Gender-inclusive Higher Education in Mathematics, Physics and Technology

Five Swedish Development Projects

Inger Wistedt, Stockholm University, Sweden

Högskoleverket 1996

Gender-inclusive Higher Education in Mathematics, Physics and Technology
Five Swedish Development Projects
Högskoleverkets skriftserie 1996:5 S
ISSN 1400-9498
ISRN HSV-SS--96/5--SE
Produced by National Agency for Higher Education (Högskoleverket),
Stockholm, in July 1996
Contents: Inger Wistedt, Stockholm University, Sweden
Graphic Design: Information Department
Printed by Printgraf, Stockholm, Sweden, August 1996

Table of Contents

Preface

The study presented in this report describes five Swedish development projects at the tertiary level of education, funded by the Council for the Renewal of Undergraduate Education: Scientific Problem Solving at Göteborg University, The Project Programme at Stockholm University, D++ (Reforming the Computer Science and Engineering Programme) at Chalmers University of Technology, The IT-Programme at Linköping University and Women in Engineering Education at the University of Karlstad. These five projects aim at recruiting women into mathematics, science and technology by changing the content and work forms of existing programmes or by launching new programmes that will appeal to female students.

The study is based on 22 interviews with lecturers, supervisors, and project leaders enrolled in the programmes, and it is intended to serve as a preparation for an evaluation of the five projects. The aim is to investigate the planners' intentions in order to find out what they are trying to accomplish and thus form a basis for a discussion of possible directions for a follow-up study of the developmental endeavour. The descriptions of the programmes focus on the essential changes in content and forms of teaching implemented and on the motives for these changes, on qualities of student learning promoted within the programmes, on the issue of gender equality and on suitable strategies for attracting female students to the programmes and keeping them.

The study was financed by the Council for the Renewal of Undergraduate Education and it was carried out from September 1995 to May 1996 a period which coincides with the implementation period of the programmes.

The quality of the descriptions presented in this report relies heavily on the good will of the lecturers and tutors who took part in the study. The interviewees' willingness to talk about their experiences, their hopes and fears for the programmes, has provided the data from which conclusions about possible and relevant ways to conduct a follow-up study have been drawn. I thank all the contributers. I also wish to thank collegues who have read and commented on working drafts of the report, and finally I wish to thank Tom Lavelle at the Department of English, Stockholm University for sensitive and professional help in polishing my English.

Stockholm, May 1996

Inger Wistedt

Changing higher education to attract women

In recent decades there has been a broad public debate in Sweden about the problem of recruitment to higher education in mathematics, science and technology. Few students choose to study these subjects at the upper secondary school and of this limited number of students even fewer choose science-related careers at the tertiary level. To make bad things worse, a general drop in application rates to universities can be anticipated in the near future, due to the fact that there will be a diminishing number of students within the age groups entering tertiary education by the turn of the century. These demographic changes coincide with an increased demand for technical expertise in society. An overheated labour market is expected to prevail in fields related to science and technology if nothing is done to meet future needs.

Where shall we turn to find the future mathematicians, physicists and engineers? This state of affairs calls for concern and in the government bill, ”Higher education for higher competence”, (Prop 1992/93:169, my translation) a programme is formulated to meet the challenges. Statistics show that women are underrepresented in mathematics, science and technology and overrepresented in the social sciences and humanities (SCB, 1995, p. 314). Would it be possible to encourage an increased participation of women in science related studies? In the programme, political goals are connected to pedagogical aims: gender issues and issues of equal access to higher education are linked to the question of quality assurance. One of the proposed measures has the form of a special grant of 5 million SEK per annum during a three-year period, allocated to promote change in the form and content of study programmes within higher education in science and technology, with the explicit aim of making them more attractive to female students. The Council for the Renewal of Undergraduate Education is commissioned to distribute these allocations (ibid, p. 92).

A letter of invitation

In June 1993, the Council sent a letter to the presidents of Swedish universities and institutes of technology inviting them to take part in a national competition for funds for development projects, in accordance with the intentions and guidelines expressed in the government bill. The general invitation was followed by a conference in Lund in September 1993, where the prerequisites for the competition were elaborated. The project plans, sanctioned by the university boards, should encompass study programmes, not single courses or subjects, and should be directed towards programmes that currently attract few women. The development projects should comprise both content and forms of teaching, project activities should primarily be directed towards the students, and "according to the Council's intention it should be considered whether it is possible to make use of forms of teaching that are more problem oriented than is currently the case" (Letter of invitation, 1993 09 13, Council for the Renewal of Undergraduate Education, my translation). Admissions procedures should also be taken into account.

A formal invitation to apply for fundings was issued by the Council in September 1993, and three months later five projects were singled out by the review board:

Within the Faculties of Mathematics and Natural Sciences:
Göteborg University: Scientific Problem Solving (3.5 million SEK)
University of Stockholm: The Project Programme (3.1 million SEK)

Within the Master of Science in Engineering:
Chalmers University of Technology: Reforming the Computer Science and Engineering Programme, D++ (3.8 million SEK)
Linköping University: The IT Programme (3.2 million SEK)

Within new Engineering Programmes:
University of Karlstad: Women in Engineering Education (2.7 million SEK)

The funding from the Council was allocated to cover the project costs up to October 1, 1996. Some of the projects, however, received additional fundings from other sources to cover other costs, such as the costs for computer equipment.

The study presented here, describes these five development works with the aim of preparing a follow-up study of the projects. The descriptions are based on 22 interviews with project leaders and teachers engaged in the development projects, 4-5 from each project, and on written materials such as applications, programme descriptions, and information brochures produced within the projects. The study was carried out from September 1995 to May 1996, a period which coincides with the introductory period of the programmes. In August 1995, the first students entered the courses. The projects, discussed and revised during two years of planning, were put into practice.

