of the questions raised in this paper concentrates on the superordinate category, which is education.

The following five different groups of definitions in pedagogical literature concerning education can be distinguished: praxeological, evolutional, situational, adaptational, modern (humanist, personalist). From the point of view of the questions of interest to us, it is worth mentioning that various authors use different interpretations of the notion of education. However, most often they refer to the praxeological meaning of education belonging to technological pedagogy, which lays particular stress on educational activities such as actions moulding and shaping pupils (on the analogy of moulding and shaping some material into utility objects). We must reject this objective style of analysis as well as the objective approach to the educational process and to persons taking part in it. This requires a reinterpretation of all the objectives and tasks of education through technical activity
which contained the recommendations for the need to mould the individuality of pupils, mould and shape their abilities with respect to various aspects.

Somewhat closer to the needs of the questions discussed are the definitions of education established by educators in circles promoting progressivist tendencies, who place a special focus on the conditions and stimuli involved in the development of pupils. Let us take, for example, the following two definitions: education is preparing for life through life (O. Decroly, early 20th century); education is … organising the children’s experience through amusement, work, conversation, creative expression as educational situations (P. Peterson, 1920’s).

Adaptational definitions express the results of educational activities in terms of the categories of adaptation to the environment (social, technological adaptation). F. Znaniecki (1930’s) defined education as preparing a pupil for performing the tasks of the member of a social group with his full rights. Let us point out that, in light of the threat of the occurrence of what is known as social exclusion, which is discussed later in this paper, that definition may prove useful for the purpose of technical education.

However, from our point of view, the most appropriate definitions of education are used in modern pedagogy, and in particular personalist and humanist currents in it, including pedagogy and the didactics of value.

We must postpone a precise analysis of the issue for another occasion, but let us just mention here a descriptive definition of the concept of education which we use most frequently in our analyses: it is the most important thing in modern education to assist in the many-sided development of the mental state of people so that they can live in the conditions of a changing modern civilisation and be able to cope with the tasks (challenges) imposed by it, so that they can take advantage of the development possibilities which exist given the achievements of civilisation so that they know what they should aim for and how and where to derive a joy of life from. In brief, we can say that education means assisting in the development of humanity in human beings.

At present, in the theory of education through technical activity, there are different ways of understanding the key notion of education. This reflects the pluralism of pedagogical views, but above all, the fact that modern pedagogy is of a polyparadigmatic character. The theory of education through technology should also have such a character.

5. We discuss the analyses carried out in the theory of education through technical activity as a whole against a wide background of civilisation and cultural references. In such a context, it is necessary to explain the contents and methods of interpreting this group of notions in our analyses as well. Additionally, this necessity is stressed by the fact that we connect
the contents of the notions with features describing the character of a civilisation when we talk about *industrial civilisation*, *informative civilisation*, *industrial society* and *the informative society*.

According to these interpretations, we also use such notions as: *technical culture*, *informative culture*, and *information culture* as well as *praxeological culture*, *labour culture*, *economic culture*.

These notions are recognised as basic concepts for the purpose of describing the objectives of the field of education in question.

To conclude, the assumptions mentioned here have clear repercussions for our position with respect to evaluating the currents aimed at making education known more practically from its history. Let us only mention various types of *handicraft*, *utilitarian models*, and finally solutions proposed by what are called *ideas of the spread of technology in education*, which used to be developed in the former socialist countries.

**Basic Assumptions**

We find it extremely important to formulate a catalogue of basic assumptions for the model of technical education theory.

In this paper we focus only on the assumptions related to the methodological and pedagogical character of the theory in question. In the paper by W. Walat, we present a catalogue of assumptions of a practical nature that are inherent in the technical education system we are providing.

1. As was already mentioned we **recognise technical education as a component of compulsory universal general education**. For this reason, we have to refer to solutions concerning problems related to the issue of interest to us that are already known, have been used for many years and are nowadays in educational practice in various countries.

   This also puts us under obligation to adopt our standpoint with respect to the significance of the objectives of this branch of education for the general education of human beings. At the same time, the results of this position should be included in the **canon of general education**.

2. Analyses and studies conducted so far lead us to conclude that **problems related to the technical branch of education should be discussed among those people espousing humanist and personalist pedagogy, and, as regards educational solutions, by those promoting the didactics of value**.

   This implies that it would be necessary to find such currents of a theoretical analysis of modern technology phenomena which **might also include mo-**
modern technology as a humanist theory. This means that they will expose the humanist dimensions of modern technology. And such a theory should find its expression in revealing all the traits and development trends of modern technology which recognise, more than before, the priority of the needs and values of human beings, while contributing to the programme of changing the quality of people; they serve the purpose of consolidating their goodness. At the same time, the theory enlightens us about the necessity of adopting in our studies a paradigm emphasising the priority of human beings over technology\textsuperscript{12}.

3. Adoption of the standpoint mentioned above implies that it is necessary to acknowledge the priority of human beings in all pedagogical processes. This assumption becomes evident in different ways in all the components of the technical education system being modelled.

