特別講演

スウェーデンの科学教育：現状と課題

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日本の科学教育関係者の間で、北欧諸国の科学教育が密かに注目されてきている。フィンランド、ノルウェー、スウェーデン、なぜ、PISA などの国際比較調査で好成績を上げているのかと？しかし、その反面、北欧諸国の子どもたちの理科嫌い、科学離れは、日本と同じように、世界トップクラスである。日本と非常に似た科学教育の現状をかかえる北欧諸国の一つスウェーデンの現状を、スウェーデンの科学教育研究者自身はどのように解読してくれるのか？

講演者のプロフィール

ロシアで生まれ、高校で物理、数学、天文学を教えたのち、1986 年にモスクワ大学で博士号（物理学）取得。1988 年からアフリカ、モザンビークの首都マプトにある国立教育開発研究所で科学チームの主任を務め、1990 年から同地の教育大学の講師兼コンサルタントと国立教育開発研究所の科学・テクノロジー教育のコンサルタント・コーディネータを務める。1994 年からスウェーデン、ウプサラ大学に拠点をおくストックホルム教育研究所の教育研究部に勤務し、1998 年からウメア大学の数学・自然科学教育学科、上級講師となり、2003 年から副主任を務める。ロシア語、英語、スウェーデン語、ポルトガル語と多彩な言語をあやつる。今回は、スウェーデンの大学に科学・テクノロジーのカリキュラム開発の大学院修士課程を設立する準備作業のため、日本の現状視察に来日されている。
Trends and issues in Swedish science education

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Science education in Sweden

The area of knowledge commonly designated as “science education” in English speaking countries corresponds in Sweden to “didactics of natural sciences” (naturvetenskaplig didaktik, in Swedish). Didactics of natural sciences as an academic subject and field of research gained recognition in Sweden, as in many other European countries, in the middle of the 1980s (Gil-Pérez, 1996, Ekstig, 2000). This discipline deals with:

- justification of natural science as a school subject,
- selection of content,
- sequencing of its presentation,
- methods of teaching.

Science education research in Sweden was part of general pedagogical research (within subject Pedagogy) till year 2002 when it gained status as an independent research subject. It focuses on teaching/studying/learning and socialisation processes taking place during the study/learning of science and the factors influencing these processes. In the Anglo-American tradition, science education research is much concentrated on explaining teaching and learning from psychological, sociological, linguistic and philosophical perspectives. This has offered important insights into how students develop scientific concepts and what is going on in the science classroom. In Sweden the subject also offers concrete recommendations for improving teach-ability and learn-ability of science content.¹

Discussion in this text will be mainly about teaching/studying/learning science in schools, but nowadays didactics of science has also become an area of interest within Swedish university science faculties. In the first section, I will raise the issue of the status of studying science that is currently being discussed among Swedish science educators and echoed in the broader public debate.

Natural sciences in crisis?

Many European countries are concerned that students find science a difficult and unattractive subject at school - especially at secondary level. Riess (2000) summarises the results of some recent surveys in Germany as follows:

“Science (except biology) and mathematics are the most unpopular subjects in German schools, where physics is disliked most. The rejection by girls and young women is particularly high.”

¹ In English language publications, this area of didactical design of teaching/learning situations for specific content can currently be found under the heading “pedagogical content knowledge (PCK)”. The concept of PCK can be described as a synthesis of subject content, pedagogy and context knowledge. It was introduced by Lee Shulman in 1986. Research on PCK is a new and influential trend in Anglo-American science education, especially at secondary and tertiary educational levels.
The "crisis in science education" is often discussed in international educational journals and conferences. Scientists and politicians have expressed concern about the decreasing level of the scientific literacy of school graduates.

During the past two decades an international trend indicates a decrease in the number of young people anticipating future professional careers connected to physical science and technology. However, this trend is not as clearly expressed in Sweden as in other developed countries. The number of students who choose to enter science and technology education programs at upper secondary school has not changed during the last ten years (total population of the country did not change significantly either). This means quite a stable interest in this field of study. There are over twenty thousand (20,000) students entering these programs every year (about one fourth of the total number). In 2003, for example, 13,872 students enrolled in the national science education program and 6,710, the national technology education program (Skolverket, 2004c).