The present study

To carry out a follow-up study of a project is to provide information that can serve as a basis for judgements about project activities: Are the activities worth the efforts invested? Do they have the intended effects or perhaps other effects never considered? Do the activities have any relations to the goals set up and, if so, are these relations favourable or obstructive?

Defining objectives

Judgements are normative and the norms, serving as a basis for evaluations, are often thought of as equivalent to the goals set up within a project. Sometimes goals are easy to define and the problematic task for the evaluator is to analyse the relations between such unproblematic goals and the means chosen to reach them. Within the field of education, however, this is rarely the case (House, 1980; Franke-Wikberg & Lundgren, 1980). Goals are very often vaguely stated, in terms that are loosely defined. Furthermore, goals tend to develop with the project activities, if the project is, in any true sense, development work. The teachers might, for instance, want to encourage an ”integrated perspective” of the different subjects presented within the programme. This could initially mean that the subjects presented within the courses should be used jointly in the analysis of given tasks. The teachers might later find out, that ”integrating perspectives”, by using them simultaneously, has a tendency to blur the picture of what single subjects can contribute to the analysis of a task. Such insights could encourage the teachers to elaborate their understanding of what ”integrating perspectives” might mean. To make the picture even more complex, goals and means are often spoken about in the same terms. ”Integrating perspectives” might denote a goal (knowledge and skills that the students are supposed to acquire), but might at the same time denote means used to reach that goal (e.g. organizing the study courses into tasks that presuppose the use of diverse subject perspectives). In conclusion, this means that an important first step in any follow-up study of educational change must be to clarify what the planners are trying to achieve (cf. Halldén, 1985) and to choose and argue for what to follow up.

The aim of the study

This study is intended to serve as a preparation for a follow-up study of the five projects that received fundings from the Council for the Renewal of Undergraduate Education. The aim has been to investigate the planners' intentions in order to find out what they are trying to accomplish, and thus to form a basis for the discussion of possible directions for a more focused study of the development work.

- Which essential changes in the content and forms of teaching have been implemented within the projects and what has motivated these changes?
- Which qualities in student learning are promoted within the programmes and how are these qualities related to gender?
- What means have been used to attract female students to the programmes and what has been done to make the studies relevant to them?

Methods

The descriptions are, as mentioned above, based on interviews with project leaders and teachers engaged in the programmes. Each of the 22 individual interviews lasted for about 45-60 minutes. The tape-recorded conversations were transcribed and the interviewee was invited to read through the transcript in order to comment on topics or to make remarks, corrections or elaborations. Seven of the contributors chose to do so. [1]

The interviews were open-ended, covering the main topics described above: the interviewee was asked to give his or her personal view on the essentials of the project and its main objectives, on desired qualities in student learning and how to bring them about and on the issue of gender inequity and how to counteract it. In the descriptions, given below, such views are sometimes presented in direct citations. The excerpts from the transcripts, translated into English, are, in such instances, italicised.

---

[1] On three occasions the offer to read through the transcript was not clearly stated. In these instances the interviewees have been offered the possibility of reading through the transcript at a later date.

Data also comprise written material of various kinds: project plans, descriptions of "Causes for concern and rejoicing" written in preparation for a project meeting arranged by the Council in February 1995 (one out of several joint project meetings held during the planning period 1994-1995), study programme syllabuses, recruitment material, etc. Such material has served as a complement to the interviews.

In the analysis of the interview data, an attempt has been made to seek variations in ways of viewing the projects, their aims and methods. Since the projects are, in essence, development work, variations in intentions are not only to be viewed as probable; they could also be regarded as potentially enriching for the project, by pointing out possible directions for future development. In order to capture such differences in intentions, interviewees with different roles within each project were selected: project leaders, lecturers from different subject areas and tutors. Seven of the interviewees are women. A higher percentage would have been desired, but within some subject areas and some of the projects, female tutors and lecturers are scarce and – all the project leaders are men.

The descriptions of the five projects, based on the interview data and the supplementary material, have each been sent to the interviewees concerned along with an invitation to comment on the presentation of the project and to make corrections of factual errors. Such comments have resulted in minor modifications of the content and phrasing of the texts.

Outline of the report

The presentation of the projects is divided into three sections. The first section describes the two projects within the Faculties of Mathematics and Natural Sciences at the University of Göteborg and the University of Stockholm. The second section decribes the Master of Science in Engineering Programmes at Linköping University and Chalmers University of Technology in Göteborg, and the last section describes the new engineering programmes at the University of Karlstad. Similarities and differences between the projects, soon to be revealed, have motivated this form for presenting data.

The presentation is followed by a thematic analysis, where the results of the study are viewed from an educational perspective. This theoretical reflection on the results is followed by a discussion of possible directions for a follow-up study.

The development projects

During the spring term of 1994, the five projects began their planning period, arranging seminars with experts from universities in Europe and the USA and sending project members to courses and conferences and on study visits to universities within and outside of Sweden (Brenner & Jacobsson, 1994). Reference groups were formed, the general philosophies of the programmes were elaborated, study programmes and study courses were planned and discussed and meetings were held with student representatives, teachers and project leaders.

The descriptions, given below, do not cover all these administrative details of the projects. As mentioned above, the descriptions focus on the intentions of the teachers, their hopes and fears for the programmes, and on their personal experiences of the projects as participants in a development process.

I The projects within the faculties of mathematics and natural sciences

General description

Statistics on the participation of women at the tertiary level show that physics and mathematics are the two university subjects that have the lowest female enrollment (about 25% of the students are women, see SCB, 1995, p. 297). These subjects are included in the programmes at the universities in Göteborg (Scientific Problem Solving) and Stockholm (The Project Programme), and supplemented by environmental science in Göteborg and by mathematical statistics in Stockholm.