4. In the methodological catalogue, it should be established that we will conduct studies of the problems in question using a systems approach, assuming that it is necessary for such an approach to be taken with respect to all the components of the system. Therefore, we depart from an additive, or holistic, methodological approach which has been used to excess. At the same time, it is worth noting here that there is a greater need than before to make allowance in our studies of the problems in question for models of quality studies or quality and quantity studies. This explicitly shows that it is also necessary to abandon a naturalistic approach to the subject of pedagogical studies. Using an anti-naturalistic paradigm\textsuperscript{13} which owocowa\_ includes in his methodology, one can expect that the experimental studies carried out so far will be reevaluated.

To conclude, in light of analyses of the results of research carried out so far, but also in light of my own experience in phenomenology and the catalogue of the assumptions mentioned above, we can say that none of the models for using technological values in pedagogical activities can be continued. Thus we reject the models for making education practical in its solutions using different forms of handicraft; we consider the models proposed by pedagogical utilitarianism to not be useful enough for the purpose of modern pedagogy; and we reject an objective style of education and the theoretical assumptions adopted in constructing the models of polytechnical education as proposed by Marxist versions.

We consider the preparation and implementation of a modern model of education through technical activity\textsuperscript{14} to be a necessary and extremely urgent task for modern educational sciences.
Main areas of analyses and studies needed as a result of the challenges of civilisation

1. **Modern technology** – apart from modern science – is one of the most important causative factors responsible for civilisation transformations. It is not an easy job to establish a definition of modern technology. **We make an assumption** that technology is a special history-creating phenomenon. It results from the many centuries of collective work of man. It has always served and still serves the purposes of people in those forms of activities where they strive for perfection with respect to themselves and their activities so that they can in fact change the quality of the world and as a result their standard of living\(^\text{15}\).

2. **The character of modern technology is also determined by its direct coupling and feedback with science.** What is essential are those properties which result from the global and total character of modern technology. These features require precise interpretation and an indication of what the consequences are with respect to educational sciences and technical education.

3. **Modern technology is an omnipresent phenomenon.** Although it is created by a few people, everyone can take advantage of it. This poses new challenges. For example, can one restrict oneself in the teleology of education through technology simply to the need to develop technical culture among the users of technology? How can one interpret the concept of the technical culture of a user of information technologies?

4. In light of such an understanding of the notion of technology, it is important to try to indicate **what challenges man is confronted with by future civilisation.** If civilisation itself is to be recognised as a value, one should also indicate the values which constitute it and their relation to pedagogy. **Values are inherent in modern technology and the technical activities of man.** What sort of values are they? Any answer to that question must first consider the fact that modern technology is different from technology in previous eras. How is the dissimilarity expressed? It is extremely important to show the **humanist dimensions of modern technology.**\(^\text{16}\) To what extent does it contribute to the programme of present-day humanism\(^\text{17}\)? What conditions are to be satisfied so that modern technology can complete its historic mission?
5. **How can one model all the phenomena which make up the contents of modern technology?** Each field of modern technology is worthy of notice. Each, to some extent and with certain dynamics, affects the character of modern and future scientific-technical-informatics (information) civilisation. Which catalogue categories of modern technology reflect to the greatest extent the contents of the most important of its phenomena? In the model we prefer, we rely on three mutually coupled categories: **matter, energy, and information**. An urgent task is to show a relation grid, but also the tendencies of their development since the results of such analyses are of key importance for modelling the contents of the branch of education of interest to us\(^1\).

6. However, at the same time, the great number of forms of human technical activities, the multitude of means and methods of modern technology (including information technologies), but also the diversity of forms for organising activities make it extremely difficult to develop a **model of technical activity** which, while not losing some important properties of modern technology, would present it from a **personal point of view** (from a creator of technology) as well as from a **cultural and civilisation point of view**\(^1\). The technical activity model structure adopted in some detailed studies, after reinterpretation of the contents of individual phases, shows in full our position with respect to the modelling forms of technical activities using a horizontal approach.

7. Also of some importance is the statement that informatics – or to be more precise, **information technologies** – should be regarded as a component of modern technology. Nowadays, it is this complex of indicating phenomena that is determined most by the trends of present civilisation transformations: **from an industrial civilisation to an information civilisation**\(^2\). What challenges confront man given the dynamically developing information civilisation and information society that are being built and which are characterised by: **variability**, dynamism of transformations; **transitory character** (enhanced transgression); **multiplicity** and complexity and even a systems character of transformations; **novelty** (creation, creativity)? In this context, how can we interpret the notion of **human information culture**?
8. **Recognition, description and evaluation of the properties of information civilisation and information society** represent a set of important tasks for pedagogy. Adaptation to civilisation transformations poses not just a challenge for pedagogy and individual branches of education. Pedagogy should **participate** in them and **be ahead of them**\(^{21}\). That is why one should constantly **recognise** the world and be able to **foresee** its development trends\(^{22}\) and **make recommendations** on that basis for educational practice\(^{23}\). We will learn all the fruits of this practice in people’s activity in future because they constitute important references to the objectives and tasks of present-day education, which are always of a prospective character. And although educational processes are ongoing here and now, they are still employed with the intention of achieving future objectives. The perspective of the future, its interpretation, and the establishment of main courses (tendencies) of development are of special significance for the educational sciences. **Education is always education for the future**, for a better tomorrow for the world\(^{24}\). To what extent should elements of the history of technology be taken into account in education through technology? To what extent should pupils be shown the sources and scope of threats – to human beings and their environment – which come into existence because of processes that take advantage of technological achievements which are recognised but which people are not sufficiently intellectually prepared for?