Girls perform better than boys in most upper secondary school programs including science and technology. They have higher final grades and make the transition more successfully from school to university (Skolverket, 2004b). The same trend is evident for university studies, the number of people studying in the field of science, technology and medicine having increased 14% between 1997 and 2002. The proportion of female students is also steadily increasing in these fields (Backlund & Fröborg, 2004).

Several reasons could be put forward to explain this relatively better situation in the status of science education in Sweden as compared to many other countries.

- Swedish society has a tradition of nurturing a technological culture. (According to the "Eurobarometer" Swedish people, in general, have a more positive attitude towards, and are more interested in, science and technology than in other European countries). (Backlund & Fröborg, 2004).

- Systematic measures have been taken at the national level to attract young people to, and facilitate their study of, science and technology. Over the last ten years two large national science and technology education projects have been funded (NOT 1, 1993-1998 and NOT 2, 1999-2003). National resource centres for the teaching of all the science subjects as well as technology have been established. Additionally, a one-year university bridging science course was introduced for students who needed to raise their competence in science at undergraduate level.

- Children of the steadily growing population of immigrants usually choose to study natural sciences rather than social sciences and humanities, because they expect these subjects to be of more value to them in progressing in Swedish society. (Nowadays, a quarter of all Swedish children has an immigrant background.)

- There is a national attempt to popularise science and technology among young people and adults. There are many different science programs on TV, and a network of well-attended science and technology centres (exploratoriums) across the whole country. Popular science books are attractively printed and available in all schools.

These are some of the factors contributing to maintaining the existing level of interest in studying science among young people.

However, before proceeding with an analysis of different aspects of science education, I would like to give a brief overview of the Swedish school system.
The Swedish school system

I will restrict myself to presenting some facts about the Swedish education system, though more detailed information can be found at the website of the National Agency of Education (in English): http://www.skolverket.se/english/system/index.shtml

An outline of the Swedish school structure is presented in the table below:

<table>
<thead>
<tr>
<th>Preschool activities / daycare</th>
<th>Preschool class Age 6</th>
<th>9 year compulsory school Age 7-16</th>
<th>3 year upper secondary school</th>
<th>3-6 year university / postsecondary education</th>
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</table>

About one million children attend five thousand compulsory schools (grades 1-9). About 6% of the pupils attend privately-run (independent) schools. Preschool and upper secondary schools are not compulsory but over 90% of children attend them. There are 741 upper secondary schools (gymnasium) attended by a third of a million students. About 45% of students continue with their studies at post-secondary level by attendance for three years upper secondary school (Skolverket, 2004c).

The compulsory school guarantees (totally during the 9 years) 6,665 teacher-directed instruction hours (= 60 minutes) for 10 subject/subject areas of which 800 hours (or 12%) are allocated to Natural Sciences (Biology, Physics, Chemistry) and Technology.

Goals- and results oriented Swedish curriculum

Sweden introduced the most recent curriculum (LPO94) ten years ago. (In 1994 it replaced a curriculum, LGR80, valid since 1980). The new curriculum includes statements about the school’s fundamental values and basic objectives and guidelines (see http://www.skolverket.se/pdf/lpo94.pdf). Objectives are presented in a form of certain pre-defined goals for school activities. There are two distinctive categories of goals:

- **Goals to strive towards** specify the orientation of the work in the school. They specify the qualitative development desired in the school.

- **Goals to be attained** express the minimum levels pupils should have attained when leaving school. The schools are responsible for ensuring that pupils are given the opportunity of attaining these goals.

When the new curriculum was introduced, a new goal- and achievement-related grading system also came into effect. The new system awards grades on a 3-point scale, with the possible grades of: Pass (G), Pass with Distinction (VG) and Pass with Special Distinction (MVG).

