# Renewing engineering education in Sweden

Editors: Ingemar Ingemarsson and Ingela Björck

Nylng

ENGLISH SUMMARY

# Renewing engineering education in Sweden

Published in 1999 by
The Department of System Technology
Institute of Technology,
Linköping university

Editors: Ingemar Ingemarsson and Ingela Björck
Translation from Swedish: Alan McLean
Graphic design: Forma Viva, Linköping
Printing: LTAB, Linköping

# Foreword

The Swedish government decided in 1996 to start a project to renew the engineering education in Sweden. Linköping University, Institute of Technology, was put in charge of the project. It has been led by Ingemar Ingemarsson together with Kent Hartman and Håkan Hult. The project is called NyIng. This report is a summary of the final report (in Swedish) of the project.

# Summary

## THE ASSIGNMENT

By force of its decision of May 23, 1996 the Government assigned to Linköping University the task of carrying out a project aimed at modernizing the education leading to university degrees in engineering. The university was at liberty to carry out the assignment as they saw fit, but in collaboration with other universities. In addition, the university was given the task of actively promoting an exchange of experience regarding modernization by means of a number of national conferences. The name "NyIng" has been chosen for the assignment.

It is probably unique for the government to entrust a single university rather than a national committee with the task of analyzing a strategically important education field of great national interest. As it turned out, the method has both advantages and disadvantages. One advantage is that it is quite easy to collaborate in a local group where there exists a common basis of values for the work. A disadvantage is that it is more difficult to engage other universities in a project that in some sense is "owned" by one particular university. For that reason it has in certain cases proved difficult to establish the cooperation called for by the directives. The base for generating new ideas narrows and the necessary establishment is difficult to achieve. A contributing factor has probably also been that the very marked expansion of engineering education in recent years has led to a shortage of teaching staff in most subjects. All available personnel have therefore been fully occupied in planning for and teaching growing numbers of students.

Analyses, views and suggestions are accounted for in this final report. In-depth discussion of certain questions is to be found

in two anthologies and a number of reports in the NyIng report series.

## EDUCATION AND RESEARCH

The primary tasks of the universities are education and research. Another task is that the universities shall ”cooperate with the surrounding community and inform it of its activities”. The Higher Education Act assigns the same priority to both the primary tasks. But that is not how things look in reality. This is apparent in may ways, for instance in the making of appointments in the universities, in setting salaries, in contacts with the media, and sometimes also in internal documents. The picture is really the same when the Government authorities deal with the primary tasks of the universities. For instance, in the party-leader debate in the Riksdag on January 20, 1999, the Prime Minister announced that a research committee is to be formed and a scientific adviser appointed. The task of the committee is to promote discussion between research workers, government and industry. The scientific adviser it to be a person ”who is both eminent and trusted by the research community”. Research committees come and go, but a basic education committee with similar support and tasks is and always has been conspicuous by its absence.

The antagonism or competition that exists between the two activities is really unnecessary. At the deepest level both are concerned with learning processes, and in both cases personal development is just as important as the actual results. Education and research are interdependent. Good basic education is a prerequisite for the emergence of good research students. Good research is in turn a prerequisite for good basic education. It is the leading-edge courses in the basic education that transmit the research results to the future engineering graduates. An important aspect of post-graduate education is indeed participation in basic education.

However, some of the developments of recent years indicate

certain change in the status of basic education. The new employment structure and the rules that will in future apply for teaching appointments point unambiguously in a positive direction. We also very much want to see the NyIng project as a positive sign.

## SWEDISH ENGINEERING EDUCATION TODAY

Complete Master's courses (180 points) are at present given at seven universities. A minor part of the course, usually the first two years, is given at a number of small and medium-sized universities in cooperation with one or more universities/institutes of technology. In all, there are at present some 5500 places for first-year students. Education leading to Bachelor's degree (120 points, 6700 places) is handled by the seven universities that provide Master's courses and at the small and medium-sized universities.