9. As was mentioned above, **civilisation transformations** include all the spheres of human life. Given their nature, we call them **revolutions**, as it is a process of rapid quality changes in this area which results in a **fundamental transformation** of the existing state of affairs or a system of relations and their sudden transition from one development stage into another\(^{25}\). A revolution refers to a transformation of the most important and fundamental phenomena for the system and always has the character of a landmark. According to the convention of science methodology, we say that revolutions are always connected with a **change of paradigm**. Which of these should be made a central point for the analysis of problems related to challenges that confront pedagogy and education? Within our scope of interest, which is education through technology and technical education, various and different directions of analysis can be indicated. However, in my personal opinion, an **axiological analysis should be the basic area of studies**.
10. A global information society issues different challenges. These refer to all the spheres of human activity. It is important to indicate these paradigms with respect to the problems connected with civilisation transformations of interest to us. Among the numerous attempts to solve the problem, the proposal of A. Tofler\textsuperscript{26} is worth mentioning; he points to the fact that civilisation transformations appear in the transformations of the system of values predominant in a given civilisation model. We can label this observation transformations in the axiological paradigm. Therefore, we ask not only what values constitute an information civilisation model. We also pose questions concerning pedagogical implications of the phenomena at the time of civilisation transformations, which F. Fukujama calls a great disruption\textsuperscript{27}. Although the development of civilisation proceeds under the influence of various factors, it is revealed first of all in transformations of the system of values. So, for an agrarian society, land constituted a value – the area of crops necessary to support the community. In an industrial society, capital, the labour force, and the means of production represented values. An information society is a society of information, knowledge and competence.

**Challenges for Education**

1. **The character, scope and direction of these transformations are of some importance for the educational sciences.** It is from here that directional recommendations for pedagogical activities take their origin. What mental dispositions should be cherished and developed so that pupils can single-handedly – and in a way that is adequate for human beings – take advantage of the achievements of information civilisation to change the quality of their life? Therefore, we focus on the ethical dimensions of the analyses carried out.

2. Information civilisation and information society models built in it are based on information, knowledge and the competence of people. Educational systems must prepare people not to make use of knowledge acquired at school and possessed once for their whole life to perform repeatable actions (these can be algorithmised, i.e. they can be replaced by information technologies), but to create knowledge. Nowadays, this competence is reserved for only a few people. In an information society, it must be shared by all classes in society. An information society, the fruit of information civilisation, is a society of creators, of people infatuated with themselves, consciously aiming to take full advantage of the single, unique, non-repeatable features of their psyche, including their intellect.
3. **Creation** is a disposition to perceive the world in full, to be surprised, to ask questions and accept dissimilarity for the dynamic and continual development of a human being. The psychodidactics of creation is confronted with new challenges. They can be expressed in an abbreviated form as tasks to establish an **educational model of creative man**. This is necessary to direct educational activity. However, it seems that even now - on the basis of an analysis of literature from this field - one can show the most important features of human creative attitudes. Undoubtedly, they include the following:

- The particular way of perceiving the world, and the resulting way of recognising the world: by means of the senses, rationally, concretely and notionally;
- The openness of mind and tolerance of ambiguity; flexible thinking; coping with cognitive situation problems;
- Independence, reflection and courage;
- Spontaneity and expressiveness;
- No fear of the unknown;
- The ability to concentrate and a fascination with tasks;
- Friendliness and a sense of humour;
- The ability to integrate contrasts.

4. This poses new challenges to educational systems but also to the educational sciences: how to **teach everyone to recognise and assess**:

- themselves;
- their abilities, aspirations and aims;
- the spheres of their curiosities, interests and likings.

5. A challenge for the education system is constituted by a **need**:

- to **educate a large majority of society on the level which today is called tertiary education**. Hence, already today, the 21st century is called the **century of universities**\(^\text{28}\);
- to more frequently brush up on and enrich knowledge which quickly becomes out of date; at the same time, the volume of knowledge will increase exponentially.
6. Another serious challenge facing education is the changeability and growth of knowledge. We know for sure that the volume of knowledge will increase exponentially. At present, we do not know the dynamics of these changes (we do not know the rate at which they will occur). The educational model which is obligatory in an information society and is expressed by the formula “20 years of education, 40 years of professional activity” can no longer be followed. This model prepared people for one occupation or at least for a change in their workplace. For the educational system, this means there is a need to develop a new model and organisational principles of education of learning through a person’s whole life (LLL model)\textsuperscript{29}. The adoption of such an educational paradigm means a transition from the principle of acquiring knowledge once for one’s whole life to the principle of learning throughout one’s life.

This determines the need to develop readiness to study and learn further. Also, this entrusts education with subsequent tasks, which are none too new:
- Develop the conviction that continuous learning is necessary;
- Teach everyone methods of learning\textsuperscript{30}.

7. Changes in the system of values have always been accompanied by significant social phenomena, including an axiological loss of people and related pathological phenomena. Finally, as we are in the sphere of these phenomena, we must ask about transformations with respect to human work which we treat as a value and source of new values. Are the quantitative and qualitative transformations in the labour market determined by the end of work foretold by J. Riffkin\textsuperscript{31}?

It is commonly known that as agrarian society was transformed into an industrial society, the demand for workers in the agricultural sector decreased. Those changes were magnified by the introduction of creations of industry but also by scientific achievements related to agriculture (mechanisation and chemicalisation of agriculture as well as transgenic breeding). Even now, agricultural employment in highly developed countries is at a very low level.