I rely on a paper by my colleague in Umeå University Professor David Hamilton, in offering some critical insights into Swedish curriculum. According to Hamilton (2003), historically, the notion of the curriculum was based on three ideas: (a) a map of knowledge, (b) a journey (course, track) across the map of knowledge, and (c) a destination. Since the end of the sixteenth century, the curriculum has been linked to assumptions that all knowledge had been mapped (and recorded in the encyclopaedia), that a methodology (didactics) was a 'short cut' to the top of the knowledge pyramid, and that human salvation was the purpose of education and schooling. I will use these three curriculum ideas (map, journey and destination) as a basis for taking a look at the ‘new’ Swedish curriculum.
LPO94 defines the goals (the destination) which leaves identification of the journey to each school and individual teacher. The curriculum does not prescribe at what level and subject to teach or how much time should be allocated for different topics. This is decided by each school according to the staff’s collective view on what is the best way of attaining the curriculum goals. Local school plans are developed for each grade and subject, and are used as the main steering documents for organising everyday teaching/learning.

The Swedish curriculum relies very much on the teacher’s professionalism. It assumes that the individual teacher will exercise his/her professional competence and judgement in selecting what, when and how to teach. There are no central prescriptions concerning what to do or how to attain the goals.

This freedom of choosing a ‘journey’ concerns all forms of educational activities, including pupils’ homework. Many teachers prefer not to give homework at all or make it optional. So, many students seldom do home assignments in science or even mathematics. A recent mathematics education study (carried out with grade 8 students in one region) shows that about 80% of them almost never work with mathematics at home. They manage, it seems, to do all their required work in school. (Workshop presentation, Umeå, 04-09-10)

The system of quality control relies on the effectiveness of school rectors (principal) and municipal departments of education. There are no compulsory national exams. Teachers in agreement with the rector can choose to do optional central/national exams in three core subjects (mathematics, Swedish and English) or develop locally their own tests.

The National Agency of Education carried out an inspection of 220 primary schools in year 2003. In the report (published in August 2004, Skolverket, 2004a), inspectors criticise school leaders for not taking the initiative to assure equality in assessment. The report also expresses concern about the need to improve quality assurance at the local level. This means that the curriculum implementation process needs further improvement.

**Natural sciences in the Swedish curriculum**

Goals formulated in the curriculum are concretised into syllabi. The Science syllabi present, first, the general goals for science studies that the school should strive towards, and then translate them into goals that pupils should have attained by the end of the fifth and ninth years in school. These goals are expressed for three subject areas: Biology, Physics and Chemistry (see schematic chart below).

<table>
<thead>
<tr>
<th>Science studies</th>
<th></th>
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<tbody>
<tr>
<td><strong>Goals to strive towards</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Goals to be attained (grade 5)</strong></td>
<td><strong>Goals to be attained (grade 9)</strong></td>
</tr>
<tr>
<td><strong>Biology</strong></td>
<td><strong>Physics</strong></td>
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<tr>
<td>Goals to strive towards</td>
<td>Goals to strive towards</td>
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<tr>
<td>Goals to be attained (grade 5)</td>
<td>Goals to be attained (grade 5)</td>
</tr>
<tr>
<td>Goals to be attained (grade 9)</td>
<td>Goals to be attained (grade 9)</td>
</tr>
</tbody>
</table>
I now give some examples of how this hierarchical structure appears as text in the science syllabi. I start with general goals to strive towards (presented in three categories) and then show how the first-category goals are interpreted into goals to be attained. I use one subject, Physics as an example.

The three categories of goals to strive towards are as follows (see table below and also http://www.skolverket.se/pdf/english/compsyll.pdf).

The school in its teaching of science studies should aim to ensure that pupils:

1. **Concerning nature and Man**
   - believe in and develop their ability to see patterns and structures which make the world understandable, as well as strengthen this ability through oral, written and investigatory activities,

2. **Concerning scientific activity**
   - develop the insight that science is a specific human activity forming part of our cultural heritage,
   - develop their ability to see how human culture influences and transforms nature,
   - develop the ability to see inter-relationships between observations and theoretical models,
   - develop their knowledge of how experiments are performed on the basis of theories, and how this in its turn leads to changes in theories,

3. **Concerning use of knowledge**
   - develop their concern and responsibility when using nature,
   - develop the ability to use scientific knowledge and experiences as a basis for examining their views,
   - develop a critical and constructive attitude to the reasoning of themselves and others, showing respect and sensitivity to the views of others.