The programmes, each admitting 30 students, are alternatives to other course programmes and single-subject courses offered within the Departments of Physics and Mathematics and run parallel to these. Within the programmes, the traditional ways of teaching mathematics and physics are challenged. Traditionally, teaching methods at the tertiary level are built on a transmissive pedagogy. The course material is presented in the form of lectures followed by exercises or laboratory work, where the students, individually or in groups, are given the opportunity to develop their abilities to carry out the types of tasks presented by the lecturer (Burton, 1995). Individual tests are the primary means of assessment. The alternatives to such strategies, offered within the programmes, consist of problem-based studies or projects:

> *"We have radically changed the course structure in physics by viewing it from a thematic perspective",* says one of the teachers in Göteborg.
>
> *"In traditional physics the subject is divided into mechanics, electromagnetic fields and electrical circuits, nuclear physics and the like, but when solving problems the students are supposed to utilize knowledge from all these fields. The basic elements have to be kept intact. Physicists and mathematicians all agree that we cannot meddle with basic knowledge, but hopefully our way of organizing the studies will help the students to see past the boundaries of a single subject field. When working with complex problems, the students have to address several fields of enquiry, within physics* ***plus*** *mathematics* ***plus*** *eventually within environmental science. The successful students have always been able to do that, but the less able students always have great difficulty in going beyond the limits of the subject-field currently studied. To restructure knowledge takes time, and we hope to gain some time by introducing them to problem solving from the very start."*

The study programmes of 160 academic credits (4 years of full-time studies) are divided into a basic course (3 years) where all the three subjects are studied, with primary emphasis on mathematics and physics during the first study year, and an advanced course (one year), where the students specialize within one of the three subjects. Having completed the advanced course the students are awarded a Master of Science Degree.

The projects end with the basic course. At the advanced level the students follow courses and seminars given within the ordinary advanced-study programmes, which means that the students, when leaving the basic course, are supposed to have knowledge and skills that are comparable to the competence of students attending other courses or programmes in mathematics, physics and the supplementary subject. Hopes are high that they will:

> *"I would be profoundly satisfied"* says one of the teachers in Stockholm,

”if the students enrolled in our programme, when finishing their fourth year of studies, and by definition are at the same level as the students attending our ordinary single-subject courses and programmes, have taken the same advanced courses and in addition have an advantage over other students when it comes to structuring problems, cooperating and presenting their thoughts and results orally or in writing. That would be the best of worlds. And,” he adds, *”this might very well come true.”*

Admission procedures

Since the projects aim at recruiting women, the departments have put a great deal of effort into marketing the programmes and into rethinking their admission procedures.

”We were so set on getting 50% women that we even thought of using sex qouta”, says one of the teachers in Stockholm, *”But we were not allowed to.”*

Of the 35 students admitted to the Göteborg programme, Scientific Problem Solving, 20 were women (57%), and 12 out of 30 applicants admitted to the Project Programme in Stockholm were female students (40%). The primary basis for admission was, as usual, grade point average from the upper secondary school, or, for a smaller percentage, the results from the university standard aptitude test or from a combination of grades and work experience credits. But students were also admitted on the basis of a written essay. The applicants were encouraged to write short biographical sketches and to describe their reasons for choosing the programme. This procedure would, presumably, favour students with an explicit interest in and aptitude for the alternative ways of learning offered within the programmes, and especially female applicants, since girls are often better writers than boys.

In Stockholm 12 of the applicants chose to send in essays, 5 of them women. Among those, all who met the entrance requirements were admitted. In Göteborg about 70 students wrote essays, slightly more women than men, and of those, 30 were admitted. The difference in figures between the programmes reveals a difference in application rates. About four times as many students applied to Scientific Problem Solving as to the Project Programme. The reasons for this will be discussed below.

Scientific Problem Solving (Göteborg University)

Studies within the programme Scientific Problem Solving build, as the name indicates, to some extent on the philosophy of Problem Based Learning (Barrows & Tamblyn, 1980; Boud, 1987; Berkson, 1990). The students work in small groups (about 6-7 students in each), composed to maximize variation in experiences (for instance mixing sexes, freshmen with students having some experience in studying at the tertiary level, older students with younger). Each group has its own study-room where the group members can meet any time they like and where they have access to computer equipment. The students can seek information on the Internet and they can easily be reached by their teachers through e-mail.

During their first term, the students take courses in physics and mathematics (comprising 6 academic credits in each subject). They attend lectures, they practice in the physics and math labs and they take individual tests, assessing their subject knowledge. Within the courses in mathematics and physics, the students also carry out shorter assignments. These tasks, often open-ended, are intended to serve as preparation for lectures or projects. One example of such a task, to be carried out by the groups and presented in written reports, is the following, given in the introductory course in mathematics:

> *"Imagine yourself, as a professional scientist, answering the following question posed to you by for instance a sports journalist: In the World Championships in Athletics, the sprinter, Gwen Torrence, was disqualified in the 200 m finals in Göteborg for stepping on the line separating the race tracks. What could one possibly gain (for example measured in time or the like) by "cheating" in this fashion? Would it say have been possible for the second best runner (who eventually was proclaimed the winner) to have won the race, had she also been stepping on the line? Analyse the problem and present your answer to the journalist."*

Parallel to the course work, the students work with group projects under the guidance of a tutor, one in physics and one in mathematics. The tutors follow the students throughout their first term and tutorial meetings are held about twice a week. After a short introductory project in physics, where the students spent a day at the local amusement park (Liseberg), getting acquainted with physical measurement, the studies commenced with a project in physics, comprising four academic credits, carried out within the introductory course "Science and Society":

*"**Part 1**: Suggest appropriate methods to estimate the Earth's:*
-Form
-Size
-Mass
-Inclination axis
-Distance from the sun
-Time of rotation
-Period of revolution around the sun
Carry out some of these measurements
***Part 2**: How would the earth, and life on earth, have been affected, if the estimated results of the measurements in Part 1 were different? Have they ever been different? Will they change in the future?"*

The projects in physics were summarized in written reports and presented orally by the group members to the other students and to the teachers and tutors. The assessments of the written reports were supplemented by individual, oral examinations, probing into the students' knowledge and understanding of the phenomena and ideas studied within the project. The students also had the opportunity to discuss their written reports with a linguist, who read their accounts and commented on the students' skills in writing academic texts.

