



FACULTY OF ARTS AND SCIENCES
LINKÖPING UNIVERSITY

Programme for the National Graduate School in Science and Technology Education

**Linköping University in collaboration with Malmö University
College, Kristianstad University College, Kalmar University
College, Karlstad University, Mälardalen University College,
Stockholm Teacher Training College, Umeå University**

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A commentary to the English version of the Programme

It is now two years since the Swedish version of the programme of the National Graduate School in Science and Technology Education (FontD, is the Swedish acronym) was published, in March 2001. The program was handed over to The National Agency for Higher Education for approval. It will be found at www.hsv.se.

Some issues in the text concerning organisational matters have been updated in the present English version to make it more informative for the contemporary reader.

No changes have been done in the original text concerning the aims and goals of the programme.

A lot of people were involved in the elaboration of the programme in 2001 (some of those are listed in Appendix 2).

The current information about the Graduate School is continuously updated and available at www.liu.se/fontd.

Linköping University
Campus Norrköping
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Jan-Erik Hagberg
Chairman of the Board of the Graduate School FontD

Helge Strömdahl
Director of the Graduate School FontD

Programme for the National Graduate School in Science and Technology Education

1 National consolidation of research-based teacher training

The University of Linköping has the main responsibility for a National Graduate School in Science and Technology Education.^{1, 2} The Swedish acronym is FontD. The graduate school will form part of an extension of research and the training of researchers in connection with teacher training.

The graduate school has a budget of approx. 12 million SEK per year.^{3, 4} It is placed within the humanistic social-sciences field. According to the Research Policy bill 2000/01:3, the aim is to train 25 doctors. The board of the University of Linköping appointed the committee of the philosophical faculty to be responsible for the formation of the graduate school.⁵

The National Graduate School in Science and Technology Education will, in accordance with the bill, be a joint collaboration between University College Mälardalen, University College Malmö, The College of Education in Stockholm and the University of Karlstad.⁶ The joint partners are natural participants in the activities of the graduate school. The network should, however, also be able to accommodate research environments at other universities and colleges. Thus, Kalmar University College, Kristianstad University College and Umeå University are now full members of the network.

2 The national context of the graduate school – network and centre

The graduate school is constituted as a network. Doctoral students are placed at each participating university/university college and each doctoral student should carry out his/her duties at one of the participating institutions or at a university college (or as a teacher in a school). At the same time it is important that the graduate school have a solid common kernel and that a knowledge base of national and international interest be developed there. The aim thus is that the graduate school should both contribute to the formation of didactic environments at the various universities/university colleges and also function as a national and international arena for didactic research and the training of researchers in the field of science and technology.

¹ The term used in the bill is technological/scientific didactics.

² “Didactics” (and related words) is used in its German and Nordic meaning.

³ Cf. the budget proposal for the year 2001 and the Research Policy bill 2000/01:3, chap. 6.3.6.

⁴ The building phase is for year 2001 5 m SEK, year 2002 10 m. SEK, and from year 2003 12 m. SEK.

⁵ A special Board for teacher training and research with reference to school and teacher training is now (2003) responsible for the activity of the graduate school.

⁶ The basis for the application for setting up a graduate school was done by the University of Linköping in collaboration with the University of Umeå, the College of Education, Stockholm, the University of Lund, Uppsala University and the University of Karlstad.

Didactic research into science and technology is a growing and dynamic field. On the international scene a number of important research environments has appeared, often within or affiliated to programmes in Science Education or Science, Technology and Society (STS), Scientific and Technological Literacy (SLT) or Public Understanding of Science and Technology (PUST). In Sweden the picture is less focussed. An overview of the field has recently been carried out by Helge Strömdahl. There are a few research environments which have been successful during a relatively long period (Gothenburg University, Uppsala University, University College Kristianstad). New investments have been made at several universities and colleges, for example new chairs. Present didactic research is mainly oriented towards science in schools (compulsory and post compulsory education). Research into the teaching of technology is almost non-existent. Similarly didactic research into the area of the environment is weak although such research is now being built up in several places. Strömdahl states in his overview that Swedish researchers within the field of the didactics of science have a good international basis.⁷

The training of researchers into didactics with special reference to science and technology has hitherto been limited in scope and mainly taken place within the subject pedagogics.⁸

Thus the general picture is that both research and the training of researchers is, in an international context, not very well developed in Sweden. The resources which the universities have earmarked for this field have been of a marginal character. The graduate school should be an important contribution to a consolidation of this competence in Sweden.

The partner colleges have an excellent opportunity to develop didactic research into science and technology in along different lines compared to those which have previously been represented in Sweden, but which are of growing international importance and which are particularly relevant for school and teacher training. The present local orientations within the network are however extremely varied and the fields of interest are partly different. This means that the local environments within the graduate school will represent and emphasise different profile areas.

Linköping University

Subject-didactic research has been rather limited at the University of Linköping. There is, however, a general didactic research tradition to build on, represented, inter alia by a chair in pedagogics with a didactic orientation. Within the Communication Studies didactic research and training of researchers in science and mathematics has been going on for a long time. In the science subjects didactic research is being strengthened. The graduate school will affect several departments at Linköping University.⁹

⁷ See the overview by Helge Strömdahl: *No-didaktisk forskning – en lägesrapport och några förslag vid millennieskiftet 1999/2000* (Science-didactic research – a situation report and some suggestions at the turn of the millennium 1999/2000), HSV/NOT project (www.hsv.se).

⁸ The number who have defended a thesis in the research field is approx. 10-12.

⁹ Department of Physics and Measurement Technology, Department of Thematic Studies (Norrköping), Department of Technology and Science (Norrköping), Department of Educational Science, Department of Behavioural Science and The Thema Institute.

The most important contribution to the establishment of a graduate school by Linköping will be the university's long tradition and experience of interdisciplinary research and training of researchers and an ability to unite scientific, sociological and humanistic perspectives in research into complex social issues. An important competence is to be found at the Centre for Technology Education in Schools (Cetis) which is located at Campus Norrköping.

The university plans to give priority to the following orientations: to teach and communicate technology in a schools perspective, to teach and communicate science starting from thematic issues (among other things in the borderland between society, nature and technology) and supra-subject perspectives, visualisation of science and technology and subject-specific didactic research into physics.

Malmö University College

In Malmö, pedagogics has a clear didactic orientation. Several theses have an orientation towards subject-didactics, e.g. the didactics of physics, the environment and technology. Special emphasis is laid on science with an orientation towards environmental issues and sustainable development and the use of information technology in didactic contexts. Several research leaders and visiting professors are attached to this field. There is a well established international network. This research concerns science and technology in a pedagogic-didactic sense, seen from both knowledge theory as well as practical perspectives. The point of departure is thematic or multi-disciplinary and, as a rule, not divided into subjects.

University College Malmö has research profiles within the graduate school in these areas: the didactics of the environment, collaborative learning in science, assessment as a quality in the teaching of science and technology, gender, the teaching of science and technology and science for citizenship.

Kristianstad University College

At University College Kristianstad there has been for several years research being carried out into a research theme with priority: the didactics of mathematics and science subjects. The activities within the research group (LISMA) are divided into three research fields, namely how students, pupils and children learn. This research connects in various ways with the teacher training programmes for pre-school, compulsory school and upper-secondary school which take place at the college. Through collaboration with research groups both nationally (for example Göteborg University) and internationally (for example the universities of Leeds, Kiel, Bremen, Melbourne and Cornell) competence has been strengthened in various areas. There is a well-developed seminar series.

University College Kristianstad, which has decided to focus on the profile area teaching and pedagogical work, can offer a creative research environment in the field of the didactics of mathematics and science, and has a well established national and international network of contacts. Within the framework of the national graduate school University College Kristianstad will give priority to teaching and communicating science from a school and university perspective.

Kalmar University College

University College Kalmar has specialised in the field of science since 1999. A major part of the research which is being conducted is thus in the fields of biomedicine/biotechnology, environmental studies and marine ecology. Didactic research is more limited and more varied. Research into the didactics of science has only recently started with a project supported by the National Board of Universities and Colleges and entitled “Language development and the formation of scientific concepts”. The newly started research into the didactics of science has the advantage of access to research environments for science research. The project can also to a certain extent profit from the competence in pupils’ reading ability and attitudes to reading which has been built up at the college over the last six years.

University College Kalmar is a partner school in the graduate school for gender perspectives. This resource is also expected to enrich the research environment for didactic research.