Initially, the demand for developing industry in the 20th century was great enough to also provide jobs for what are called manual workers or in fact poorly skilled labourers. Over time, production technologies have been improved, causing substantial changes in the organisation and processes of production. The introduction of new generations of machinery and technological lines (nowadays robots) has also been of some importance. All this has resulted in decreased industry dem-
and for workers in general, and particularly for manual workers. They have been replaced by machines which are continuously being improved. Human beings lose out to machines (including computers).

One can expect that with the transition from an industrial society to an information society, the demand for what are called white-collar workers, who perform a number of actions related to the processing of information for the purpose of administration, will also drop. These jobs will be done by information technologies and computers. Let us add that this phenomenon refers not only to the administration staff in industry but also employees in most types of service.

6. A question then arises: what workers will be required by an information society? First of all, workers for such jobs where humans do not lose out to machines (computers). In our opinion, this means work based on mutual relations between people, and what is called creative work.

7. A market of employees will assume the character of a market of competencies. And this means there will be no continuity in the traditional labour market, a market of employees. Some new forms of employment have already been propagated: outsourcing, employment contracts; telework has also emerged.

8. The labour market in the models of information societies will force the educational system – more than ever – to pursue their interest in the problems connected with education through work for work. This being so, there should be an expansion of pedagogical studies on new educational solutions related to these problems. At the same time, this challenges the educational system to provide pupils with systems of competence which will enable them to get along in a difficult labour market. We can mention some exemplary competencies here. They include: creative competencies, abilities to use knowledge in an interdisciplinary way, abilities and skills for collective action as well as self-reliance in initiating and performing tasks.

9. For education, this means that educational systems have to prepare people:

➢ to co-operate in teams responsible for solving specific problems (and not as has been the case so far to operate equipment or handle customers);

➢ for the changeability of work, mobility, known as a stepwise professional career. In an information society people will be forced to change their profession several times throughout their professional career. This
is both because of the growth of knowledge, which is a scientific basis for a given professional activity, and the evolution of professions. Some of these will disappear while new ones will emerge.

10. Within the framework of this model, it is necessary to formulate new methodological solutions, including:
   ➢ models for working with adults;
   ➢ abandoning the approach where knowledge is imparted by teachers in favour of one where knowledge is acquired by teachers together with students;
   ➢ shifting the focus from knowledge possessed by the teacher to knowledge needed by the student;
   ➢ developing abilities to solve problems, particularly important problems related to making decisions and diagnoses;
   ➢ inventing and implementing methodology for team work, teaching attitudes and intercommunication skills as well as organisation of work into teams and groups;
   ➢ developing new methods of work using new information technologies, including teleducation, virtual schools, etc.
   ➢ developing a new model of educational services which takes into consideration the needs of the public sector, employees and employers;
   ➢ inventing methods of work which develop the essentials of creative activity;
   ➢ inventing a methodology for developing people’s cognitive interests and likings.

**Basic Ideas of the Technical Education Theory**

1. **Preparing people for a change in life quality** as the reality of civilisation changes should be considered to be the basic mission of the educational sciences and educational practice.

No sphere of life can escape civilisation transformations; neither can the pedagogical sciences and education system or the theory of practice and education of humans. Pedagogy is interested in all the transformations relating to the theory and practice of human education through a person’s participation in various technical activities. In other words, we seek an answer to the question to what extent the values of technology and technical activities can be used to induce and consolidate changes in the human psyche. Furthermore, educators are interested in how to organise a didactic and educational system so that the effectiveness of the actions undertaken can be the highest. What model of the technical education system is to be proposed
to make it possible to attain objectives resulting from the civilisation challenges briefly mentioned above?

2. For the pedagogical sciences, everything is essential which refers to human development in all its dimensions of personal, mental and spiritual life. What really matters, above all, is humans and their development; this defines the essence of pedagogical activities, and this results from doing anything in the pedagogical processes which is good for humans.

We adopt the paradigm which recognises the priority of humans over technology and the organisation of pedagogical processes as a basis for our discussion.

Therefore, we assume that:

- technology constitutes a value and carries a syndrome of values. They remain connected with the system of values embracing the whole of humanity. This system of values is to be interpreted and viewed in terms of pedagogy;
- the values which represent inherent components of modern technology should be the subject of interest of educators given the contents of pedagogical processes being modelled;
- the values mentioned above are essential to humans (otherwise they would not be values); they are important from the point of view of the needs of humans, their aspirations, and more precisely from the point of view of their influence on the contents and quality of changes in human life;
- modern technology and its entire results will constitute values for humans only when they can be acknowledged by humans as such or as a result of their possibilities of creating new values.

3. Education through technology or education through technical activity represents a domain of education. It is a component of the system of general education. The essence of this domain of education manifests itself by aiming to take advantage of the values of technical activities to make conscious changes in the psyche of pupils who are willing to actively take part in differentiated and complex-arranged systems of technical situations. Owing to this, it will be possible for THEIR psyche to develop to such an extent that THEY are prepared not only to take advantage of the benefits of civilisation, but also to make active changes in the quality of their lives.