The physics project, stretching from September to the beginning of November, was followed by a four-credit project in mathematics. The students were presented with a list of ideas from which they were to choose one to work on in their study groups. One example is the following:

"The speed of light is generally considered to be a so called "universal constant", i.e. an immutable magnitude. An Australian researcher has, however, pointed out that the continuous measurements of the speed of light, carried out since the end of the 17th century, show a remarkable pattern. The speed of light seems to decrease by each measurement. As a consequence, the researcher has raised a question: If the speed of light really is a constant, independent of time and space, what is the probability for randomized errors to have given rise to such a series of measurements? He claims to have shown, that the probability for such randomized effects is "improbably small" and that there are reasons to question the assertion that the speed of light is independent of time. This, in turn, leads to new, exceedingly interesting questions: If the speed of light was faster in the past, how much faster was it? What would the consequences of such a notion be, for example for our estimations of the age of the Earth, etc., etc.?

The mathematics projects were supervised, reported and assessed in the same way as the physics projects. The students started their work on the mathematics projects in early November, and in January they reported their results.

By working with the projects and tasks the students also acquired skills in handling the computer programs available. They practiced using the software (LaTeX and MatLab), they learnt how to write texts and draw graphs and how to present their results so as to make them understandable to others.

This short outline of the first term has been presented in order to give the reader a brief idea of the forms of teaching practiced within the programme Scientific Problem Solving. But what about the pedagogical aims? What intentions have motivated these ways of organizing the studies?

The essentials of the programme

The programme, Scientific Problem Solving, was initiated by the Faculty for Mathematics and Science. When the teachers were enrolled in the programme, the overall idea of the project was already in place.

> *"I slipped into the programme because it was assigned to me"*, says one of the teacher with a laugh, *"but I think it is rather exciting and it feels right to change the forms of teaching".*

Another teacher describes the project as on the one hand an opportunity and on the other a difficult task:

> *"Since I've worked for so long within the university system I know the difficulty of changing things from within. At the same time this is of course what you always wanted: to be able do something about the education. But you find yourself faced with the problem of keeping a constant balance, between staying within the traditional framework and accomplishing something entirely new."*

In the interviews, the teachers stress the following aspects of the developmental work:

- the breakaway from the traditional forms of teaching with a heavy reliance on lecturing (*"I've always felt that listening to lectures must be a stupid way of learning maths. I, myself, have always learnt in dialogue with others"*)

- the focus on problem solving (*"...although our version of PBL probably wouldn't be called PBL by those who have seen the light, there still is a great difference between our ways of teaching and the traditional forms"*),

- the emphasis on the applied aspects of the subjects (*"I want them to see the physical aspects of the world around them"*)

- the intergration of mathematics and physics within the study programme (*"Earlier there were watertight bulkheads between the two subjects"*)

- the group work (*"...where you can consolidate your ways of thinking, where you can twist and turn your arguments and pose questions about concepts and models that are unclear or fuzzy to you"*), and

- the considerations for the social aspects of the study milieu: the close contact between teachers and students (*"I believe in our small-scale model. Thirty students! That's living in the lap of luxury"*), and the contact between students within the groups, where each group have access to their own study room (*"A clear quality raiser, that one would wish all students to have the benefit of."*)

The main arguments for these changes bear reference to the learner's perspective, either to the interviewee's own experiences as a learner or to a more generalized student perspective.

Desired qualities in student learning

What qualities in student learning do the teachers refer to when they discuss their teaching methods?

All of the interviewees problematize the traditional forms of teaching. Within the established system, students learn to perform adequately on tasks and tests, but quality in student performance is not always linked to equal quality in their understanding:

> *"One way of explaining why our examinations look the way they do, is to view them as means for teachers to fool themselves into believing that the students are better than they really are, that they are as brilliant as you would want them to be. They can perform all the difficult tricks and we pretend that they are masters of the game. But if you pose a simple question that they are not prepared for, they*

can be unbelievably inadequate. "The students are like trained dogs: *"They can master the toughest tasks, but if you make even minor modifications in the assumptions they are cornered. Trained dogs are not supposed to cope with variations of a given act."* (Lecturer, mathematics)

"It's a relief to get away from questions like 'What page are we on?'. I hate such questions. We try to work on their understanding by giving them questions that will make them reflect, not only to handle standard tasks." (Lecturer, physics)

By emphasizing problem solving, the teachers hope to foster what might be summarized as a 'scientific attitude' in the students. Different qualities in student knowledge are linked to this notion:

- a critical and reflective attitude (*"...their abilities to reflect upon what constitutes a correct solution and not to rely on a key, their skills in viewing phenomena from different perspectives. But in order to develop such qualities you have to find tasks that will allow many different interpretations"*)

- a balance between critique and acceptance (*"It is difficult for students to know what can be taken for granted, what you, yourself, must problematize and what teachers will elaborate in their lectures."*)

- a feeling for the essentials of physics or mathematics (*"You might call it a 'mathematical maturity'. You are able to read a definition and understand that this is nothing but a definition; something to utilize. If you are given a theorem to prove you know what to do. Maybe you can't solve the problem, but you have a notion of what it's all about."*)