Karlstad University

At the University of Karlstad there is an ambition to develop research into subject-didactics and present initiatives to establish research into the didactics of science and technology will be reinforced. Subject-didactic research is thus at an initial stage, but it does however form part of a research field given priority to – Learning in school and at work (LISA). A research programme is in the process of being formed at the university. At the departments of Biology, Physics and Chemistry there is development work being carried out into didactics. Interest is focussed on the development of subject-defined research, e.g. the didactics of Biology, Physics and Chemistry. In the future there could be a shift to include issues relating to teaching and communicating science and technology. Courses at the C/D level in the didactics of science have been designed, and they will form a basis for future training of researchers.

Mälardalen University College

University College Mälardalen specialises in technology. The breadth of subjects here is however great and there is a great deal being done in the fields of the Social Sciences and Behavioural Sciences. The college has had its own teacher education programme for almost three years with an orientation towards grades 4-9 and the upper secondary school (16-19). Besides the many technological subjects there are such science subjects as Physics, Chemistry and Biology. Information Design (visualisation) is seen as particularly relevant to the graduate school. Chairs among other things in Pedagogical work, Information design and Electronics are of great significance to the graduate school. The didactics of Physics is part of an area given priority to in the college’s strategy for Physics.

Stockholm Teacher Training College (The Stockholm Institute of Education)

Subject-didactic research is in process of development at Stockholm Teacher Training College. The field is represented by a chair of didactics specialising in subject didactics, and a chair of didactics specialising in science or mathematics has been advertised. Subject didactics is today a research field within pedagogics and more and more theses with a didactic orientation towards different subject areas are being written. Recently the Municipality of Stockholm financed a graduate school in subjects

didactics with ten places for doctoral students at the college. Some of these will specialise in subjects related to science and technology. The College of Education also participates in the OECD's international evaluation project PISA on the scientific knowledge of 15 year-olds.

Research and tutorship, especially in the didactics of science have been conducted during the last decade by several senior researchers with a background both in pedagogics and the science disciplines at the College's three departments. There is also collaboration with other universities and colleges in the country. This competence and environment form the College's most important contribution to the graduate school.

The College of Education will give priority to scientific and technological knowledge cultures. In addition to the subject didactic research environment there is also a research group being formed which will specialise in studies of knowledge cultures and learning environments in school and society.

Umeå University

Since 1997, there has been training of researchers at the University of Umeå in areas of interest to the graduate school at the Department of Chemistry (3 doctoral students). Since 1996/97 there has been a special study-plan for research students at the department with an orientation towards teaching/subject didactics: this leads to a doctorate in Chemistry or Mathematics. This programme has a well-established co-operation and network of contacts both within the university, nationally and internationally. There are also concrete plans to establish a special research training-programme oriented towards teaching/subject-didactics in Physics and Biology.

Collaboration between the subject- and teacher training departments has been strengthened since the introduction of a new examination, Pedagogical work. At present there are three doctoral students at the Department of Mathematics and Science. At the Department of Mathematics and Science there is at present a professor of Gender-research. The Department has a well-developed international network of contacts.

Umeå's most important contributions to the establishment of a graduate school can be summed up in the following fashion: 1) There is an established programme of didactic research linked to subject departments, 2) The emphasis placed on collaboration in the fields of research and the training of researchers between different departments within teacher training has led to the establishment of a common, local, interdisciplinary supra-departmental environment for research students from different departments.

The university will give priority to the following orientations: teaching and communicating technology and science starting from both the perspective of the subjects and the perspective of schools. This will include various teaching/learning forms, the teaching of technology and science and its interaction with society's value-systems and trends. Priority will also be given to research which aims to develop the didactics of technology and science with a starting point in children's/ pupils'/students' interests and culture as well as subject-didactic research into Chemistry.

3 Responsibility, leadership, national and international co-operation

Being a member of the graduate school's network implies a responsibility for the development of the school. First of all, it implies close co-operation on the training of researchers and an acceptance of the fact that the graduate school accepts doctoral students. Secondly, it is expected that each university and college will establish and reinforce its own environment which relates to the graduate school's field and in this way support the doctoral students' local research environment. Thirdly, the participating universities and colleges should be prepared to contribute economically to the training of researchers, for example through partial financing of study-grants or, in some cases, covering the total cost of studies for one or several doctoral students.

The graduate school must also try to achieve a close co-operation with universities and colleges which are not formally connected to the network. This means that the network can be expanded. But there can be other forms of co-operation. This could mean that tutors are attached to the graduate school from other universities and colleges, that courses are arranged jointly, that there are seminars, shared guest-lecturers etc.

The work of the graduate school is led by a board constituted on a national basis. Here the University of Linköping appoints a chairperson and one other member; other universities/colleges have one member each. There are two student representatives. These are appointed by StuFF¹⁰ after consultations with other students unions. Two members representing working life (school or other educational field) can also be appointed.

Each participating university/college will be responsible through its regional development unit (or similar) for the co-operation of the graduate school with schools and local authorities.

The formation of a scientific committee is ongoing at the moment. Through it leading international researchers will be linked to the school. The committee should meet once or twice a year. Its task is to advise on decisions concerning programmes and orientations, strengthen international co-operation above all for the doctoral students and collaborate in the quality control of the training programme for researchers.

The centre for the graduate school is situated at Campus Norrköping. The host department is The Department of Thematic Studies (ITUF) in close co-operation with the Department of Technology and Science (ITN). The Municipality of Norrköping supports the development of the graduate school by funding one doctoral post.

4 The field and the vocational area

The excellent opportunities offered to link the graduate school with the vocational area should be taken advantage of. At each university/college there is a regional development centre or something equivalent. Within this the development project in science and technology can be given priority to. The graduate school will actively work to promote collaboration between the regional development centres. As an example an account is given below of local collaboration initiatives at some of the participating universities and colleges.

¹⁰ Student Union at the Faculty of Philosophy, Univ. of Linköping.

At *Linköping University* the teacher education programmes (including training of researchers) have a field organisation with partner schools. The schools can participate both in research projects and INSET courses for teachers. The other colleges taking part have a similar organisation. An important national contact net is to be found through CETIS (National Centre for Technology in Schools), which is located at Campus Norrköping. Another important meeting place for teachers and pupils in schools is KVA's [The Royal Swedish Academy of Sciences] and IVA's [The Royal Swedish Academy of Engineering Sciences] joint programme "Science and Technology for All". Contacts and co-operation with the NTE project should also be reinforced. In the NyIng project (a government remit regarding the training of civil engineers) the importance for technological training of, among other things, experiments has been studied. Here, too, there are points of contact.

At *Karlstad University* there is a well-established field organisation with partner schools for teaching practice within the teacher education programme. Through this contact net, research with relevance to schools can be established. Similarly, the contact net represents a point of contact between research and practice since research results can be communicated and embedded in the practical work of the classroom. The regional development centre (RUC) is also a contact net for the university as regards schools.

At *Mälardalen University* the teacher-education and tutor-training programmes are still in process of establishing links with field activities and are using certain contact schools with which an intimate co-operation has been established and this is being complemented by other schools with a lesser degree of involvement in teacher training. The co-operation with the contact schools should provide a basis for the training of researchers. Initial contacts have also been made with the regional development centre for the counties of Södermanland and Västmanland to find out about possible funding and other support for a research-training programme based on practical school activities. The college in general has a wide network of contacts both with the compulsory school and with upper secondary. One example is the team competition Young Mathematicians for upper secondary pupils in which some hundred schools take part each year. There is also a centre for ICT pedagogics which works with different schools on a commission basis. Local schools are also involved in discussions about local science centres.

At *Stockholm Teacher Training College (The Stockholm Institute of Education)* the didactics of science subjects has for a long time been a separate subject in the pre-service training of teachers and sandwich courses are offered to teachers up to a masters degree. These courses have been an important basis for creating contact between development work in the field and research in the didactics of science. The college also offers courses for teachers in collaboration with Tom Tits Experiment in Södertälje.

The Stockholm Institute of Education is represented in the steering group for KVA's and IVA's school-development project Science and Technology for Everyone, and takes part at different levels in the NET project. The college has a special remit to develop a teacher training programme geared to special teaching needs for teachers of the deaf and partially deaf. This remit is linked to a development project in the teaching of maths and science.

Umeå University is at present developing collaboration with partner schools. The basic thinking is that students for the duration of their training will be attached to a partner area and thus have an opportunity to follow the children's/pupils' qualitative development in different ways over a number of years. This new organisation will be completed by the time the new teacher education programme is in place in the autumn of 2001. An important link between the university and schools is the regional development centre which the faculty committee for teacher training has established. The centre consists of a co-operation group between the university and representatives of local authorities in Västernorrland, Jämtland, Västerbotten and Norrbotten. It also includes representatives from The National Board of Schools and the Swedish Association of Local Authorities. The centre has an important role to play regarding mutual development of competence and information-spreading between the pedagogical staff in pre-school, school and the staff and researchers at the university. The centre is also supposed to promote contacts between research and the training of researchers at the University of Umeå and local authorities, among other things in order to enable in-service teachers to take part in research and research training.