With this approach, education through technical activity – as a domain of compulsory universal general education – integrates all the pedagogical actions taken by these teachers, who aim to develop the instrumental side of the psyche of their pupils (instruction - teaching of techno-
logy), as well as all the pedagogical actions taken by these educators, who aim to develop the directional mental dispositions of their pupils (technical education).

Learning technology means aiming consciously to study, understand, internalise and adopt one’s actions in technical situations whose systems of values are carried by modern technology.

Teaching technology – in this context – should be assisting pupils in learning technology. Assistance should find its expression in organising systems of technical didactic and educational situations at school where pupils can take certain actions and consolidate their actions, which are in accordance with preferred values.

Technical education means a process of conscious and organised use of information in order to prepare people to take advantage of information in order to solve the problems they face in their lives.

4. This way, pupils will be active at school in the environment of values which will constitute the contents of their adult life.

As the activity (both professional and non-professional) always takes place in a given technical situation, it thus becomes necessary to refer people to the components of technology which are found in such a situation. Giving sense (significance, a role) to certain actions of people constitutes their behaviour in a given situation. Repeatability of this behaviour as expressed in organised didactic and educational cycles is requisite for attaining an expected level of skills and consolidating the types of behaviour of great worth.

5. How should the processes of pedagogical actions understood this way be modelled in order to maintain the priority of humans over the organisation of the information society? At the same time, this means that a pedagogical model must be sought which, while recognising the autonomy and identity of individuals, their uniqueness and the non-recurrence of their mental dispositions, will assist in their aspirations to further development – even after leaving the system in future.

6. Once modern technology can and actually does change the quality of human life, a question arises about the criteria for the quality of human life. We assume that such a list should contain the following:

A. A variety of subjective experiences, and in particular, a variety of personal experience with respect to values;

B. A high level of consciousness, being conscious of taking part in the activities offered;
C. **Self-reliance** in undertaking and performing actions;
D. **Creation**, including technical creation;
E. **Participation** in adhering to preferred values;
F. **Possibilities of self-development** and taking advantage of them to achieve one’s own aspirations and plans.33

7. The criteria for the quality of human life given above are of a subjective character. As a result, some recommendations can be made in terms of **expected features of the system of education through technical activity that is being modelled**.

One should aim to make the system that is being modelled friendly to pupils. Therefore, its features should include, among others:
- Many-sided and complex technical **activities** for pupils;
- Intellectualisation of technical activities; **awareness** of participation in technical activities; an enhanced role for the **processes of understanding**;
- Activating high levels of cognitive actions; **self-reliance** in performing technical actions;
- Technical **creation** which is adequate for the level of the pupils’ cognitive abilities;
- **Participating** in the world of values; abandoning preparation for social roles, including the role of a rational consumer;
- Developing a disposition for **self-education**;
- **Elasticity** with respect to pedagogical solutions.

8. A more precise analysis of the features mentioned above enables us to establish a catalogue of pedagogical instructions for the organisation of the technical education system.

A. Giving this educational domain a clearly humanist character. At the same time, it should be added here, that the character and contents of the concept of **modern (new) humanism**34 need closer consideration.

B. **Restoration of subjectivity** in the processes of technical education should be the main task of theoreticians and practicians from this field of education. It requires a precise analysis and pedagogical reflection on the priority of people in educational processes. It is necessary to introduce instructions for the practice of implementing the **style of subjective education**, overcoming the style of objective education.35

C. Showing modern technology as a causative factor of civilisation transformations, which is at the same time closely connected with the system of values embracing the whole of mankind. The continually dyna-
mic development of science and technology changes the character of human activity. This makes it necessary to prepare pupils for changes, for continuous study;

D. Generally, the doctrine of education has to be changed. **It is necessary to abandon the adaptation doctrine in favour of the creative education doctrine.** The purpose of schools should be to promote the many-sided development of their pupils and to prepare them for independent study throughout their lifetime. The creative education doctrine should stimulate pupils to innovation, creation and change. Pupils should learn to make their own decisions without restraint but trustworthily, to think independently (and also creatively), to estimate sensibly, to act with a full sense of their responsibility and openly express their own ideas and feelings.36

E. Showing modern technology in its multiple connections with all forms of human activity: professional work, learning, culture, leisure, creation. Showing the fact that modern technology both advantageously and disadvantageously changes people’s environment. This requires making pupils understand basic phenomena of importance for the present day;

F. The contents of technical education should be modelled in such a way that it can ensure **many-sided activities for pupils, who assume the task of solving systems of technical problems** since this is a requisite for multi-stimulus influence on the pupils.

G. At the same time, each of the forms of technical activity undertaken should be widely based on cognitive processes which are strongly intellectualised, and the processes of **understanding technical phenomena** should be the basic ones.

H. Intellectualisation of the processes of education through technology in the context of the diversity and differentiation of the contents of technical education means the need to accept, in the model being constructed, **all the conditions determining the development of cognitive processes** as conditions which constitute all the methodological solutions being implemented in the system. It is necessary to adopt the development of **technical imagination, creative technical thinking and technical language** as a matrix of all pedagogical actions. **Nor should the processes of the development of memory and attention be neglected.**

I. **Diversity with respect to the contents** of technical education as the consequence of reference to modern technology forces the need for **continuous optimisation of the solutions** proposed by the theory of education through technology. This should apply both to the entire system
being modelled and to the pedagogical processes which are to take place in it, but also to all types of methodological studies which will appear in the system.