- an ability and a sense for abstract reasoning (*"Students can often handle concrete matters, but when you wish them to see the structure of a problem they are stuck."* By working on problems that are not too demanding in subject knowledge and skills, the students have an opportunity to uncover the wonders of abstract thinking. *"It doesn't matter within which field you get the experience. If you have learnt how, you can do it again within a new subject area."*)

By focussing on the applied aspects of the subjects the teachers hope that the subjects will gain in relevance for groups of students who are not spontaneously tuned in to mathematics and physics:

"The interest in mathematics varies a lot, within our ordinary courses as well as within the programme. Many students need to see how the subject knowledge can be used within other areas. I, myself, do not belong to that category. As a student I loved to devote my studies to pure mathematics, and, naturally, I also want my students to see the esthetic charms of the subject. They approach the subject from a different direction, through its applications, but perhaps some of them will, nevertheless, become fascinated by mathematics. I don't know. But it is a possibility."

The teachers also express the belief that by applying subject knowledge the students will be able to bridge the gap between the lived world and the scientific domain:

"Suppose that the students stumble over something while walking down the street: water running in the wrong direction, a sudden chill or a hot airstream, and suppose that they begin to wonder: Good Lord! Why is this so? How can it be explained? And suppose that they take their questions seriously and carry out an investigation. I want them to develop a belief that reality is explainable, not in every detail, but anyway possible to grasp. Many people say, "physics is too hard. It's no use, I won't be able to understand it anyhow. Physics is not for me." I want them to surmount such feelings and find out that physics makes it possible for us to understand our everyday world. A lot of decisions require knowledge of physics: about the environment, about energy consumption, the building of the Öresund Bridge. Take any example. If you don't understand the issues involved you will not be able to act or to take sides in a discussion."

Integrating mathematics and physics is described by the teachers as one way of making the applications viable, i.e. making mathematics more tangible by accentuating its use within physics. All of the teachers, however, are well aware of the difficulties in developing an integrated view of the subject knowledge or, more generally, the difficulties of applying knowledge from one domain within another:

"When the students descibe something in everyday terms, they seem to forget all about the stringency of scientific arguments. And when they calculate and use formulas, they refrain from using verbal argumentations or discussions."

The group work is argued for by reference to learning as a collective enterprise. One of the teachers cites a student, who said:

"Usually you just do assignments, but now you have to defend your views in discussions with others."

In the group discussions the students have an opportunity to develop their communicative skills. In arguing for their assertions and ideas, they have to make their reasoning explicit and they have to relativize their own perspectives. Group work also makes studies more rewarding socially. For a student left alone to walk from lecture hall to lecture hall, one among many anonymous students, it can take years to find someone with whom to discuss course content. Within the programme, peer discussions are part of the learning process from the very start.

To summarize, the teachers hope that the activities implemented within the programme Scientific Problem Solving will foster a scientific attitude in the students, raise their interest in the subjects and develop an integrated view of the different perspectives presented within the courses. The students will, hopefully, be able to link theoretical descriptions to reality, without losing their reasoning capabilities in the process. Argumentative skills and skills in presenting thoughts and ideas to others are important qualities pointed out in the interviews. But, how are all these qualities related to the issue of recruiting women to science and mathematics? How do the teachers view the project activities in light of gender?

The gender issue

In the interviews the teachers were asked to give their opinions on the aim of recruiting women to study science. How do they view their newly implemented teaching methods as means for recruitment? Do the teachers, for instance, judge the traditional forms of teaching as particularly ill suited for female students?

All four interviewees expressed difficulties in discussing the gender specifics of the programme. That mathematics, for example, has a tendency to scare people away is something that both of the mathematicians interviewed are well aware of, but they point out that this seems to apply to women and men alike. The subject is often described as generally hard to master:

"I call it 'lifting-the-heavy-stone-syndrom', perhaps more accentuated in Swedish mathematics than elsewhere in the world."

The view of the mathematician as the lonely genius, who single-handedly solves complex problems in the most elegant way, has been much of an ideal within the subject.

> *"As a consequence, we have not developed a tradition of helping each other, such as by sharing problems. Mentorships often end at the postgraduate level."*

Traditional teaching methods tend to reinforce such notions:

> *"Studying gets tedious. The social environment is scanty and dull. You listen to lectures, work through some exercises and then you go home. You have too little contact with others, too few chances for discussions and... cocksure boys are not good for girls."*

Making the studies more relevant to the students and more socially rewarding, in short, more fun, can be viewed as common features characteristic to PBL, group work and the ideas of integrating subjects by, for example, focussing on the applications of subject knowledge. These features are also described by the interviewees as possible ways to recruit female students:

> *"You can ask yourself the question: Why do girls choose to study social sciences or biology? What attracts them to these subjects? Is it, possibly, that such studies give them a chance to understand phenomena in the world around them? Then, why shouldn't that apply to physics as well."*

On the other hand, it is not obvious to the teachers that girls should be more attracted by, say, applications than boys:

> *"I don't believe that, even if it is an opinion often expressed. I don't think that the secret of attracting women lies in problem-based learning or in the application of knowledge. Other factors play an equally important role within our programme: the ways of teaching and learning for instance, which I truly believe in."*

To summarize, the teachers all have difficulties in pointing out effective means of recruiting women, and they can often find examples to counter their own arguments.

> *"I find the question extremely hard to answer"*, says one of the female lecturers, *"I don't know what preferences girls have."* *"But"*, she goes on, *"the fact that there are so many of them matters. They are more visible and since we have talked so much about making the studies relevant to them, maybe we are a bit more aware of taking good care of them."*

From the student essays, sent in as part of the application procedure, it is possible, however, to draw different conclusions about what has attracted female applicants to the programme. Of the 41 girls who wrote essays as part of their applications, 23 mention environmental studies as a major field of interest, and so do 14 of the 32 male applicants. Combining studies in physics and mathematics with a general interest in the environment and the future problems facing the inhabitants of the Earth seem to have motivated these students to choose the programme Scientific Problem Solving.