5 Research training subjects and admittance to the graduate school

The graduate school is to be organised in such a way that the local environments and the growth of an integrated research environment is strengthened. It is necessary that tutors and doctoral students, despite the fact that for the greater part of the year they are working in different parts of Sweden, accept responsibility for the joint research environment and for the development of the knowledge base of the graduate school.

All doctoral students, regardless of background, should take part in common courses. Experience from other graduate schools has shown that a basic model with common, compulsory courses during the first year and thereafter more individually chosen courses is the best solution.

A joint subject for the main group of doctoral students should be the normal model (preliminarily referred to as the Didactics of Science and Technology, or the Didactics of Science, the Didactics of Technology) Specialisation should be able to be indicated (the Didactics of Science with specialisation in ..., or, alternatively, specially ...).¹¹ A joint subject strengthens the graduate school and emphasises the common field of research. Bearing in mind the breadth of the graduate school, training should also be able to lead to an examination in other locally established research subjects – for example, a science subject with didactic orientation, pedagogical work and pedagogics. The University of Karlstad is planning on subject specific research training (physics, didactics etc.) Umeå already has such examinations. The universities/colleges which have examinations can accept doctoral students to the graduate school. A condition is, however, that the research training subject and syllabus match the orientation of the graduate school, which means, among other things, that the joint courses must be allocated space. Decisions about admitting students must be preceded by the national test within the graduate school. Doctoral students at colleges with no examinations will be admitted by Linköping University.

¹¹ The English equivalent is Research in Science and Technology Education.

Prior qualifications for the doctoral training must be relevant to the programme of the graduate school and to the competence of the tutor-group. At least 60 points in a subject relevant to the graduate school with a good C-level essay (or similar) are the minimum demands. There is no reason to specifically limit the admittance of doctoral students to applicants who have in their undergraduate work studied certain given subjects or programmes.¹² What is decisive here is that those who are to be admitted must be able to benefit from the research programme. Admittance should be preceded by a careful individual assessment of the applicants with a special eye to C- and D-essays and examination work. Everyone considered to belong to the leading group should be interviewed.¹³

Admittance to the graduate school should be national and international. Besides this, doctoral students should be able to be admitted who are linked to the participating colleges/universities and who have a grant from their respective colleges. A graduate school assumes that doctoral students can work together and they should be aiming at completing the whole programme. For this reason admittance should be on the basis of batches. Doctoral students who already have a semi-completed research training behind them and who wish to have it taken into account, should not be admitted, at least not until the school consists of at least two year-batches.

The normal model should be that studies are planned so that an examination is taken after five years. Thus there will be space for a 20 per cent assistantship or teaching work parallel to the course. At a later stage part-time students should be admitted so that in-service teachers can take part in the programme.

6 Tutors

Availability of tutors is critical for how many doctoral students that can be admitted. An inventory of interested tutors at the University of Linköping, at the colleges in the network and at other colleges/universities is on-going. The group of tutors should represent a broad spectrum. Each doctoral student should have a main tutor and a secondary tutor. These should complement each other. For example one tutor may have mainly competence in the natural sciences and one mainly competence in the social sciences.

7 Timetable

Work with the programme will continue during the spring of 2001. The faculty committee should be able to establish goals and guidelines for the graduate school by May 2001 at the latest.

The committee for the graduate school must be constituted by March 2001. The committee must draw up a budget and decide which doctoral students to recommend for admittance by the various colleges/universities. A chairperson will have the task of being responsible for the routine business and to submit reports to the committee. The

¹² Special attention should be paid to recruiting doctoral students with a background and interest in pre-school and younger children.

¹³ Regulations on admittance to the research programme can be found in chap. 9 of the University statutes.

scientific committee should be formed during the spring of 2001. It should meet at least once during 2001.

The field of research is very unevenly developed at the participating universities and colleges. A comprehensive work of preparation is needed both as regards the content of the training programme and its organisation. At each university and college there must be extensive local development work. The network model with local environments in combination with a national centre needs to be established before the training programme starts. With this in mind, the participating universities and colleges in the network have decided that admittance of doctoral students will be done for the first time in the spring term of 2002. The programme will be advertised in October, 2001.

Development of the training programme's joint courses is at present being carried out. Syllabuses should be ready by May, 2001.

8 The aims of the graduate school

In the general syllabus for a research training subject the main content of the programme must be indicated. Besides the syllabus there will be a shorter programme with aims and orientations for the graduate school. A preliminary description of aims intended to be incorporated into the programme is presented below.

- The graduate school will train future researchers, future university teachers and schoolteachers in the didactics of science and technology respectively.
- The research training programme will recruit doctoral students with different backgrounds: scientists, technologists (as a rule with a documented didactic profile) humanists, social scientists (as a rule with teacher training qualifications) and teachers of science in schools and municipal adult education.
- The graduate school will promote equality in colleges and in schools.
- The research training programme will strengthen each doctoral student's specific competence as well as develop both a broad, and for each individual, specialised didactic scientific competence.
- The graduate school will contribute to the development of knowledge in schools in a broad sense (pre-school, compulsory school and upper secondary school, and adult education).
- The graduate school will contribute to a research base for teacher training and to providing conditions for an improved research-based education.
- The graduate school will contribute to the establishment of didactic research environments focussing on science and technology at the participating colleges/universities.
- The graduate school will contribute to a better understanding of the various knowledge cultures which have a relevance to teaching and learning science and technology.

The graduate school will contribute to understanding of and reflection over the fields of science and technology both among scientists and technologists but also among social scientists and humanists.

- The graduate school will contribute to increased knowledge of gender systems in relation to education and research in science and technology.

- The graduate school will contribute to increased knowledge about the conditions for educating the general public about science and technology (general knowledge about science)

9 The orientation of the graduate school

The main task of the graduate school is to carry out the training of researchers. A great deal of research will also be carried out partly through the students' thesis-work, and partly through research programmes and projects linked to the graduate school. Attempts should be made to secure a great deal of external funding. A master's examination should also be able to be run by the graduate school.

The interdisciplinary scientific basis

The content of the research concerns science and technology. The methods are as a rule from the social sciences or the humanities. Research is thus by nature a social-science and humanistic practice in the sense that theories and methods are taken from these fields. At the same time it is not possible to carry out qualified didactic research without knowledge of the fields of science and technology. Svein Sjøberg states in an article "Naturfag-didaktik – tverrfaglighet som styrke og problem" that the common or unified perspective for researchers within the field should be the point of departure that the field is genuinely interdisciplinary.¹⁴ He points to three necessary fields of competence: knowledge of science, knowledge of social sciences, and experience of planning and carrying out teaching.

In order to achieve success within the field of the didactics of science and technology it is necessary for researchers and in-service teachers in a wide range of disciplines to co-operate. This necessary co-operation takes in researchers/teachers with a primary base in the scientific and technological disciplines and also in various humanist and social-science disciplines. There is, of course, also a need for knowledge of the field of practice, i.e. what happens in schools and in classrooms, learning outside school, the work of teachers etc.

We should note here that an interdisciplinary and comparative approach fit well into the national context. There are many important didactic research groups linked to a specific subject or to pedagogical departments. Research into larger wholes is less common. By addressing interdisciplinary research the graduate school can contribute important new knowledge while at the same time enriching and increasing knowledge about research being carried out elsewhere.

The interdisciplinary basis means that a theoretical and methodological variation should be the aim. This is natural, too, if we keep in mind that the doctoral students and tutors at the graduate school will belong to different subject orientations and "represent" different scientific fields. In the courses and seminars offered by the school

¹⁴ Sjøberg, Svein, *Naturfag-didaktik – tverrfaglighet som styrke og problem* (Science Didactics – an Interdisciplinary Approach's Strengths and Problems), Lecture given at the sixth Nordic research symposium on science in schools, Joensuu, Finland 12.16 June, 1999.

See also the overview by Helge Strömdahl: *No-didaktisk forskning – en lægesrapport och några förslag vid millennieskiftet 1999/2000* (Science-didactic research – a situation report and some suggestions at the turn of the millennium 1999/2000), HSV/NOT project (www.hsv.se).

questions of a theoretical and methodological nature as well as contacts with international and national research should be given special attention.

Schools and teacher training

How children learn about science and technology, which knowledge is important, what they learn and in which contexts learning takes place are the central issues facing the graduate school. The focus is on how science is taught in schools (including pre-school), but there are two important and natural extensions for the graduate school. The first is to bring about a holistic view of children's and pupils' learning which subsumes the school situation. This means that other institutions than the compulsory school can be in focus, e.g. museums, (science centres), libraries, media and ICT, societies of various sorts and the activities which children and pupils organise for themselves.