The goals concerning “Nature and Man” (first category) are interpreted in the science syllabus as following:

**Goals to be attained (grade 9) concerning Nature and Man:**
- have a knowledge of the universe, the earth, life and Man's development,
- have an insight into how matter and life is studied at different levels of organisation,
- have a knowledge of the cycles of nature and the flow of energy through different natural and technical systems on the earth,

**In the Physics syllabus we can read goals to aim for concerning nature and Man:**
- develop their knowledge of fundamental concepts in physics in the areas of mechanics, electricity and magnetism, optics, acoustics, heat, as well as atomic and nuclear physics,
- develop their knowledge of energy and energy forms, their transformation and properties, as well as society's supply of energy,
- develop their knowledge of different kinds of radiation and its interaction with matter and living organisms,
- develop their knowledge of the world view of physics on the basis of astronomy and cosmology,

**Goals to be attained (grade 9) in Physics concerning nature and Man:**
- have an insight into how the planets rotate around the sun, as well as how the earth and the moon move in relation to each other, and be able to relate the calendar and seasons of the year to these movements,
- have an insight into basic meteorological phenomena and contexts,
- have an insight into technical applications of electricity circuits and permanent magnets,
- have an insight into the fundamentals of dispersion of sound, hearing, as well as the properties of light and the functions of the eye,
- have a familiarity with narratives about nature, which are to be found in our own culture and that of others,

As we can see from the text above, teachers are able to exercise a lot of freedom in interpreting these goals and defining what level of requirement they should put on students knowledge and skills. This is not an easy task for the subject teacher who is
overloaded with pedagogical and administrative tasks. So, in practice, textbooks are used to define the “mapping of knowledge” and the choice of ‘journey’. Schools can choose different textbooks but after the choice is made, teachers and students stick to the chosen text.

Working towards the goals presented in the science syllabi contributes to the development of what may be described as general citizenship literacy. The Swedish curriculum does not include concepts of scientific literacy nor the notion of scientific method. However, these ideas are built in into the curriculum (e.g. in the extract from the syllabi text presented above) and under categories of “knowledge about nature and Man, knowledge of scientific activity, as well as the use of this knowledge to determine personal views on values connected with, for example, environmental and health issues.” (Skolverket, 2000, p 40). This ideas correlate well with modern definitions of scientific literacy provided, for example, by OECD http://www.pisa.oecd.org/pisa/science.htm

Issues and contradictions in Swedish curriculum and school praxis

Every curriculum reform is both a link with the past, and a break with the past. In Sweden, LP094 could be seen as a continuation of the educational reforms started in the 1960s alongside the introduction of nine years of compulsory schooling. It also draws on educational traditions of “folkbildning” (education of people) that has deep roots in Swedish society. However, the curriculum seems to assume a more idealised picture of Swedish society as a uniform organism (in cultural and economic terms) than it is in the reality of today. I present briefly some example of the contradictions built into the curriculum. They reflect also more general contradictions in Swedish society, which are also in many ways, relevant for science education.

Values versus religion

The recent Swedish curriculum has a very strong focus on values. It could be seen as an instrument for implementing fundamental human and democratic values throughout all subjects. One of the first curriculum statements is that values education should be based on “the ethics borne by Christian tradition and Western humanism” (LPO 94, p. 5). However, a quarter of Swedish student now have a “foreign background” with most of them practicing Islam. As we understand, they do not share Christian values and traditions.

Individualism versus collectivism

"The task of the school is to encourage all pupils to discover their own uniqueness as individuals (LPO 94, p.5). This statement contradicts the deep-rooted Swedish cultural concept of “jantelag”, meaning “be like others, do not try to show off, do as others do, etc”. Perhaps, this cultural feature is still strong in the classrooms where individual work on the whiteboard or individual oral responses in front of the class are rare events.