The Project Programme (Stockholm University)

The Project Programme was initiated by a group of teachers at the departments of mathematics, mathematical statistics and physics. The ideas originate from a research project, recently carried out at the Department of Mathematics at the Stockholm University (Jacobsson & Elwin-Novak, 1994). The KIM-project (Kvinnor I Matematiken [Women In Mathematics]) investigated the conditions for female students at the mathematics department. The results, based on surveys and interviews with students and lecturers, showed that the female students preferred working in groups, that they were sensitive to the social climate within the department and that they all wished for a qualitatively better pedagogy with closer contact between students and lecturers.

When news of the possibility to apply for fundings reached the departments within the mathematics and science faculty, the physicists knew that this time the departments of physics and mathematics had to join forces if they were to start a developmental project:

> *"An uncoordinated application was bound to create problems. The programmes do, after all, comprise mathematics, physics and math/computers and singling out one subject was bound to fail. I read through the letter of invitation and saw that you could use this opportunity to develop the pedagogy in general. I was of the opinion that our forms of examination, for instance, were inadequate, the testing for genius that tends to go with them. More of submitted papers, group work and the like seemed reasonable. And by getting rid of the genius aspect we would, possibly, open up to new groups of students,* ***including*** *women."*

The teaching methods, implemented within the Project Programme, resemble those that can be found at Roskilde University Center in Denmark:

"We asked ourselves how we were to organize our courses. Well, we were to have projects. But why on earth should that be attractive to women? The only thing we knew was that they had tried out such an organization in Roskilde and they have a lot of women enrolled in their programmes. It could be worth a try."

In Stockholm, as in Roskilde, courses run parallel to the work on projects. The students take courses in mathematics and physics and later in mathematical statistics and throughout the entire first term the students also work with group projects in mathematics (under the heading Mathematical models and their applications), comprising 7 academic credits. The students are organized in study groups of 3 to 6 students. The groups choose one project to work with from a catalogue presenting ideas for projects. One of the projects is the following, chosen by two study groups:

Forms in Nature are often more intricate than simple mathematical figures, such as circles, spheres or rectangles. But even in complicated structures such as coastlines or mountains, branches, blood-vessels or the leaves of furns, you can find regularities, if you just view them in the right way. You will have to abandon some well-known concepts such as 'length' and replace them with new ones. If you ask yourself how long the coastline of Sweden is, you will naturally have to measure in an atlas and, taking account of the scale, give an answer for the length. If you measure on a map showing the whole of Sweden, you will get a different result than if you measure on a more detailed map showing the coastal areas and add the lengths. If you visit the sites you will find small points of land or inlets that cannot be found on any map, so the real length must be longer than the length you can measure on a map. And what about boulders or stones that can be found at the water's edge?

In what respects can mathematical models shed light upon the question of the length of the coast line? Can mathematical concepts be applied when you want to compare, for example, the coast lines of Finland and Sweden, or when you compare the branches of a fir and a birch?

In August 1995, 25 students started their projects. Of the 30 students admitted to the programme, only 28 appeared when the courses started. A few weeks later 23 students remained, 7 of them women. The drop-outs have to be viewed in relation to the low application rates. A majority of the students had not chosen the Project Programme as their first option, and in the turbulence that always occurs at the beginning of a new academic year, students were offered places in courses that they preferred to attend. When the groups reported their results at the end of the term, 16 students remained, 2 of them women.

The low application rates were, of course, a great disappointment to the teachers who firmly believed in their programme. The reasons for the setback were commented on by the teachers in the interviews:

> *"First of all, the Faculty showed a mild interest in our venture. Our ideas were new and not at all elitist, so they were not well received. Secondly, the situation in Stockholm is a bit special. The competition for students is more fierce here than elsewhere. Our catchment area is chiefly Greater Stockholm and all universities within the area compete over the same students and Stockholm University generally has a lower priority among the applicants. Thirdly we deliberately chose not to use terms such as IT or Environment in the title of our programme. /.../ We want to train physicists and mathematicians and mathematical statisticians, not environmental physicists."*

The essentials of the programme

The philosophy of the programme has its origin within the KIM-project, but roots can also be found in the interviewees' own experience of teaching university students. When the teachers described the essentials of the programme, they chose different perspectives for viewing the changes. Three of them (all men) chose the perspective of the educator, while one (a woman) chose to view the changes mainly from the perspective of the learner. The following aspects of the project were identified by the interviewees as essential to the programme:

- the breakaway from traditional forms of teaching and assessing students, which have developed largely as ways to recruit students to a research carrier (*"I view our programme as a way of making science less exclusive, which means that you don't have to be a dedicated scientist to be interested in the studies."*)

- the emphasis on the applied aspects of the subjects (*"Today's young people ask a lot of relevant questions and we will offer them a chance to seek answers to them."*)

- the 'consultant approach' to the course work (*"Courses are designed to give the students the instruments, not to give them an immediate understanding* *of all the exceptions to, for example, certain types of functions or the like, but to supply them with means to carry out investigations."*)

- the project approach (*"Students are given a larger problem area to penetrate, mostly on their own, which will lead to a greater independence of thought."*)
- the group work (*"You can reach a deeper understanding when you are forced to explain something to another human being. I experienced it myself when I started tutoring. It was an eye-opener."*)

These are the means mentioned in the interviews, but what do the teachers hope to achieve, in terms of qualities in student learning, by changing education in the directions described above?