The number of programs that lead to a Master's degree has increased greatly in recent years. In 1991/92 there were 15 study programs; for the academic year 1998/99 no fewer than 32 different study programs are being offered. The number of entries with their own admission codes in the common admission procedure of the National Admissions Office is even larger. The Bachelor programs (120 points) have developed both from the previous general 80-point engineering courses and from local courses linked to regional/local industry. At present there are rather more than 60 Bachelor programs.

The education programs are thus readily available and offer many alternative study routes all over the country. Recruitment to Master's education is on the whole very good, with more than two first-choice applicants per available place. The situation is not so favourable for Bachelor's education. There are areas with very good recruitment, for instance courses connected with IT, whereas other programs have a smaller influx of prospective students. On the whole, however, there is no crisis.

Evaluations by national and international authorities show that the quality of the engineering programs maintains a good international standard. The marked emigration of Swedish Masters of Engineering – currently noted by the media – is considered to depend in part on their education being of "world class". But in the internal debate the picture is often a different one. The word "crisis" is often used there in various connections. In the discussion there is talk of a mathematics crisis, inflexible educational forms and a general lack of resources. On the positive side, there is increased student activity in the discussion regarding educational forms, a vital pedagogical debate with subsequent action, fairly good recruitment, internationalization and the potential of IT development to affect education.

NyIng has reported its analyses and proposals in chapters with the following headings:

- Flexible engineering education
- Cooperation with industry
- Man – technology – society
- Engineering education and gender
- With learning in the centre
- Engage the senses
- Examination and evaluation
- Recruitment
- International aspects
- The students' visions

## FLEXIBLE ENGINEERING EDUCATION

Core questions in this chapter are the structure, content and disposition of the education. Special emphasis is placed on the question of coordination between the Bachelor's and Master's education. The "Y model", which is described in this section, implies a common entry, in the first instance for Bachelor's and Master's courses, but also for other courses built on a two-year technical basis. The model has for many years been applied in Germany and Denmark. NyIng's proposal has many new

ingredients. One of them is that the first two years should have a new content, with an emphasis on technology courses and projects intended to provide sufficient knowledge of the fields of activity of engineers both with Bachelor's and Master's degrees. Initially, therefore, the courses do not include as much mathematics and other theoretical subjects as today's engineering courses. Instead, mathematics runs in parallel with applied subjects throughout the entire course.

This chapter also contains a proposal in the form of an outline of an idea for fundamental changes in the Master's course by making the mathematical-scientific subjects an integral part of the technical courses, changes that would reduce the extent of mathematics and physics as independent subjects.

Two reports in the NyIng series are connected with the chapter: Ingemar Lindskoug's report "From T4 to education to Bachelor's level" and Stefan Olofsson's report "A unified engineering education". Lindskoug's contribution is a history of an important era in Swedish technical education, namely the abandonment of the fourth year (T4) in the technical program of the upper secondary school and the creation of a 2-year and later 3-year univerity course. In his report, Olofsson suggests that the Master's course should in general have the Bachelor´s course as its basis. NyIng does not share this view. On the other hand, we support the proposal for common, simple rules for the transition from Bachelor´s courses to Master's courses.

The chapter also takes up questions of flexibility and opportunities for choice in the courses and interaction between programs. NyIng proposes that the trend towards an increase in the number of programs should be broken. Universities with Bachelor's and Master's programs should review their course offering and agree on principles for the structure of the future education offering. The first year should include basic courses where technology and projects, mathematics and science meet on a basic level but where there is also room for a block of basic courses with MTS (Man – Technology – Society) content.

"Open entry" is an established possibility for postponing the choice of program. In NyIng's view it should be used more often than has been the case. Furthermore, NyIng believes that the students should have more influence on their studies through increased possibilities to choose courses also in the lower years.

## COOPERATION WITH INDUSTRY

The engineering courses are broad in nature, with a large and a many-sided labour market, important parts of which lie within industry. The programs normally have good contacts with industry and important parts of the education take place in close cooperation with firms in a variety of areas. These firms constitute an important part of the educational environment for the majority of the future Master's graduates. NyIng has chosen to give an overview of the cooperation between universities and industry with emphasis on the industrial contacts of the small and medium-sized universities. As an example, two major successful collaborative projects are described: the COOP activity at the university of Trollhättan/Uddevalla and a project with sponsor companies at Jönköping university.