Boys versus girls

"The school has a responsibility to counteract traditional gender roles.” (LPO 94, p.6). Nowadays, Swedish girls perform better than boys in all school subjects and all educational levels including science, technology and mathematics.² This is becoming a real social issue in that boys have less academic success and therefore less chance for social mobility than girls. Immigrant girls, whose first language is not Swedish, now perform better in Swedish language tests that do boys born in Sweden.

¹ For detailed statistics in English see: http://www.skolverket.se/english/statistics/sos/part1.shtml
Student influence versus responsibility

"By participating in the planning and evaluation of their daily education, and exercising choices over courses, subjects, themes and activities, pupils will develop their ability to exercise influence and take responsibility." (LPO 94, p.6) Students’ influence over subject teaching and choice of study topics has also led to a reduction in the practice of basic skills such as reading, writing and arithmetic. This is a warning sign from recent school inspections (Skolverket, 2004a). These skills need time for training, but children do not like long practical exercises. They can vote them out.

Subject teaching versus interdisciplinary thematic work

Thematic work that integrates different subject areas and forms of work is currently popular in Swedish schools. One example is on environment protection in Västangård primary school in Umeå (North Sweden) for children between 6 and 13 years old. The school organises thematic work around different integrated issues every year. For the academic year 2001/2002 the theme, chosen jointly by the children and the teachers, was “champions of the environment”. During the first meeting, students watched a short film about recycling of cans and PET flasks. It was shown that Sweden is one of the best in the world in recycling this kind of material, but that there are many more things that can be done to protect the environment. Students work within five workshops (sculpture, painting, creative writing, drama, nature) held on the same day for five consecutive weeks.

The work takes place in small, mixed-age groups, and is based on ideas and responsibility coming from the students. Information, knowledge and skills from different subjects are brought together. The final products include sculptures made from waste materials and litter, written articles based on literature studies and interviews with local administrators on waste management, short theatre performances, essays and reports etc.

However, thematic work may contradict the more systematic and structured work needed to build up the fundamentals of subject knowledge.

Indoors versus outdoors

Outdoor activities are popular in many Swedish schools. Their popularity can be explained, on the one hand, by the cultural tradition of a close relationship with nature\(^3\), and on the other hand, by the easy access to the countryside granted by the “Allemansrätten” (literally: Everyman’s right). This is a unique Swedish law that gives every person free access to the forests and lakes regardless of ownership. Most Swedish children thus know how to behave in the forest. They feel comfortable building a hut, or picking wild berries or mushrooms. The nationwide project “Forest in school” has attracted students of all ages. It is organised by the Swedish Ministry of Education in cooperation with the forest industry. Primary schools pupils engage with study activities in the forest for several weeks each year in each of the four seasons. They learn how to measure tree height and forest area, plant a new forest, identify birds and plants, and do environmental studies. Many activities are organised in the form form of play or

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3 Results of our comparative study on leisure time habits of Russian and Swedish student teachers:

<table>
<thead>
<tr>
<th></th>
<th>reading</th>
<th>nature</th>
<th>friends and family</th>
<th>sport</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sweden</td>
<td>13.6</td>
<td>31.8</td>
<td>56.8</td>
<td>52.3</td>
</tr>
<tr>
<td>Russia</td>
<td>46.4</td>
<td>9.1</td>
<td>8.2</td>
<td>6.4</td>
</tr>
</tbody>
</table>

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competitions. The project has its own newspaper and web page which are developed with active participation of the children (see http://www.skogeniskolan.se/).

Thus, in many Swedish schools, outdoor education is an important curriculum component (see e.g. http://www.naturskola.a.se/). However, the different kinds of excursions and activities in natural surroundings seldom include physics or chemistry topics. Teachers appear to have particular difficulties in organising the study of physics or chemistry in outdoor settings. This fact was also confirmed by research presented in a thesis by one of our graduate students. In our department, we actively work on this topic by providing students with experience of physics and chemistry activities in natural settings and supporting them with Internet-based resources.