The other extension concerns the relationship of the graduate school to the didactic issues of colleges and universities. Teacher training has a double didactic problem: how are the students to learn the subject knowledge they need, and how are the trainee teachers to learn how to teach others science and technology? It is clear that this adds a special dimension to teacher training. The graduate school should address this problem. In this way the didactics of colleges will be included in the work and comparisons and parallels should be made with the teaching and learning of science and technology in other tertiary education programmes. Another interesting aspect is how colleges meet schools and how the teachers at colleges and students interact with schoolteachers and pupils.

The teaching of science and technology at pre-school, in schools and at college level should thus be seen as a whole and in its proper context. The graduate school should thus have an interest in the learning about science and technology at all levels, from the youngest children to adolescents and adults.

About similarities and differences between the didactics of technology and science

The very name graduate school contains a built-in dilemma. The graduate school is to concern itself with questions which have to do with teaching and learning in connection with science *and* technology. Two very comprehensive fields are to be addressed.

Even if the two fields are closely connected to each other and the borderline between technological as opposed to scientific knowledge is in many cases more and more difficult to see (or pointless to mention!), these two fields are parts of different traditions and are borne up by partly different knowledge cultures. In developing the graduate school. It is vital to address the tension that exists between the problem-oriented and practical technological tradition, and the theoretically based scientific tradition. There is also a difference in attitudes regarding how teaching and learning should be conducted in scientific and in technological subjects respectively. When it comes to teaching technology in schools there are goals which besides imparting technological basic knowledge are also concerned with how society at large views technological culture. Aims which are concerned with the development of children's and young people's creative abilities are also an important aspect of the subject technology.

Knowledge structure and knowledge needs

The rapid growth of knowledge and the weakening of traditional borders between subjects means that a number of new issues must be addressed concerning the conditions for long-term scientific and technological learning. Several basic didactic questions are touched on. One way of expressing this is to point to the growing tension which exists between the academic teaching disciplines, the structuring of scientific knowledge which these give and the development of knowledge and knowledge needs in various practices (fields of activity) which use scientific knowledge. It is not only in schools we see this dilemma; the problem is similar in companies, in social planning, politics, work with the environment and journalism.

In schools science is studied as separate subjects (physics, biology, chemistry), as an integrated subject (nature-knowledge or nature orienteering) or in a problem-based way around a specific area (e.g. environment). In the lower age-groups there is normally not a division into subjects. The background of the teachers can vary enormously, from the upper-secondary teachers' subject training to the teachers in grades 1-7 and the pre-school teachers who have a much more general background. Regardless of level and form there is an obvious need in schools for synthesised and problem-oriented knowledge. This need should indicate in which direction the graduate school must move. Research should therefore contribute to the development of scientific and technological learning both in integrated and thematically organised scientific areas as well as in subject-defined areas. To see problems *both* from the needs and conditions of different activities and from the perspective of academic disciplines should be an important point of departure for the graduate school. This means that *both* subject-specific problems and issues which impinge on scientific and technological fields should, in a wider sense, be addressed. Research should thus both address the special questions which concern science subjects and be able to problematise the traditional subject structure from both a knowledge theory standpoint and from a practical perspective.

An interest in integrated areas does not of course mean that we suppose that science disciplines are unified in nature. Quite the opposite. It is important that the graduate school problematise the differences between various scientific fields (both traditionally and in practice) and point to the very great variation which exists in science, both as between subjects/fields as well as between theories, methods, and levels. In the same way the studies into the didactics of technology must have as a starting point variation and tension, partly within technology and partly in relation to science.

The breadth of the graduate school means that research should also be extended in relation to pedagogical theory-formation and its practice. Many of the problems which are central to learning about science can only be seen in a wider social context. Thus pedagogical, sociological, historical and socio-anthropological orientations should, for example, be aimed at.

An important area of development for the graduate school is the study of how technology and science are learned in relation to different knowledge cultures, knowledge traditions and professions. The question of which science knowledge children and young people acquire is closely related to general knowledge and ideas in society at large. This forms a framework for learning which supports or complicates teaching in schools. It is therefore important that we link to it what is internationally referred to as 'Public understanding of science', and which, among other things, includes studies of

public attitudes to and understanding of scientific issues. Basic education in science and general education in science and technology are thus an important issues for the graduate school as are questions about which knowledge basis (concepts, knowledge, understanding) in science and technology schools should communicate to all students regardless of what their life-goals are. What basis do we need in order that our knowledge will develop throughout our lives? What knowledge is needed so that we can participate in and understand social debates on science and technology and exercise our democratic rights?

Children's and young people's interest and curiosity

An important starting point for the research programme is the interest and curiosity which children and young people show in science and technology and how this is maintained or disappears during their schooling. Children are often imbued with a strong sense of curiosity and excitement, which should lead to involvement in questions which are treated in science and technology. A general belief however is that it is difficult for schools to maintain and develop this interest. Various explanations are offered: the school situation in general, general, among other things, parents' attitudes and demands, teachers' lack of knowledge and interest in science and technology, educational forms, the content of science subjects and the character of the insights they generate.¹⁵

All in all, schools' teaching of science and technology and the problems of attracting young people to higher technological and scientific courses raises issues both of how teachers communicate with children about science and technology (see section 10:1) but also of how science and technology are perceived, the content of science and technology and their character as knowledge cultures and traditions (see section 10:2) and of the significance of gender, social class and ethnic background.¹⁶

Questions arising from children's and young people's (and teachers') interest in science and technology must be seen in the light of gender, class and ethnic group. The social system in schools provides aims and ambitions for boys and girls and affects how communication between teacher and pupils takes place. It is possible that the system can be seen more clearly in science and technology teaching than in other areas.¹⁷ It is often stated that, for example, girls are not encouraged to take part in science and technology education.

Other attempts to explain lack of interest in science and technology have among other things focussed on the fact that these are areas which are characterised by a high level of abstraction and which demand a propensity for formal thinking (in the sense that

¹⁵ For example proponents of "Outdoor Education" see a main problem in the separation of school from its special environment. Dahlgren, L-O & Szczepanski A: *Outdoor Education. Literary Education and Sensory Experience*, Linköping Univ. and Kinda Education Center No. 1, 1997.

¹⁶ Jan Schoultz deals with the question of abstractions and the importance of the character of communication between teacher and pupil for understanding of scientific phenomena. Schoultz, J: *Att samtala om/i naturvetenskap. Kommunikation, kontext och artefakt (To Converse About Science. Communication, Context and Artefact)*, Linköping Studies in Education and Psychology, 2000.

¹⁷ The science programme at the upper-secondary school is more and more characterised by a socially skewed recruitment. The earlier 2- and 4-year science programmes attracted many pupils with a different social background than the present one. One question is what significance the Technology programme for upper secondary will have.

Piaget meant, which includes the ability to reason hypothetically). Since many 13-16 year-old are not thought to have reached this level, it has been said that science teaching has “gone over the heads” of many students. Another explanation offered is that the times we live in mean that young people are attracted by other areas such as media and ICT. This last point can be linked to an argument taken up by among others Sjöberg. He sees a possible explanation for the lack of interest in the fact that science as a culture does not appeal to young people. He has in mind those values, the ethics and the way of relating to nature which are implicit in science as well as the special knowledge-forming processes which are associated with such areas.

Despite the fact that science and technology exist in many different activities and forms, it has been reduced to a small number of relatively integrated subjects in the compulsory school.

Traditionally university science has been the model and discussions have been limited to whether or not it is a good thing to teach biology, physics and chemistry as separate subjects or as an integrated whole. This is related to certain ways of seeing what scientific knowledge consists of as well as how science is learned. Since this simplified communication problem (i.e. to not see the question of what scientific knowledge actually is as being problematical nor to see the question of what the practical teaching of science in schools actually achieves as problematical, but to simply problematise pupils’ ability to learn about science) has been challenged during the last decades, there has been a growing need to more closely study the character of knowledge and knowledge-building processes in science and technology both in schools and outside.

10 The programme of the graduate school

Introduction

We have chosen to describe the content of the graduate school from three perspectives:

- Learning and communicating science and technology
- Scientific and technological knowledge cultures in school and society
- Scientific and technological knowledge – general education, democracy, gender and ethnicity

The three perspectives do not mark clear-cut boundaries. It is easy to see that individual theses can, and in many cases should, addresses issues which are approached from and inspired by all perspectives. We wish, therefore, to emphasise wholeness and context as a basis for the content of research training programme and of research. We use, however, the three perspectives to divide the programme into three sub-programmes. We will describe these in the following sections. The sub-programmes should be seen as accounts of a step in the development of the graduate school. Work with the programme will continue during the spring of 2001.