J. **Methodological and organisational flexibility** obliges educators to introduce a great number of methods and educational forms for practice in this field, with the principles of good practice being observed.

K. The necessity of a systems approach to the problems of technical education will be expressed by a **unification of solutions in a horizontal plane**, i.e. for individual stages of education. This is manifested by preparing and accepting a uniform point of view with respect to the structure and character of the technical activities proposed. In our solution, we propose a systems approach to various technical actions in the model of technical activity. A detailed presentation of this can be found in the paper by W. Walat.

L. Of no less importance is the **solution to the problem of a vertical approach to the issues** related to this field of education or integrating the solutions around some old ideas for various stages of education. We propose that the point of departure for the processes of technical education, employed on a systematic basis, should be the level of the school technical maturity of students (which is required at the start of the student’s school career). Subsequent stages include the following: the **level of technical knowledge** (a standard of achievement for students completing their early education); the **level of observation and interpretation of technical phenomena** (the level of understanding for elementary technical phenomena; this applies to students who complete their elementary education); the **level of technical analogies** (a standard of achievement for students completing their upper secondary education); and the **level of technical activities systems** (a standard defining the achievements of students completing their secondary education and other types of complete comprehensive schools).

The theory of technical education is aimed at the description and operationalisation of individual levels. This is the more urgent task as the solution to these issues has a bearing on the level and contents of educational standards, including the programme standards. It thus affects the selection of the contents of technical education and their didactic instrumentalisation.

**Conclusions**

In this paper, we have undertaken the task of giving a synthetic presentation of the catalogue of basic assumptions which we take into consideration in our work on a new model of technical education.
It is not possible to discuss all the necessary questions in one study. Therefore, although we consider this paper to be introductory, we reckon that time will allow us to present these problems concerning the theory of education through technical activity in a wider monograph.

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Gajda J. (red.): *O nowy humanizm w edukacji*. Kraków 2000.

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Furmanek W.:

**Additionally**

Notes

2 Cf.: W. Furmanek: 14, 16.
3 Cf.: W. Furmanek e.g. 2 through 10, 17, 18, 19, 20.
4 Por. W. Furmanek: 4,17.
8 Cf. W. Furmanek: 25,26, 27.
10 A description of a theory requires: presentation of its characteristic subject and considerations and a discussion of the methodological assumptions, tasks and functions of the theory and terminological conventions.
12 Cf.: W. Furmanek: 17, 18, 19.
14 I have already taken up the problem in other papers but from a different theoretical perspective. Cf.: 1, 14, 17, 22, 23, 24, 28, 30.
18 Cf.: W. Walat: *Za_o_emia praktyczne systemu edukacji ogólnotechnicznej w szkole podstawowej i gimnazjum w Polsce*. 
In the study, Zrozumie technik, I interpret the notion of technology in its etymological, praxeological, epistemological, ontological, anthropological, humanist and global meanings (as metatechnology).


From: life-long learning.

The following reports are relevant here: Uczy_ si_ aby by_ oraz Edukacja, jest w niej ukryty skarb.


Cf.: W. Furmanek: 22, 23, 24, 29.

Cf.: W. Furmanek, Item 17.


Serendipity is a word that was coined by the British statesman Horace Walpole in 1754. On January 28 that year, Walpole wrote to the British envoy to Florence, Horace Mann:

“... This discovery indeed is almost of that kind which I will call serendipity, a very expressive word, which as I have nothing better to tell you, I shall endeavour to explain to you: you will understand it better by the derivation than by definition. I once read a fairy tale called The Three Princes of Serendip: as their highnesses travelled, they were always making discoveries, by accident and sagacity of things they were not in quest of …”

The fairy tale Walpole was referring to told the story of three princes who were highly trained in the arts and sciences. They were sent on a prolonged journey by their father, the king, to acquire empirical experience. On the journey they met a camel driver searching for his lost camel. Although the three princes had not seen the camel, they asked the camel driver if the lost camel was blind in one eye, missing a tooth and lame. This description was based on signs they had observed along their way. They also deduced that it probably carried a load of butter on one side and honey on the other and was ridden by a pregnant woman. After this detailed description of the camel, the camel driver was convinced the three princes had stolen it and they were imprisoned. Later on, when the camel was found, they were released.

How the three princes, deduced their description, through knowledge and sagacity, I will leave to the reader to find out. But the concept of serendipity, making unexpected discoveries and insights by accident and wisdom, and how this could be related to technology and education is something I would like to discuss. I would claim that serendipity plays a great role, more or less deliberately, in everyday life as well as in science, technology and art. I also believe that serendipity can be used as a tool or approach in educational contexts.
Serendipity in practice

*Serendipity of Science* is a series of three radio programs that was recently broadcast on BBC’s Radio 4. The program was made by Simon Singh, a British author, journalist and TV producer known for the books *Fermat’s Last Theorem* and *The Code Book*. Singh focuses on how serendipity has led to several great breakthroughs in science, such as antibiotics, microwaves, and the post-it note. He points out how some lucky accidents made the inventors aware of new perspectives on what they studied, or new application areas for their discoveries.

Gary Fine and James Deegan have also stated that serendipity plays a role in research. In the paper *Three Principles of Serendip: Insight, Chance, and Discovery in Qualitative Research*, they argue that “serendipity is the interactive outcome of unique and contingent ‘mixes’ of insight coupled with chance,” and that “planned insights coupled with unplanned events can potentially yield meaningful and interesting discovery in qualitative research.”