With the Government directives as starting point, NyIng has made a survey and analysis of the COOP activity (Cooperative Education, which means that studies are interleaved with salaried work). The activity implies an active contact between university and industry. It provides scope for reconciling the educational content and incentives to change. Of equal importance is the fact that the university can influence industry by way of its leading-edge courses. There is no difficulty in establishing that this form of organized educational cooperation between university and industry, where studies are interleaved with salaried work, is superior to the students' normal practical training over a number of weeks.

But the activity implies a major undertaking and extra costs for the responsible university. Administrative personnel resources are required as coordinators with responsibility for integrating

theory and practice and for developing and maintaining networks with a large number of companies. COOP lengthens the course for Bachelors by a full half-year. Meaningful COOP activity in the Master's programs would perhaps need to be even longer, about one year. Such a prolongation may be justified for special programs, but hardly on a general basis. The nominal study time for a Swedish Master's degree, 4.5 years, is among the shortest in Europe for comparable education. If the time of study were increased, it is likely that an increase in the course content would be given priority over COOP. The opinion of NyIng is that growth of COOP activity should be stimulated in the Bachelor's programs but that it should not be introduced on a large scale in the Master's courses.

There has for many years been talk of life-long learning, but it is only now that this has become a tangible reality. The knowledge explosion and the major changes in the labour market and society in general make it natural and essential to start competence development quite soon after graduation and continue with it throughout life. It is important that the technical education gives the students both joy in learning and a desire to continue learning, while also finding forms for development of the competence of the personnel at their places of employment. With the aid of modern technology much of this education can take place at each individual's workplace.

Finally, NyIng takes up the question of an organ for discussion with industry. There is a lack of a good forum for the strategic discussion of education between universities with technical education and industry in the wider sense. The Swedish Academy of Engineering Sciences (IVA) is one important forum of this type, but the Academy has many diverse tasks besides questions of technical education. NyIng does not wish to formulate any proposal for a solution but wants to start a debate on how the contacts regarding higher technical education between industry and university on a national level can be strengthened. The aim shall be to draw up strategies for the im-

portant technical education sector as regards the direction and dimensions of the basic education, and to clarify the full weight of the activity and its importance for Sweden as an industrial nation.

## MAN – TECHNOLOGY – SOCIETY

The humanistic and sociological elements in higher technical education have increased in recent years. This area has in some quarters been called MTS (Man – technology – society) and in others TMS. "Non-technological courses" is another term that has been used. The basic idea is that the engineering education – and the engineering professions – need to be broadened, and that the students must be given knowledge and perspective from areas such as communication, ethics, history and philosophy in order to position themselves and their professional role in a wider context. Putting it another way, one can speak of a desire to give the students a chance to train "utilities" that lie close to technology, such as communicative ability and leadership, as well as to increase their theoretical understanding of, precisely, the role of communication in the community, the ethical standpoint of the engineer, and so on. Obviously, the conveyance of such knowledge must be closely allied with the technical education – and the teaching staff – in the wide sense, if it to be seen as an essential part of technology.

The chapter on the MTS activity contains descriptions of the lessons learnt at various universities. There are various ideas of how this should be incorporated in the courses: as theme days or courses? At an early stage or later on in the course? There are also various opinions regarding what new knowledge the students should be informed about: that which lies close to technology or that which is more concerned with broadening the mind, or both? These question are also dealt with in greater depth in the NyIng anthology "Man – Technology – Society in higher technical education".

NyIng proposes that the task of conveying humanistic and so-

ciological knowledge in higher technical education would be developed and deepened. A modern engineer needs such breadth. We also propose that room is made in the various courses for the integration work between teaching staffs that is a prerequisite for fruitful MTS work: it is important that a unified view is developed, while at the same time those involved respect one another as specialists in their subjects.

Experience from the various universities shows that mandatory courses in certain central subjects are of value, since the students can also study the same material, which can also be integrated as recurrent themes in their programs. In addition we also recommend optional courses going to greater depth and the possibility of following single subject courses in the humanities and sociology, so that every individual can choose what interests him or her.