10.1 Sub-programme: Learning and communicating science and technology

In the sub-programme *Learning and communicating science and technology*, it is the learning individual, the teacher’s teaching and the environment which learning takes place in which are central. We are dealing with the basic questions of didactics concerning the content of an area of knowledge, which choices are made, and how learning as well as teaching take place and what is actually achieved i.e. which knowledge,

insights and attitudes are developed by the teacher and the pupil. With terms borrowed from Björn Andersson we can speak of the identity, legitimacy, selection and communication of content.¹⁸

The graduate school should have a long-term perspective on the learning of science and technology. This means that questions should be asked about how knowledge and understanding are developed over time and what significance early-learned knowledge has for later learning. The opposite is also of great importance: What does it mean for children's and young people's knowledge of and interest in science and technology if the final aims are far removed in time? In order to address these questions it is important that the graduate school devote itself to learning in all age groups and in groups with different interests in science and technology. This means that the research should concern itself with small children, children at school, young people at the upper secondary level, university students and adults, for example in adult educational associations and in municipal adult education programmes.

By *communicating* we mean the exchange which takes place between the learner and the teacher and forms and methods for communicating and illustrating content. Here is to be found the kernel of the teaching situation but also the complex of teaching aids of various kinds to facilitate understanding and to make communication possible. A number of research questions exist on the character of scientific areas in relation to how we can talk about them (experiments, field observations, copying, simulations, calculations, virtual environments). The graduate school should pay particular attention to the growing opportunities to use ICT-based illustrations. Another interesting development potential is thus to be found in scientific and technological teaching making use of visualisation techniques and interactive media. This orientation should include both studies of how visualisation techniques change the basis for teaching and the development of applications.

It is natural in the graduate school with its breadth that different basic perspectives meet. Didactic research can, for example, be carried out within the traditional subjects and in relation to their content. Questions about the correlation between the different universities' education and research and teaching in schools are important in this respect. From another perspective the scientific area of knowledge is perceived to be in part moving away from a division into subjects. There are interesting research questions here about learning and communication based on similarities and differences between different types of science (green and white biology, the visible and the invisible, what is near and what is distant, the experimental and the observable etc.). A third perspective which is often natural in pre-school and the compulsory school is to start from the local environment, from social problems or from thematically chosen areas. How is the knowledge and the analytical ability of the learner developed from this perspective?

Difficult areas?

Science and technology are often perceived as difficult both for pupils and teachers. Does this difficulty have anything to do with the fact that the subjects are abstract and thus can be seen to be removed from reality? One reason in that case could be that

¹⁸ Björn Andersson: *Om ämnesdidaktikens natur, kultur och värdegrund* (On the Nature, Culture and Values of Subject Didactics), Unit for Subject didactics, Univ. of Gothenburg, Oct. 2000.

many phenomena which are studied cannot be seen with the naked eye; another is that a basic thesis in science is that simple models are preferable and that simplifications often lead to a higher degree of abstraction; a third is that scientists' image of science does not match the picture "others" have.

Content and selection

Science and technology are two very comprehensive areas of knowledge. It is neither reasonable nor possible that the goal of teaching in schools should be to cover the whole range. It is rather the case that only severely limited sub-areas can be studied, which means that these areas can be structured and delimited in a number of different ways. For the teacher it is a case of seeing the large picture in the small. He or she should be able to give a logical and comprehensible structure to his/her teaching, for example how different concepts form a hierarchy and be able to clarify the difference between definitions, postulates, deductions, empirically discovered connections, idealisations and special cases. How do different ways of structuring, delimiting and approaching science and technology affect children's, young people's and adults' learning about science and technology? *What* is it one can learn using different approaches to and structuring of content?

Here we find, for researchers into didactics, the familiar question of curricula and objectives, of teaching aids and of teachers' and pupils' actual choices. A possible focus in the graduate school could however be the tension between structure in the content as it is prescribed inside and outside school, inside and outside the classroom, and the freedom and subjective starting point (for example children's questions and concepts) which promote learning and the improvisation which is the result of creative communication. Here too, it should be interesting to look at a combination of studies of the learning situation and of studies over time (from a lower to a higher degree of structure?).

Pensum or abilities

Another aspect of the question of selection is if it concerns what is to be learnt or the abilities the learner is expected to develop through the study of science and technology. The differences between comprehension-oriented science and applications through technology are then highlighted.

Both the educational debate and everyday life in schools are full of rhetoric about goals and ideals. These are well described and problematised in earlier didactic research. One area of interest for the graduate school would however be to investigate how teachers and pupils in science and technology respectively communicate about goals (the teacher is familiar with them as a part of his/her professional competence; for the pupils they can be a hidden agenda) and to what extent the abilities which are desirable actually form part of and are promoted by the learning process.

Examples of such abilities are the development of

- curiosity and creativity
- a scientific and critical approach
- comprehension as a basis for democratic participation
- social, emotional and intellectual maturity, which, among other things, increases one's ability to assess statements and theories presented both by scientists and laymen.

- the ability to use theories and explanation-models
- the ability to look for and develop information and knowledge
- the ability to use and develop working methods and approaches which are common in science and technology
- the ability to work in both an artistic and practical manner (motor skills) (especially with regard to technology).
- the ability to apply knowledge to questions and problems in everyday life and in professional life.
- the ability to understand the importance different concepts, theories and principles have in different contexts, how they can be used and what limitations they have.

Studies of those abilities which are developed through science and technology could for example be taken from the school classroom, texts which are used or various types of examinations in which the pupils' knowledge is assessed.

Formalisation and shaping of scientific and technological knowledge

Science and technology are communicated in a number of different ways: through writing and speech, models, formulae, tables, pictures, simulations etc. One area of research concerns the forms of communication in different learning situations in relation to the content which is to be treated. There is an interesting tension between the formalisation of science and technology through formulae and other exact modes of expression and the need to illustrate and explain.

Operationalisation

A fundamental aspect of all teaching of science and technology and of research is to make things measurable, i.e. to transform (operationalise) abstract concepts into measurable units. Mass is operationalised, for example, through weight, climate through temperature, precipitation through wind conditions, sickness through body-temperature, pulse and sedimentation tests, and eco-systems through species-profiles. Temperature in turn is operationalised through changes in a mercury pillar, precipitation through the number of millimetres of water in a calibrated glass. Which factors are most suitable for realising a phenomenon is a basic question and has implications regarding both the usefulness of science and its credibility.

How do children, young people and teachers communicate about measurable factors in relation to the abstract phenomena and processes and about the relationship between the measurable factors and their illustration through, e.g. graphs?

Models and reality

Different types of images are often used in science and technology education as an aid to understanding or to explain that which is difficult or impossible to explain only in words. Phenomena can be visualised with the help of a number of different tools like, for example, models, illustrations, graphs and tables. Magnetism, for example, is illustrated by placing one or more fictional magnetic rods with a red north pole and a white south pole in the magnetic object, the structure of molecules is illustrated by using different-coloured balls fixed to rods, complex connections are illustrated with the help of squares joined by different arrows.

What kinds of images are used in teaching? What imagery and to what extent do analogies, metaphors, mental-pictures adulterate the underlying comprehension?

Which fallacious concepts arise if images are taken at face value? How do children, young people and teachers talk about pictures whose purpose is to explain scientific and technological phenomena? How do children/young people themselves visualise knowledge? What kind of information do children, young people and teachers take on board, how do they understand a phenomenon when it is visualised with the help of different techniques? An interesting example is the illustration of light (waves, particles), which is in itself a pre-condition for all visualisation. Is it possible to develop an alternative image language which is more faithful to what is being described or where the risk of misunderstanding is less? To what extent is it evident that science in itself contains images? The person who has constructed an image in order to explain something offers, through this image, his/her interpretation in preference to other possible interpretations. The image becomes thus not only the elucidation of something complex which we cannot see but are trying to understand, it also becomes a rendering of the phenomenon, chain of events, connection or process. The uninitiated observer is lured into thinking that the image is a true illustration of reality.

In this way scientific models and theories are often presented wrongly, not least in textbooks and in popular contexts – as an enlarged, simplified and manipulated picture of reality, rather than an aid to interpreting, understanding and coping with the often very complex reality behind the model. This is perhaps particularly evident when we look at the approach to scale-problems in both time and space. These are closely linked to how we attempt to illustrate movement, velocity and change. Pictures of atoms, cells and planets are often, for example, illustrated in a similar fashion, but they differ greatly in regard to size and can with difficulty be illustrated using the same imagery. The movements of electrons, the metabolic activities of the cell and changes in the universe can hardly be studied using the same time-scale. If we study weather for example, it behaves somewhat stochastically and is completely unpredictable if we are looking at a time-scale of more than four to five days. If we, on the other hand, study it over a 30-year period we can see a clear pattern obviously linked to seasons.