Relating to my own experiences, I find that serendipity is an important concept used more or less deliberately in several contexts. Working with art, engineering, research or in everyday life, what you eventually come up with is not always decided in the beginning. It is often a result of several small incidents and would not be the same without this specific journey. Reflecting on and perhaps realising why the process and result evolved as they did could be a great step towards an understanding of how you learn or work, and could be very useful in both education and technology.

My own experiences lead me to at least state this: developing a software application and making dance choreography are two areas where serendipity is included in the process. I also find these processes comparable to several extents. By from my point of view, it is mostly the form of the result that separates the two. To illustrate this, I will present a simplified and generalised description of the two serendipitous processes.

When I confront a task, I often get an immediate and subtle vision of how to solve it or what the result will look like. This vision could be a partly detailed picture or just a feeling, a sense of something. It could be based on my previous knowledge and experience of similar tasks or related questions. I may find inspiration from totally different problems that for some reason, at this moment, seem relevant. In a dance context I often “see” geometric patterns or directions in the room in which the dancers should move. After I have finished the task, I sometimes end up with a completely different result than the original vision. But more often, the result shows traces of my vision, albeit with crucial parts which I could never have thought of in the first place.
In addition to the task and vision, the process consists of five more or less fixed points, which I jump between, reuse or combine when I need to (Figure 1). The references I use for the different points in this example are taken from the software engineering industry. This field has developed and marketed several different methods and named them, in contrast to the artistic field. But as you will see, some of the working principles are the same, at least from my point of view. As I started making choreographies and teaching dance before I did any programming, I drew direct parallels between the two processes when I became familiar with software development methods.

![Figure 1. A serendipitous process](image)

To be able to solve a task, you need different resources. Your result will always depend in some way on what resources you have access to. These are part of the requirements that are present in the process. Money, space, time and material are examples of external requirements. The choreographer or system developer may also have internal requirements like personal preferences or skills, for instance dance technique or a programming language. Other requirements could be what functions the system should contain, the target group or target audience and the context in which the choreography or system should be presented.

Another step is to analyse your task with respect to your requirements. What is really the problem? What do you want to convey to the audience? Is it possible to do this despite the given requirements? By what means will this be done? Working with a certain material, you will have to deal with its properties and constraints. Certain trained dancers will perform differently from others, and different programming languages and platforms have different properties.
A third point is the *design*, in which you decide what you are going to do and how you are going to do it. This relates of course to your analysis. I may start visualising the choreography in my head or sketching on paper. That means drawing the big picture. After that, you can separate the task into sub-tasks, like trying out some movements, building the choreography or application.

When all the planning is done, it is time for *implementation*. In a software development project this would consist of writing the code. In a dance context this would be the rehearsal.

Running *tests* is always important for checking the reliability and usability of the system, choreography or whatever the result consists of. Does the application provide the functions? Does the system or dance piece work in the right context, on the actual stage? Are the dancers able to perform the choreography?

There is no sharp dividing line between the five points presented, and the process may consist of several iterations and refinements. Depending on the circumstances, you have to move back and forth, between them, combine them and always look out for new possibilities and solutions. So, independent of the task, whether it be developing a software application or making dance choreography, I use similar methods or the same systematic, serendipitous approach.

Still, it is important to note that the result will differ in several ways, depending on what the aims of the processes are. A system developer certainly has different intentions than a choreographer and might focus on other aspects of each step. But what I want to emphasise is that both processes include aspects of serendipity, and require an open-minded attitude in order to increase the quality of the result. If you are too focused on the goal, you will not be able to see the new possibilities that lie hidden there in front of you or use them when they arise. There will always be changes during the process; a dancer could be injured, the system should function on several platforms etc., and then it is important to use these opportunities in a constructive way.

In a serendipitous approach I include the methodological and systematic work towards something you have a vision of, the intended result. But in this process, I find it important to be open to new insights, possibilities or directions, the serendipity. To be able to use these unexpected possibilities, you have to use your knowledge and sagacity. In order to know how to relate them to your previous work, you need basic and sometimes expert knowledge on the subject.

In the Oxford Advanced Learner’s Dictionary, 5th edition, the word “serendipity” is defined as “the ability to make pleasant and unexpected disco-
veries entirely by chance”. This definition, from my point of view, is an inaccurate one, as the aspect of sagacity is left out. I find sagacity, knowledge and wisdom to be very important aspects of serendipity, especially in educational contexts. You cannot rely on luck alone.

**Technology as a school subject**

When I think of the word “technology”, one of my first associations is machines, big machines and small ones. Other thoughts that occur are computers, industry and complex systems. I also imagine men developing this technology and specialised, competent, men working on their own using it. I think of dark colours, black and grey, and I sense a hard, edgy surface. Spontaneously, I think of education, in contrast to technology, more as interaction and collaboration between teachers and learners – both humans. I think of light colours and soft objects.

These pictures could be considered stereotypical and conventional, and not very well thought out logical?. Still, they are my associations and other people’s as well. So where do these stereotypical associations come from? After second thought, I realise and know that both technology and education should be described in a much broader sense.