## ENGINEERING EDUCATION AND GENDER

The proportion of female students in the engineering programs has in general increased over the past ten-year period. Both in spite of this and because of this the gender-related aspects of engineering education must be kept under continual observation.

Gender-related aspects are important in spite of the proportion of women having increased, in part because women still constitute a minority of 26 – 28% of the student body. Not least with the recruitment base for coming years in mind, it is important to increase this proportion until engineering education is balanced between the sexes. According to NyIng's research survey, girls drop science in secondary school as a result of their experience of the upper secondary school courses in science and technology and because the technical universities are not considered female-oriented institutions. NyIng would like to point out the need of increased resources to improve the quality and gender-consciousness in the science and technology education. An additional development is the foundation year in mathe-

matics and natural sciences which gives women who have dropped technology and science in the nine-year compulsory school a chance to seek entry into engineering courses. Additionally, the work of reviewing and improving the way in which women's needs and preferences are met by technical university-level education should be intensified, with regard to content, teaching methods and patterns of interaction among students and between students and teachers.

The gender-related aspects are also important because the proportion of women has increased. As distinct from the time when the traditions of engineering education were established, the programs now encompass quite a large group of women whose needs must be taken into account. In Sweden it is principally the educational methods that have attracted interest in this connection. NyIng's research survey shows, on the other hand, that group-based forms of education, which are often assumed to be favourable for the learning of female students, entail special problems in the often masculine environment characteristic of higher technical education. It is important that the teachers in higher technical education get a wider knowledge of gender in an educational context, in order to increase their consciousness of how education is experienced by male and female students, regardless of educational method.

In conclusion, the chapter establishes that gender-related aspects of education have an intrinsic potential for change. Starting from the needs and perspectives of a minority group stimulates new thinking and questioning of old practices in education.

## WITH LEARNING IN THE CENTRE

The division between research and teaching has created unnecessary antagonism in higher education, in the opinion of an increasing number of research workers. The two activities have learning in common. In both research and teaching the aim is to learn, of course with the difference that in the case of research

it is mankind that ”learns” and gains new knowledge, whereas in teaching it is the individual student who learns and thus increased his or her knowledge.

The chapter – like the whole of NyIng's work – has learning as its starting point. In the context of education, this means that the teachers should have the students' learning rather than teaching as their starting point when planning and implementing education. NyIng sees it as one of the most important tasks in technical education to make the teachers adopt this attitude and put it into practice. If learning is put in the centre it follows as a natural consequence that more student-centred forms of teaching are used – PBL, project form, case studies, etc – and that laboratory activities should be reviewed, as these usually have the aim of having the students carry out pre-planned laboratory work rather than experimenting so as to gain understanding.

The chapter reports on trials with teaching that uses PBL as a pedagogical model and courses built on project-organized activities. NyIng has also studied the activities at three new universities (Malmö, Södertörn and Norrköping) in order to gain an impression of the ideas used when making a fresh start without having to take notice of ingrained patterns and structures. At these new universities student-centred forms of teaching are the guiding star, from which it follows that an inter-disciplinary approach is aimed at. In order to facilitate cooperation, discipline-based departments are not used but the teaching is organized into areas such as technology and economics (Malmö), divisions (Södertörn) and a department for three Master's programs (Norrköping). Internationalization in various forms and in many ways is also something on which all three place great emphasis.

All higher education must build on a scientific foundation. However, teachers in higher education usually lack a long pedagogical training, for which reason their theoretical knowledge in the fields of teaching and learning (what is often called

”didactics”) is limited. In order to support the teachers’ development, NyIng recommends the development of a new system of ”critical friends”, i.e. that teachers visit each others’ lectures and provide feedback from this. There are many indications that this develops both the individual teacher and whole educational processes. In addition, NyIng proposes a national effort to establish more didactic research into both subjects and professions in this technical area, research that shall be carried out to a large extent by teachers in these educational areas.