How do illustrators cope with the problem of size? How do children, young people and teachers talk about the relation between the choice of illustration and the phenomenon to be described? How do they discuss scale-problems in time and space? How does the visualisation techniques affect comprehension of scales? How do children, young people and teachers discuss the relationship between the representation and what is to be represented? Is one of the reasons that children lose their interest and belief in science that the representations are presented as if they were reality, whereas the children, who are now trained to be critical, realise that they are only representations? How is children's and teachers' understanding of a phenomenon affected by how it is represented (colour, sound, form, smell etc.)?

Is the picture imagery of textbooks changing and is there a greater incidence of pictures? If so, how does this affect pupils' and students' understanding? Do teachers need training to interpret and use pictures? Are pictures seen to be "neutral" or are they seen to contain subconscious messages? Questions arise here about how the gender system affects choice of picture and the understanding of pictures. Do we build in unknown codes of which the illustrator too is unaware and which make interpretation difficult? It is also important to address the issue of how new forms of images, 3D, animations etc., can affect interpretation.

The role of language

Even if we talk the same language there are large variations in how we express ourselves and understand words and phrases. This applies to verbal information, pictures and physical experiences. In order to understand communication about scientific phenomena we need insights into pupils' and teachers' linguistic abilities and how they can be developed. These insights are especially important in the teaching of science since its language is often analytical and abstract. Different people's abilities to understand science can in several contexts be more dependent on how information is formulated than by any inherent difficulty in the content-matter. It might be profitable to investigate if the language of different people and groups limits their ability to understand phenomena and objects. Gaps in language can also limit the ability to, for example, generalise and differentiate verbal or other information and in this way the ability to understand. It could be of value to look into how language teaching in schools relates to the linguistic ability necessary in order to understand and communicate science and technology.

It is not unusual that simplifications or attempts to link scientific phenomena to everyday life lead to abstractions which only make them more difficult to understand. One such example is to be found in a textbook for grades 7-9. This states that a cheese sandwich contains solar energy. This is a very dubious example if we bear in mind that with the same logic petrol is to be seen as an example of solar energy. This becomes an abstraction of a part of our cycle despite the fact that a sandwich is in itself a very concrete object. Scientific concept-formation contains many examples of how linguistically complex, concrete descriptions of events are condensed into one or a few words. These concepts are then regarded as facts and are learned. We can ask ourselves how much of the important information is taken on board when this definition is memorised. How is it possible to achieve the comprehension goals our schools set store by?

It is often the case that scientific *representation* is seen and communicated as being synonymous with what is to be represented. In this way an impression is given that there is a direct link between nature and science. An anecdote about Picasso can serve to illustrate this view of things. Picasso is sitting in a railway compartment with a stranger. The man asks Picasso why he paints such strange pictures instead of painting things the way they are. Picasso asks the man what he means. The man then takes out a photograph from his wallet. "look at this", he says, "this is my wife!" Picasso looks at the photo and then says "isn't she rather short and rather flat?"

10.2 Sub-programme: Scientific and technological knowledge cultures in schools and in society

In this sub-programme our perspectives on teaching and communication are broadened by focusing on the social and cultural contexts for science and technology. This means an interest partly in the actors (individuals and groups) who are the trustees of science and technology, partly in how pupils and students studying science are included in (or excluded from) knowledge cultures and partly in how children and adults in general relate to scientific and technological knowledge.

A starting point is thus that knowledge is not perceived only within an individual, but is also situated in cultural, historical and social contexts. Knowledge exists in and is created in interaction between people, in cultures and their artefacts. This means that

scientific knowledge exists in a discourse of its own where concepts are systematically related to other concepts within the same discourse. The same is true of technological knowledge. Scientific and technological discourses thus describe reality in a special way which differs from other discourses, e.g. everyday discourses.

Learning takes place in social interaction fixed to a situation. To learn science and technology means therefore to acquire the special concepts, to understand their communicative possibilities and to be able to use them. This means transcending everyday understanding and perhaps creating some kind of link between the two. There is hardly any obvious continuity between everyday thinking and scientific and technological thought. They belong to different contexts and represent different languages. An important question is how the teaching of science and technology in schools and universities relates to these discourses. We use the term knowledge culture to denote those suppositions and those attitudes which are taken when science and technology are to be taught and learned.

Organised learning in schools and universities is always carried out in relation to both professional knowledge cultures and to the everyday. Teachers and pupils are a prey to conflicting pressures from the content matter and knowledge theory which is propagated by textbooks, university departments and other teachers, and the knowledge, assumptions and attitudes which exist in their vicinity, among other pupils, parents, in the media etc.

The interest of the graduate school starts from the importance of knowledge cultures for children, and from how young people and adults learn about science and technology. This means that research should address the significance of different knowledge cultures for how and what people learn, and what level of involvement or lack of interest is developed. In schools there are more or less obvious bearers of different knowledge cultures. The pupils move from the pre-schools everyday way of looking at nature and everyday technology, through compulsory school's mixture of thematic and subject-specific starting points to the secondary and upper secondary schools' in general subject-centred teaching. Here there is a number of important research questions which have hitherto mainly been addressed at an initial stage in research.¹⁹

In the courses offered by the graduate school the knowledge cultures of science and technology should be treated both from a historical as well as a culture-sociological and science-theory perspective. Here too, we should strive to maintain a close relation between learning and teaching. The relationship between science and technology and other fields such as religion, art and handicrafts should also be addressed.

Scientific and technological activities as knowledge cultures

Among the activities which avail themselves of scientific and technological knowledge there is a variety of different traditions. These involve more or less explicit agreement as to what type of knowledge is relevant as well as the most suitable way to make knowledge available. Different traditions can differ as to what is perceived to be

¹⁹ Svein Sjøberg presents a detailed overview of both the relationship of schools to science and technology and that of the general public in the book *Naturvetenskap som allmänbildning – en kritisk ämnesdidaktik* (Science as General Knowledge – a Critical Subject Didactics), Studentlitteratur 2000. He presents among other things an overview of research into Norwegian and Swedish science teaching and pupils' knowledge.

meaningful and valid ways of using terms and criteria. Meaning pre-supposes concepts which in their turn pre-suppose criteria for their use. Differences can be about concepts as such, about the logical structure of propositions and about criteria for truth.

Examples of knowledge traditions are technology, medicine and science. Technology and medicine have from a historical point of view mainly been concerned with solving problems (“doing”) whereas science has been characterised by an interest in seeking, explaining and understanding (“knowing”).

Today there is no clear line between these three traditions. Neither is there a map of how knowledge cultures can be described or classified. It is thus possible to imagine a number of different ways to analyse the different traditions and cultures which characterise today’s scientific practice. It is also possible to see a number of different dividing lines between different disciplines and which in their turn are related to several different knowledge cultures. Within universities it is possible to discern fairly clear-cut borders between basic and problem-solving science, between empirical and theoretically oriented science, between experiment and observation, between lab-work and field studies, between science which aims at explaining and understanding natural phenomena and science which has human beings as its starting point. Regardless which categorisation we choose, we will see that there are differences in traditions which result in basic differences in how we think that knowledge should be produced, communicated and reproduced.

If we go from university to school we can ask ourselves the question which knowledge culture applies. In practical lessons in schools we can register the influence of various views of scientific knowledge: going out of school with the children into the countryside and observing or investigating, letting the children carry out experiments or demonstrations in the lab, lectures, so-called “research” where the pupils are encouraged to look for the answers to questions in textbooks.

School and everyday life

An important part of the analysis of the teaching of science and technology in schools is to relate questions to the pupils’ and students’ socio-cultural contexts. In order to be able to analyse how schools affect pupils’ and students’ relation to and knowledge of science and technology other sources of knowledge must be studied, that is the pupils’ /students’ everyday life (films, TV soap operas, advertising, computer games, literature, music, friends, family etc.) This includes questions about where people gain their ideas about how things work and how this is affected by school-teaching and if (and in which case how) there is a difference between the various age-groups.

Many concepts in science and technology have another meaning than they do in everyday language. To what extent is this taken into account? This question can be elucidated by especially analysing teaching forms which differ from the ones traditionally practised in schools. Lengthy experience in the use of alternative pedagogical methods in the teaching of science and technology at various Science Centres) should be made use of.²⁰

²⁰ We can mention the attempts carried out in the USA with “predestined dropouts” from high school who were able to work as assistants teaching at Science Centres; it turned out that a large number went on to college (see www.astc.org/resource/youth/index.htm).

Science and technological activities in and outside school

A number of activities in society generate scientific and technological competence. This is often about developing and applying knowledge which builds on and transgresses the boundaries for science, technology and social sciences. Schools need access to knowledge which has been found “outside” among other things, for teaching about the environment, health-care and medicine and foodstuffs-production.