When I attended the conference *Technology and Education – a Socio-Cultural Perspective*, I was curious to hear about technology as a school subject. It is a subject that I have no personal experience of, as I grew up in Norway, where this subject is non-existent. Because of this lack of experience, I tried to sort out what the subject represented. But the conference left me with even more questions and thoughts.

One aspect that made this even more complicated was the fact that the name of the subject in Swedish is “teknik”. In Swedish, this means both what in English is called “technology” and what is called “technique”. As a result, when I think of the Swedish word “teknik”, I think of gadgets, machines, etc. But I also think of the technique or method by which you could operate these gadgets. To confuse people even more, the Swedish language has a word called “teknologi”, similar to the English “technology”, which means the science, “teknik”. (This distinction between technology and “technology science” does not exist in English.)

To continue my investigation, I studied the syllabus for technology as a school subject, made by the National Agency for Education (Skolverket). Skolverket emphasises the importance of technology as a multi-disciplined subject and its connections to science, sociology and the fine arts. Technology should also be a meeting point for ideas and knowledge of different kinds, something that has characterised technology since ancient times, ac-
cording to Skolverket. They also argue that technology has an emotional dimension and relates to other forms of creativity. This indicates that technology as a school subject should contain more than just knowledge about technology per se, which thus also means the relation between technology and humans, and between technology and society.

Technology as a school subject aims to give students an understanding of how production, society and the physical environment in relation to technology affect our living conditions. This includes making everyday technology more visible. Students should develop a basic technical understanding of its concepts and a historical overview. They should also be able to reflect on and solve problems using technology. The syllabus for technology supports the idea that learners are discovering human beings. It also insists that discoveries should be made through the learners’ own experience and activity.

**Serendipitous learning processes**

So is it possible to include more serendipity in today’s education, especially in teaching technology as a school subject? In my view, this subject presents a great opportunity to encourage learners to pursue their own inventions and experiences. Most people have experiences where they have suddenly arrived at an insight or made a connection when they least expected it, or found a solution to a problem while aiming for something else.

It may seem impossible to have a totally serendipitous attitude towards education, as teachers and learners have certain goals they have to achieve, and time is limited. But instead of teaching what to think, I would argue that it is important to teach how to think. That means that the teacher should function as a serendipity guide and encourage learners to use serendipity in their work. This certainly requires sagacity and wisdom from teachers. They should also encourage reflection about findings, or why the process or result was what it was.

To be able to include serendipity in educational contexts, and especially in the subject of technology, there are three aspects I think are important to highlight. First, dealing with technology means dealing with humans in several ways. Technology has often involved humans striving for better solutions to everyday problems, trying to find more cost-effective ways of producing, extracting, etc. Technology is developed by humans, and humans the ability to draw unexpected conclusions. People are sensitive to impressions, other people’s opinions etc., and can change their mind just because it feels right, while a machine is programmed for a certain behaviour. Machines are not wise, and can therefore never make any serendipitous discoveries.
Second, as Skolverket also points out, technology is and should be multi-disciplinary. Today’s technology is extremely complex and leading-edge. We need collaboration between different sciences and between people from different backgrounds to develop new high-tech products and services. Having different perspectives and experiences is a way of increasing the possibilities for new insights and non-traditional solutions. What I find important is accepting an open-minded environment and respect for each other’s knowledge and sources.

Third, the difference in backgrounds also includes differences between male and female cultures. It is a well-documented fact that male students are over-represented in higher education in technical disciplines. A commonly-held view, and a rather obvious one, is that the whole society and technological development would gain from increasing the representation of female technology students. It is therefore important that both boys and girls are given the same chances to experience different aspects of technology and related areas. In order to improve the gender balance, I think it is important to focus on people’s preferences and why they find technology interesting, and use that as a starting point for the learners’ further investigations of the subject.

As teacher I have found that an open-minded serendipitous approach is often useful. I feel that an important aspect of my work, and my professional as well as personal development, is meeting and discussing with other people and, through their perspectives, finding new approaches to my material. So when I systematically aim for and work towards a certain goal, I am always looking out for traces of serendipity that might enrich my work.

The same approach could also be used in education. That means trying to use the students’ different perspectives and experience. Something that seems absolutely logical to one person could appear totally irrational to another, and it is therefore important to keep in mind that there are often several different correct answers rather than one that is correct and several that are wrong. Starting from this point of view, we could create opportunities for a new serendipitous approach to teaching and learning.
Notes

1 The original story, *Peregrinaggio di tre figluoli del re di Serendippo*, by an author who called himself Christophero Armeno, was first published in Venice in 1557, and exists in several translations, e.g. Serendipity and The Three Princes: From the Peregrinaggio of 1557 (University of Oklahoma Press, Norman: 1964). The article *The Three Princes of Serendip* by Richard Boyle retells the fairy tale and can be found at www.livingheritage.org/ (September 2002.)

2 Audio links to the programs can be found at www.bbc.co.uk/radio4/discover/archive_features/36.shtml (September 2002.)

3 The full paper was first published in *Qualitative Studies in Education*, 1996, Vol. 9, No. 4, and can be found at www.ul.ie/~philos/vol2/deegan.html (September 2002.)

4 The syllabus for technology as a school subject can be found in Swedish at www3.skolverket.se/ki/SV/0102/sf/11/kurs/_TK010.html, and in English at www3.skolverket.se/ki/eng/comp.pdf, pages 94-98. (September 2002.)