**ICT versus practical experience**

In Sweden, ICT has penetrated into science education and everyday school life. Most students have computers at home and a permanent broadband connection to the Internet. The explosive development of the Internet demands development of new basic skills. In Sweden, we talk about *S-knowledge: search, sift, sort, structure and systematise*. Use of the Web and web-based learning platforms are organic parts of formal and informal learning in Sweden.

Sweden also has a nation-wide system of audio-visual resource centres (*AV-centralen*) from which schools and teacher education departments can borrow AV-equipment and materials. It is also possible to order from *AV-centralen* any educational film shown on TV. Municipal libraries, universities and schools usually have multimedia departments which hold, for example, “talking books” on science education and school textbooks recorded on audio tapes. This provides new opportunities for learning for people with visual impairments, reading problems and for whom Swedish is their second language.

However, this ICT-multimedia development seems to have a downside. New technology provides students with different practical experience of the world today that should be reflected in science education. There are many examples for this. Computers are changing students’ writing skills such that young people feel that they do not need to bother with grammar or correct spelling; the computer programs help them with this. So, they are in danger of losing skills of composition and writing. They are also in danger of not developing skills of mental arithmetic because of the presence of calculators in the school and outside.

During my teaching, I have found that many prospective science teachers have never seen an inner structure of an electric bulb nor have had the experience of taking to pieces a lamp or a battery. People in Sweden are very conscious about their environment. They are good at sorting and depositing things for recycling. But this also leads to parents seldom letting their children look at how technical devices are constructed. Industry does not encourage people to try to repair broken things; rather, they are expected to just throw them away and buy new ones. In this sense, students now do not have the same experience of things in the real world as that of previous generations.

**Swedish science education as a dynamic field**

In this short essay I have presented a brief overview of some of the trends and issues in science education in Sweden, which has been drawn from an analysis of relevant literature and my personal experience of work as a science teacher educator in Sweden.

The teacher is a key figure in the school. In the end, it is inevitably an individual science teacher who transforms curriculum, theories and ideas into classroom practice. The
Swedish government is concerned about creating possibilities of continuing professional development for science teachers. For example, between 1999 and 2001, in parallel with NOT project, the government allocated an additional 75 million crowns (7.5 million euros) for in-service training of science, technology and environmental studies teachers (Backlund, Fröborg, 2004).

However, as experience shows, stories of success in science education are based not only on teacher knowledge, pedagogical skills and experience, but to great extent, on the personal qualities of the teacher. At the heart of Swedish didactics of natural sciences lies the close relationship between the teacher and learners. This is what astonishes my Russian friends when they visit Swedish school – how close, and how almost informal is this relationship between teacher and students.

Science education is a dynamic discipline. There are many trends and discourses in Sweden that swing between depth and breadth, subject-based and interdisciplinary teaching, collective and individual work, academic and everyday content, teachers teaching and learners’ activity, and so on. Teachers have always to find a balance between these polar opposites.

It is not only individual talent which drives scientific progress today, but rather the collective teamwork of colleagues. The same principle of teamwork is applied in the Swedish educational system. Science teachers in each school form a subject team that draws up a work plan, interprets a syllabus and develops science teaching.

Traditional curriculum was understood as a linear course, a sequential instructional presentation with predefined journeys for students to follow across the map of knowledge. But modern technologies are opening new possibilities for exploring rapidly expanding field of human knowledge. The Internet structure, for example, allows multiple ways to navigate in this field.

It seems that pedagogy based on constructivist ideas (considering individual learners’ previous educational baggage), cultural diversification of societies and the Internet lead us to a new vision of curriculum. Swedish model of objectives and results based education could be one of the possible attempts to accommodate future visions of the societal development with local socio-cultural and economic conditions.

In 2002, the national research school for science and technology education was founded in Sweden. It has a yearly enrolment of about a dozen of graduate students. Next year we plan to start at Umeå University an international Master of Science Education program, first at this level in Sweden. So, the field of science education and research is developing very actively in Sweden today.

**Literature**


Skolverket (2004a) Pressmeddelande 2004-08-30


http://europa.eu.int/comm/public_opinion/standard_en.htm