In everyday life, too, scientific, technological and social perspectives are mixed. In what way is this made evident in schools and colleges? How do pupils define scientific and technological competence in relation to their everyday life? Who, in the eyes of the pupils, has such knowledge and competence? What competence are they themselves interested in acquiring and how do they think they can acquire it? How do teachers define scientific and technological competence in relation to their daily life?

The teacher and new fields of knowledge

The majority of scientific and technological fields are developing fast. The teacher finds himself in a growing tension between modern knowledge and obsolete. In many areas there is a risk that the subject knowledge the teacher has will only have a weak relevance to new fields of research and to how modern scientific theory is presented by researchers and the media. A dynamic approach to knowledge is demanded of the pupils, students and teachers. The teacher must in his/her teaching, as must the schools in those environments which they organise for the teaching of science and technology, communicate/show their view of constancy and change in the given field of knowledge. It is important to analyse the role of the teacher, his/her training and development in relation to the fast changing areas of knowledge which he or she represents.

To communicate (teacher to teacher, and teacher to pupil) science and technology should reasonably at all levels from pre-school to college imply carrying on an on-going discussion as to what basic knowledge is and how it can be developed. A particularly important question is how teacher training prepares students for working as subject experts in areas which are changing not only because the amount of knowledge is increasing but also because basic theories are in flux and new areas of knowledge attract the attention of researchers.²¹

The development of modern biology will serve as an illustration. New knowledge about the structure and function of the DNA molecule as a bearer of our genetic inheritance as well as the charting of the genetic mass of more and more organisms (genome research) is changing the conditions for scientific and technological education and research is changing the map of the disciplines. It is not only biology which is affected but also the physical-, chemical-, technological- and mathematical subject-areas and humanistic and social-science research fields are directly affected too; new “hybrid disciplines” and interdisciplinary environments are being developed. Whole new fields whose aim is to reach a scientific understanding of life-processes have been given the name life science/life sciences.

²¹ The differences between humanities and social sciences on the one hand and science on the other in relation to knowledge-growth is discussed in Liedman, Sven Erik: *I skuggan av framtiden: modernitetens idéhistoria* (In the Shadow of the Future: the History of Ideas in Modernity), Stockholm, 1999.

The growth of life sciences means many new challenges to teaching and learning; disciplines with different cultures and languages must collaborate. How can we make visible what cannot be seen: small molecules, gene-transfer, weak forces and molecular dynamics? To what extent is the situation remedied by using visual presentations with pictures and ICT technology? What other avenues are open to us? The rapid development within this field demands that knowledge which is being communicated is not obsolete. We need a new attitude to the communication of knowledge from both students and teachers.

Examples of possible research questions

Studies of scientific and technological knowledge cultures outside school

Different research practices but also “applied” or “practical” traditions where science is used and developed could be studied. A point here would be to throw light on what kind of knowledge and competencies are used and to create a repertoire of good examples for the teaching of science and technology in schools. By going outside school, it is possible to clarify important knowledge which school should be communicating. What is the basis of “scientific literacy” seen from the point of view of working life?

Studies of scientific and technological knowledge cultures in school

Studies of different teaching traditions both in pre-school, compulsory school and upper secondary school. These can be described as “hybrid cultures” i.e. they borrow their content from science and technology outside school but frame it in a school context. Sometimes this means a reformulation of content into clear questions with exact answers (questions with answer key). Studies of these could among other things provide us with knowledge about what takes place under the labels of science and technology in schools – what kind of scientific and technological knowledge do schools give the students an opportunity to develop and which of these actually develops the pupils.

Studies of relationships between the home, pupil-cultures and knowledge cultures

Different pupils find it more or less easy to become socialised into the different school-cultures. A number of studies exist which have looked into the importance of the home-environment for children’s work in schools and the significance of social and ethical and gender group. Few of these, however, deal with the issue of learning science and technology. Different groups develop different forms of communicative competence which can be more or less homologous with the patterns for communication which exist within different school subjects. The field also concerns the relationship between everyday culture and scientific and technological knowledge culture.

Life sciences in school and general education

The meeting between school and life sciences can give rise to a number of important research questions. How do different schools and teachers react to the changes taking place? Which knowledge will become central, how does this field relate to others, how can ethical and social issues be dealt with, how is teachers’ competence to be developed?

The growth of gene-technology and the possibilities it opens up means that both specialists and the general public need to communicate and discuss rather abstract, complicated and ethically difficult contexts. A basic knowledge in this field is

important for everyone. Both specialists and other citizens should therefore have knowledge and a readiness for discussions of this sort. How is general public knowledge to be promoted? What is the importance of school in this process?

10.3 Sub-programme: Scientific and technological knowledge – general knowledge, democracy, gender and ethnicity

Science and technology from a civic perspective

It is possible to identify a number of different ways of looking at the relationship between scientific knowledge and technological knowledge on the one hand and the ordinary human being/citizen on the other (e.g. Westlin, 2001).²² The relationship can be seen as that between a knowledgeable expert who can make well-informed choices and an uninformed citizen with few opportunities to influence decisions. With this as a starting point, it becomes less important to promote scientific knowledge in everyone. The relationship can also, however, be seen as a part of a democratic conversation in which each individual can and should take part and where respect is shown for each participant's interests.

In a society which has been formed and is being formed by science and technology this knowledge invades all aspects of society. Decisions regarding the present and the future are to a very great extent affected by such knowledge. Thus the everyday lives of each of us are affected. This concerns an interest in and opportunities for understanding and participating in conversations about the development of society, and about our opportunities to affect this development. A relevant question is what knowledge is needed for us to be able to participate and what knowledge people have and would like to have in order to participate in this discourse?

In the rest of this section we discuss the question of the responsibility and role of schools, the universities and adult education institutions as regards general public education in the field of science and technology. This is done against the background of the organised interest which has existed for many years in USA and Britain in the relationship between science and technology on the one hand and the surrounding society and the general public on the other.²³ A broad tradition has developed called Public Understanding of Science and Technology, abbreviated PUST – or sometime just PUS.²⁴ We have in Sweden too looked at these questions in recent years. Our starting point has been a real or expected shortage of scientists and technologists in industry. There is no accepted Swedish acronym corresponding to PUST.

²² Westlin, A.: *Teknik och politiskt handlande. Rationalitet och kritik i den samhällsorienterande undervisningen* (Technology and Political Action. Rationality and Criticism in Teaching Social Sciences), Uppsala Studies in Education 95, 2001.

²³ It is rather often the case that science and technology are interpreted as "scienceandtechnology", as one concept and often with the understanding that technology is a sort of adjunct to science. We are well aware of this, but this text is not the place to discuss this important issue. It is, of course, of great significance for when we choose to organise a field of research around the issues treated here.

²⁴ In some places special PUST chairs have been founded. An interesting discussion of the "PUST tradition" is to be found in J. Gregory, S. Miller: *Science in Public*. Perseus Publishing 2000/Plenum Press 1998.

Problem fields

Behind this interest in the development of research into the didactics of science and technology there are a number of assumptions and problems concerning the interest in and knowledge of these areas, in the general public, and especially in children and young people. This has been described by inter alia John Ziman in terms of lack, usefulness and interest.²⁵

Lack of knowledge and interest among the general public?

Proponents of the “lack” model describe what they call a weak interest in science and technology as well as fragmentary knowledge. Ordinary people, they claim, know too little and are furthermore uninterested. A number of investigations in Sweden have confirmed that children and young people are lacking in knowledge (National School Board, 1993, 94, 96, 98) and that interest in academic knowledge of science and technology is lower than what politicians and planners would wish judging from the numbers choosing such educational programmes at upper secondary level and at the universities.

Ziman points out that the claimed gap between scientists and ordinary people is not new. The same thinking lay behind the British and American organisations for “the Advancement of Sciences” in the early 19th century.²⁶ Throughout time a number of people have invested time and energy in attempting to counteract this lack, but we are forced to conclude that these efforts have been in vain. Ziman is critical of the “lack” model. He says that we are assuming that scientific knowledge is the same as academically formed science. Ziman thinks among other things, that this shortcoming is a result of the fact that the term *science* is too wide and imprecise. At the same time different scientists in the same field have often contradictory views, something which effectively puts in question the claims that science has to objectivity and absolute truth. The “lack” model, which assumes that people in general are uninterested and scientifically illiterate, is thus, according to Ziman, fallacious.²⁷

Usefulness for everybody?

From a social perspective it is assumed that we have a great need of people with scientific and technological knowledge. Behind this assumption there is the idea that the economic development of society is wholly dependent on developments within science and technology. This in turn implies that it is necessary that people in general and children and young people in particular develop an interest in and have good knowledge of science and technology. From an individual perspective too, this knowledge is assumed to be decisive. For the individual, “legitimate” academic knowledge of science and technology is of decisive importance. Such knowledge usually offers advantages in many areas: work, economy, influence and status.