## ENGAGE THE SENSES

The most important ingredients of technical education are to impart and train theoretical knowledge and make use of it in more applied subjects. A large mass of factual knowledge must be conveyed. This is interfoliated with laboratory work, the extent of which varies between programs. The purpose of the laboratory work is often unclear. In some cases it can be seen as an essential component in the proficiency training, e.g. for chemists, but in many cases it is only retained more by habit. Laboratory work often takes the form of the student preparing an experimental situation following detailed instructions, performing various measurements and writing (or copying?) a report. The benefit of this is rather doubtful.

The laboratory activities are often based on the opinion that technology is applied science. But that is a distorted picture. Technology has many bases that are not at all scientific. And in a historical perspective technology has more in common with art than science. Properties like creativity, total experience and striving for beauty are extremely important for an engineer, and this is fostered by both art and science.

At the same time as it is easy to criticise today’s laboratory work one can declare that our students need laboratory and practical activities to a much greater extent than previously. The reasons are that many students of today have much less personal experience of such activities when they come to university and that

today's technology is much less accessible. Practicing technology is a matter both of engaging logical thinking and of utilizing the emotional, sensual, intuitive abilities. This requires that the teaching provides sufficient opportunities for processing technical questions, not only as theoretical (formal) speculations but also for experiencing them in the real world, and tying together these two types of experience.

In this chapter NyIng presents two examples of elements in which the laborative and practical/sensual aspects are focused on: the "Labotek", a new way of organizing laboratory work and the "Mekotek", an establishment where the students can see the theories implemented in concrete objects that can be experienced by all the senses. Opinions are also given on Swedish "Science Centres", their history and future.

The conclusions of the chapter are that the quantity of laborative/practical elements in the teaching should increase, or at least not decrease, that the laboratory should only in exceptional cases be replaced by computer simulation and that the laboratory work should seek for forms that promote the sensual experience.

It is also important that the students have the opportunity of themselves planning their experiments, making their own observations and drawing their own conclusions. In these situations the teacher should play the role of discussion partner rather than instructor.

## ASSESSMENT AND EVALUATION

This chapter treats questions of assessment and course evaluation. Two projects that have received economic support from NyIng are presented, together with a compilation of trial activities in progress at various places in Sweden. Even if, in the opinion of NyIng, the number of trials and the degree of new thinking are in general too small, attempts are being made at a number of places to change and develop the forms of assess-

ment. Several of the projects are concerned with self- and peer-assessment, which depends, among other things on the assessment then becoming an opportunity for learning. Other projects, described as the ”learning assessment”, ”recycling of knowledge” and assessment by a panel, have also as their principal aim to make the assessment both a check and an opportunity for learning. Continuous assessment is also done in several courses, but assessment periods are still the most usual.

Assessment has a very central position in higher education. It steers study effort to too great an extent, and NyIng is of the opinion that the engineering programs must instead work towards letting the objectives steer. We think that this should be achieved if a transition is made to more student-oriented forms of education, such as PBL, project-organized teaching and case studies. We also see the assessment as a part of the student's learning and not merely as a knowledge check. NyIng proposes that the teachers should devote more time than today to the assessment by adopting a more continuous examination and more highly developed feedback to the students regarding their work. Some research workers consider that some 30% of the teaching time should be devoted to assessment. NyIng does not wish to specify any guide values but merely points to the need of new thinking regarding the tasks to which the teachers should devote time.

In engineering education it is usual to use a system with parallel courses and assessment periods. All the courses are the subject of assessment during the examination period, and then a number of new courses start, all of which shall be subject to assessment during the next assessment period. This leads to jerky learning, with much learning bunched together. NyIng would like to strongly recommend that assessment periods be discontinued. This would probably require that the courses comprise at least 5 points, that at most two courses can run in parallel during 10 weeks, that more assessments are held

continuously during the courses and that more frequent use is made of self- or peer-assessment.

## RECRUITMENT

The basic thought in the Government directives is that the recruitment to higher technical education should be broadened, especially by changing the course content and pedagogy. Proposals for such changes – but with a wider aim – are reported in Chapters II to VIII. In this chapter (IX) educational alternatives are discussed that can directly improve recruiting. These include qualifying preliminary courses (”Foundation year in mathematics and natural sciences”), an initial academic year combined with a basic semester and educational programs for certain target groups.