Desired qualities in student learning

By breaking away from the somewhat elitist styles of teaching and assessing, the teachers hope to attract new groups of students with a different attitude towards the subjects:

> *"By defusing the elements, which I, perhaps being prejudiced, think of as male oriented: The achieving approach and all the attitudes that we normally associate with mathematics and physics, we will, hopefully, attract an equal number of men and women from new groups."* These students would bring new qualities: *"We have had long discussions within the project group, if our programme should educate physicists and mathematicians or if we are supposed to produce something entirely new. We did not agree. But my opinion is that we should produce physicists, but physicist with a different background, with experiences in problem solving, in presenting results, with skills in writing and structuring, but with corresponding weaknesses within other areas, for instance, in their knowledge of facts."*

Within the science faculty more than 50% of the students continue their studies at the postgraduate level, a percentage that some of the teachers find absurd. No other faculty even comes close to such a percentage.

> *"If the University sees as its mission to educate its own teachers we cannot justify our existence."*

The students leaving the Project Programme will, hopefully, find their lines of business outside of the University:

> *"This might be a bit prejudiced, but my belief is that our programme will attract people with a bit more problem-oriented and practical approach than the pure theorists. The probable continuation for these people, /.../ would be to continue to the licentiate level and then to work-places in society."*

On the other hand, the programme must not become a blind alley:

> *"...in the sense that those who have studied within the programme will never be able to join the exclusive group that we have educated so far."*

There is a risk, and some people within the section and the faculty have expressed their concerns:

> *"The astronomers for instance do not believe that these students will function as doctorial students. They don't believe in it. Not for the moment, anyhow. They might change their minds, but they are, in my opinion, more sceptical than is reasonable."*

Emphasizing the applied aspects of the subjects is a way of making the studies interesting to these new groups of students:

> *"The strength of the problem orientation is that you can more easily see the relevance of your studies. My hopes are that the projects will not be so restricted and pre-formulated, that they will appear artificial and academic anyhow."*

An interest in the subject matter as such, cannot be taken for granted:

> *"I have always been interested in mathematics, and since I was young I have devoted my time to studying it, and the interest has been a major driving force for me. But if I look at my students they do not always have such a drive. But there can be other motivating factors, such as, for instance, when you are interested in something else which requires you to use the subject knowledge to accomplish some other results."*

The consultant approach to the course work has to do with the intention of revising the course system without making radical changes. The students must, after all, be able to join the ordinary courses at the advanced level.

”The students must not be guinea pigs. Studying costs them time and effort and they have to be given what we have promised them and we can only accomplish that if the programme is flexible. If it works as we intended – Great! If we have to compensate for shortcomings, we must be willing to adjust.”

The courses are intended to function as resources for the students.

”You can’t just have projects. In order to work through a project you need to have some knowledge. Otherwise the project will not be a success. I would like to put it this way: If you take a course, maybe you don’t remember all that you have learnt, but at least you remember ***that*** *knowledge exists and you know* ***where*** *to find it.”*

When discussing the project approach the teachers point to other qualities, beyond the ones already mentioned – the motivation to learn, the desire to pose questions, and skills in presenting thoughts and results:

- the ability to structure problems (*”First of all you have to define the problem, which isn’t easy. Secondly you have to pose the relevant questions that need to be answered in order to illuminate the problem that you have, with some effort, been able to define. Thirdly you have to design an overall approach: how to seek answers to the questions asked.”*)

- the independence of learning (*”Which means that you can reason with some self confidence, that you can handle tasks that are not necessarily of a standard type.”*)

- the ability to model complex situations (*”We find ourselves in a situation where some of us doubt that physics has anything to do with the real world. But we have very good models that fit and work.”*) Proficiency with model concepts and the ability to judge their relevance are qualities pointed out by the physics teachers.

The advantages of working in groups, are described in both cognitive and social terms. Group work helps the students to come into close contact with their peers. This will give them ample opportunities to communicate their thoughts and ideas, which some of the teachers describe as means to reach a deeper understanding of the subject matter. But group work also allows a closer contact between students and teachers. When tutoring, the teachers get to know their students. Such contacts might serve the teachers with a broader foundation for assessing student knowledge. The overly ambitious testing of student knowledge, might as a consequence, be reduced.

The gender issue

In Stockholm, as in Göteborg, the teachers have some difficulty in expressing the gender specifics of the programme:

> *"The sad truth is that we don't know anything about what will recruit women. It's so darned hard to know. Indeed, some of us are women and we are supposed to know. But we are, in fact, the wrong kind of women."*

Answers to these questions also fell outside the scope of the KIM-project:

> *"...since they did not investigate into the attitudes of women who were about to choose a programme, but those who had already made their choice, which makes a hell of a difference."*

That women in particular should prefer applied sciences is nothing the teachers believe in:

> *"My belief is that the differences have nothing to do with women being less interested in theorizing. If we lose the women I believe that this has more to do with attitudes. From collegues and others. Without wanting to point a finger at anyone, it is a fact that female researchers are trusted less than their male collegues, an insight that has struck me rather late in life./.../ She is competent, alright, but we need other capacities./.../ We have recruited some women to our programme and we have to take good care of them, and watch ourselves all the time, so that we treat them in the right way. You must have faith in them. I believe that there are differences between men and women and everyone needs to be respected for what he or she is. That's where my own experiences come in: Try to judge qualities without ranking them. Different qualities are important in their own ways and together we can accomplish something really good. I think it is of vital importance that there are both men and women within every field of human affairs."*

The goal, even if not reached during the implementation year of the programme, is still to recruit more women to physics and mathematics:

> *"Many people formulate this as a question of equality. It would be more fair if women were allowed to devote themselves to abstract reflection in the same way as men, being able to play around with theoretical ideas. Personally I find that aspect of the problem of minor interest. There is so little room for fairness in the*

world anyhow. Personally, I would find it much more exciting if someone told me that the lack of women deprives us of alternative perspectives that we, as men, are incapable of formulating. Many assert that physics is a subject where individual differences do not matter. /.../ I, myself, do not view physics in that way."