From a more everyday perspective it is claimed that people in a society which has to a large extent been formed by science and technology need knowledge to be able to function as good citizens. This model builds on the assumption that people cannot

²⁵ Ziman, J.: “Not Knowing, Needing to Know and Wanting to Know” in *When Science Meets the Public*. (Ed. Lewenstein, B.V.) Proceedings of a Workshop, AAAS’ Committee on Public Understanding of Science and Technology, 1991.

²⁶ The British Association for the Advancement of Science (BAAS) was founded in 1831.

²⁷ Ziman, J.: *Not Knowing, Needing to Know and Wanting to Know*, p 16.

manage their daily life or their daily tasks as citizens if they do not have access to relevant, scientific knowledge. Such an argument implies that people in advance, during their school years, must be given sufficient scientific knowledge. What is meant here, usually, whether it is explicit or not, is academically formed science. The pupil should, it is contended, have at least a good general proficiency in the nature of science and the world-picture which science projects so that he or she, when the need arises, can mobilize a scientifically related understanding of the problem and how it might be solved.

Ziman is of the view that this model rests on an exaggerated belief in rational choice. It is usually the case that it is quite different knowledge and considerations which influence us when we talk about which motives we have had and how we have reasoned before taking a decision. Again we are talking about different knowledge traditions and their social context.

The individual's own questions?

A completely different starting point is adopted if we see knowledge of science and technology as a question of people's own interests and perceived needs. The question is what people in a given situation feel they want to and need to know. It is, for example, a well-known fact that girls and boys in a school context have different ideas about what is interesting to know.²⁸ This perspective builds on the knowledge of nature and technology which each of us has in our everyday knowledge. An important question is how this context-related knowledge is related to the academic knowledge of science and technology.

PUST – who for and why?

An interesting area of study, both historically and in the present, concerns then motives and interest regarding how we make a case for an increased interest in science and technology. Who have been prominent and which target groups were involved? Which content as regards general education is thought to be important?

In *Science in Public* several interesting examples of this development are described.²⁹ The distinction between science and the general public was first formed when science could be said to have become a culture, or sub-culture, of its own, i.e. in connection with the scientific revolution of the 17th century. This development was, of course, gradual. In the Royal Society, which was started in 1660, there were at least as many laymen who were interested in the new science as there were scientists. It was only during the 19th century that the institution became more strictly scientific. At that time the interested, but non-researching gentlemen disappeared from the organisation. This was a step in the process of professionalisation.

During the 18th century science became a sort of entertainment in educated upper-class homes. Books and laboratory equipment designed for use at home became more common. But with the increasing professionalisation of science experiments moved from the homes and into more publicly organised but closed laboratories. This is when the "PUST need" arose.

²⁸ E.g. Lie, S. & Sjøberg, S.: *Myke jenter i harde fag* (Soft Girls in Hard School Subjects). Tanum, Oslo. 1984. Jacobsson, A: *Pupils' Interactive Learning When Solving Problems in Groups*. Unpublished manuscript. Institution for Pedagogics. University Malmö.

²⁹ J.Gregory, S. Miller: *Science in Public*, Perseus Publishing 2000/Plenum Press 1998. P. 20ff.

However in some sections of society in England towards the end of the 18th century there was hesitancy about introducing the new knowledge to a broader group – “the public”. It was felt that the popularisation of intellectual culture in France during the Enlightenment was to be held responsible for the mental arming of the masses before and during the French Revolution. This was hardly something to be imported from the other side of the Channel. Thus we find here an “anti-PUST” ambition among those in power. Is this possibly unique?

This attitude changed. Already during the first decades of the 19th century there were people, like Jeremy Bentham, who argued that an increased understanding among workers of scientific matters would also increase their understanding of the then prevalent, “natural” social order. But there were other motives. The lectures at the Royal Society were not only frequented by interested members of the middle and upper classes. Skilled workmen could be seen sneaking in the back door to be able to, out of sight of the rest of the audience, learn things which they hoped would improve their lives, not only as individuals, but also as a class. There was a growing political motive among groups who at this time had not been enfranchised.

The popularisation of science during the 19th century thus had several aims. It was felt necessary to bring joy, and the moral quality which followed on increased insight into these questions, to the masses. People also wanted to show how the hand of God guided nature. Through knowledge of the laws of nature the working masses would also come to realise that society rested on a similar basis and would therefore shun political violence. On the other hand, there were groups which felt that the new sciences would be a lever in the political struggle.

Yet another interesting question deals with the very communication of scientific and technological knowledge. During the 19th century the number of newspapers and magazines, which in various ways presented scientific insights and debates, grew in number. The media thus served to increase both formal and informal learning. The same is true about later developments in the media where we now, for example, have museums, radio, TV and, not least, the “Net”. How is teaching in schools influenced by this exposure? What does it mean for pupils and teachers who are learning and teaching about science that NASA’s web portal has a special section for home “education”?

Conclusions

During the 20th century actors, motives and target groups change, as do the media which act as go-betweens when it comes to public perception of science and technology. And this process is still continuing. To study this development could provide us with perspectives on our motives, desirable and feasible solutions concerning the content of and forms for education. PUST-projects in education and research are difficult to delimit. But it is beyond doubt that this area is of great significance for the didactics of the graduate school. It also dovetails nicely with the sub-programme on scientific and technological knowledge cultures.

Appendix 1

The organisation of the graduate school

1 Network

The graduate school is set up as a network among the participating colleges and universities. A centre is established at the University of Linköping, Campus Norrköping. The aim is that the graduate school will both contribute to the formation of didactic environments at the participating colleges/universities and act as a national and international arena for didactic research and training of researchers in science and technology.

2 Responsible faculty board

The board of the University of Linköping has decided that the graduate school will come under the field of responsibility of the Philosophical Faculty, The Board for Educational Sciences. This means that the board is responsible for carrying out those duties which are incumbent under the university statutes and that the board will be responsible for other decisions regarding principles. The faculty board should be able to delegate a number of issues to the board of the graduate school.

3 Board of the graduate school

A board leads the work of the school. The board consists of one representative of each college/university participating in the network. (After agreement eight.) The University of Linköping appoints the chairperson. Students are entitled in accordance with university statutes to three representatives. These are appointed by StuFF¹, but we presume that discussions are held with other students unions. One or more representatives with a good overall picture of school development and problems experienced by school should be elected.

The board of the graduate school decides on a detailed budget, the general design of the research training as well as admittance of doctoral students.

The daily and current leadership of the school is the duty of the school's director. PhD Helge Strömdahl is the Director of the graduate school since 2001. Chairman of the Board of the graduate school is PhD Jan Erik Hagberg. For information about the current staff see www.liu.se/fontd.

4 Scientific committee

An advisory group of internationally prominent researchers will be attached to the school. These should meet once or twice a year. One aim is to increase the opportunities for the doctoral students to carry out parts of their education abroad at universities with interesting research opportunities within the student's particular field of research. Naturally Swedish researchers can belong to the scientific committee. It should consist

¹ The Students' Union at the Philosophical Faculty, Univ. of Linköping

of from six to eight people. In order that the committee can follow the activities of the school programme texts, drafts of theses etc. should be written in English (or translated from Swedish). For information about the current members of the scientific committee see www.liu.se/fontd.

5 Teaching and tutorial staff

Everyone with tutorial duties in respect of doctoral students admitted to the school should be considered part of the staff. Staff members should have a common responsibility for the development of the students who have been admitted.

6 Admittance of doctoral students

Admittance of doctoral students is planned to take place in the spring of 2002 with 12 students, in the autumns of 2003 with 8 students, 2004 with 8 students and 2005 with 4 students. Approximately half of the total cost for financing studies is calculated to be covered by subsidies. The participating colleges and universities are expected to contribute funds towards financing studies and to give priority to local projects in connection with the graduate school. Approximately 10 doctoral students must have defended their thesis no later than 2007. The aim that 25 students are to have defended their thesis can be reached by 2009 at the earliest.

Appendix 2

List of participants in the work with the programme

The following have formed an editorial committee:

Björn Andersson, Göteborg University, Ingrid Carlgren, The Stockholm Institute of Education, Lena Tibell, Umeå University, Gunilla Svingby, Malmö University and Jan-Erik Hagberg (editor), Linköping University.

Contributors to the text have been: Jonte Bernhard, Ingrid Carlgren, Thomas Ginner, Lars-Alfred Engström, Gunilla Svingby, Lena Tibell and Gunilla Öberg.

Comments have been received from, among others: Gustav Helldén, Kristianstad University, Sven Engström, Uppsala University, Mats Lindahl, University of Kalmar.