The chapter starts with a report on the situation of the science and technology subjects in the nine-year compulsory school and upper secondary school. The report arrives at a challenging and interesting conclusion. If the aim is to make a larger number of young people study science and technology, perhaps the only possible strategy is to let the junior schools devote their energy more into attracting and strengthening young people’s interest in the science and technology subjects than pursuing a policy of quality that discourages many young people from taking any interest in these subjects. Further, the chapter comments on a questionnaire on university education aimed at students who had an upper secondary-school background in science or technology but chose ”non-technological” programs at Linköping University. The questionnaire contains a question regarding the reasons for their choosing another study field than engineering. The respondents had to mark three of the alternative responses given. A large proportion, 71%, stated that the engineering profession did not appeal to them and 40% that the program contains too few non-technical subjects. A large group considered that the pedagogy ”does not appeal”.

Several evaluations show that the technical/scientific foundation year is an important recruitment path to technical and scientific education. NyIng proposes that this activity should continue at not less than the current level. As at present, the aim should be to increase the recruitment of women, but also to a greater extent recruit students from the trade-oriented upper secondary school programs. In order to strengthen this recruitment it is necessary to intensify the flow of information to the trade-oriented schools and also to improve the contacts between university and secondary school. NyIng suggests that universities should take the initiative to create permanent contact agencies with this objective.

There are examples of educational programs for certain target groups, in particular programs aimed at computer science and technology for female students. In most cases these programs have worked well and should be more widely spread. NyIng proposes further that academic initial years with a sociological slant (as at Södertörns högskola) should also be given a mathematical-scientific orientation.

## NTERNATIONAL ASPECTS

Over a short period, less than 10 years, Swedish engineering education has markedly increased its international contacts. This applies to exchange of students and teachers, mutual course-development projects and, not least, questions regarding international assessment of quality and quality work in the basic education. In many cases the international contacts directly give incentives to renew our own teaching. NyIng has therefore considered that an integrated presentation of various countries' systems for engineering education could prove valuable in the task of developing and renewing Swedish engineering education.

The descriptions focus especially on questions related to NyIng's assignment. Cooperation within the European Union

is being development by way of SOKRATES and other programs. A majority of the countries chosen in the presentation are therefore EU countries, but we have felt it important to also describe engineering education in some countries outside the Union. In Europe we have chosen Norway and Switzerland, and outside Europe, Australia.

An appendix contains brief accounts of engineering education in some countries in Europe and in Australia. Apart from some fundamental data on engineering education at university (or corresponding) level, the ambition had been to present currently interesting educational questions that lie within NyIng's sphere of interest. These include changes in the organization of the education, systems for quality assurance, examination, etc. In the same appendix there is a compilation of examinations, study times and universities in engineering.

## THE STUDENTS' VISIONS

Starting to study at a university of higher technical education entails considerable change. A newly accepted student is expected to adapt to a completely new way of studying at the same time as he/she has to build up a new circle of friends and acquaintances. High requirements are placed on the student, who has only a couple of weeks to adapt to the new environment and its conditions. In the final chapter of this report, students from a number of universities give their suggestions for improvements in the teaching. On the basis of their situation as students they describe their visions for future higher technical education.

Among other things, the students think that the various courses included in an educational program must be planned in such a way that teaching and examination stimulate the student's creative side and encourage curiosity. The future engineering education should encompass deep technical and mathematical knowledge but also knowledge in the form of other subjects, knowledge that the students are expected to master when they

enter into working life. Maintenance of the high quality of Swedish technical education also calls for continuous scrutiny and quality assurance.

The students also emphasize the importance of having a creative environment and of encouraging critical thinking. The learning should concentrate on giving the learner an overall view of the knowledge which is the aim of the teaching. In order to accomplish this it is essential that the student's first encounter with the university gives a good, rich picture of the education and also conveys a study technique that leads to active learning. The university's contacts with industry are essential, not least as regards practical training and thesis work.

In a future where these visions become reality the engineers will have knowledge that spans over a wide range and a creative vein that has been activated during their education. Creativity and curiosity lead Sweden forward. That is what the students think, and NyIng shares their opinion.