II The projects within the master of science programmes in engineering

General description

Master of science courses in engineering are by tradition highly specialized. The students are trained to solve problems within specific technological areas, such as computer engineering, systems analysis, engineering physics and the like. The new master of science programme at Linköping University (The IT-programme) and the reformed D-programme at Chalmers University of Technology in Göteborg (D++), both aim at giving the students a broader education in technology, furnishing them with general skills in solving problems within the fields of computer technology, computer science, systems analysis and the like, but also with abilities to communicate technological perspectives and results to social scientists, economists and others who might need to consult technological expertise.

In order to present such a broad view of technology within the time boundaries of a programme comprising 4.5 study years (180 academic credits), there is a need for a radical re-thinking of the course content, the teaching methods and how teaching is related to learning. Self-directed learning in study groups and problem solving based on real-life examples are some of the hallmarks of the programmes. Such forms of organizing learning are also supposed to be agreeable to female students, and thus to attract women to engineering education.

The students are organized into study groups of 6 to 8 students, similar to the groups at the universities in Göteborg and Stockholm. In Linköping the groups are composed so as to maximize differences in experiences (following the philosophy of Problem Based Learning, PBL), at Chalmers the groups, formed to function during the first term, are composed by the student board on the basis of a survey, where similarities in interests, age, residence and the like are taken into account. The study groups have access to their own study rooms equipped with computers, where the group members can meet for several hours of the day and where they can easily be reached by their tutors, personally or by e-mail.

The first three years of the degree programme are described as a basic course, while the last three terms consist of advanced studies comprising an individual degree project filling the requirements of a Master's Degree.

> *"The effect is that the first three years can be viewed as a whole"*, says one of the teachers at Chalmers, *"a firm foundation to build on. The students will also have opportunities to evaluate the qualities of their knowledge, since, during their third year, they work with an extensive project that ties it all together."*

In Linköping, PBL is viewed as a means for laying such a broad foundation for later specializing, or 'profiling' as they choose to call it, contrary to the logic of the traditional engineering education, where specializing is aimed at within almost all separate courses constituting a programme:

> *"We don't believe in that. We believe that if they have a broad technological competence and advanced knowledge within some area, it does not matter much which area this is."*

By digging more deeply into some limited field, the students learn how to tackle difficult assigments, they experience the satisfaction of being able to master demanding problems, and, since knowledge within any area quickly becomes outdated, the general ability to master intellectually challenging tasks is worth more than any factual knowledge that they acquire.

Admission procedures

Both programmes aim at recruiting women to engineering education. Computer sciences have, in general, difficulties in attracting women. The percentage of female students lies steadily somewhere between 5% and 15%; at Chalmers the percentage has been near to 5% for several years (SCB, 1995, p. 314). The name of the programme at Chalmers, D++, indicates the aspiration to increase the percentage. The first plus sign denotes the aim of making the programme more suitable to female students. The second plus sign proposes to tell us, that by fulfilling such an aim the studies will be more rewarding to all students, male or female.

Following the standard admission procedures at Chalmers, students were admitted on basis of grade point average from the upper secondary school. Among the applicants 10% were women. Among the 110 students admitted the percentage of female students had risen to 16%, which means that the female applicants had better grades than the males applying to the programme.

In Linköping the planners of the programme aimed at 50% women and the admission procedures were designed to enhance the chances for female applicants. Since girls are in minority within the technical and natural science programmes at the upper secondary school, the planners decided to admit some students from the social science programme. On the basis of grades the planners chose a group of 20 applicants. These were invited to write a short self-introduction and an argumentative essay on a given topic, for example, ”The consequences of computerization for society”. An admissions group of two people (one male and one female), a teacher and a representative from the trade and industry, read through the essays and selected a smaller group of students to interview. Seven students from the social science programme were singled out. They took a preparation course in mathematics during the summer and when the IT-programme started in August, five of them remained, four of them women. The rest of the students, chosen on basis of grade point average, came from the natural science or technical programmes. Of the 37 students admitted, 15 were women (37%).

D++ (Chalmers University of Technology)

The Swedish master of science programmes in computer science and engineering have recently been subjected to a national evaluation. In the evaluation report the programmes are criticized for being too fragmented, conglomerates of separate courses rather than coherent study programmes aiming at developing student competence. The recently appointed professor of the Department of Computer Engineering at Chalmers, who had been a member of the evaluation team, saw the need for a radical change of the computer science and engineering education at Chalmers. When the Council's letter of invitation reached the department, he took the opportunity to begin the revision process.

> *”We see to it that we start out by providing the students with an overall view of computer technology and what it means to work within the area and we also*

present an overall view of the study programme. /.../ Secondly we see to it that the core subjects are studied throughout the whole programme. Earlier it could take years before some of the central computer engineering subjects were introduced."

The programme begins with a group project comprising 4 academic credits, under the heading "Computer Science and Engineering in Context". The groups choose projects from a list of 20 suggestions, open-ended tasks such as "Internet connections for the blind". Within the projects the students are supposed to get a picture of what Chalmers can offer them as a resource for their competence development. The students gather information about the topics they have chosen, and give tentative solutions to the problems posed:

"The idea is that they will get to know Chalmers, as a place where researchers work with these problems, and that even very exclusive researchers, working for example within the field of speech synthesis, have their missions within a social context."

Parallel to the work on the project the students take courses in mathematics, computer programming, and digital and computer systems. Normally Chalmers' students take three parallel courses. After 7 weeks of course work the studies end with individual tests. Within the new D-programme, the students take four courses during their first study period, including the project. As a consequence the 7 week cycle has been changed and so have the ways of examining subject knowledge:

"Since tutoring is organized in such a way that we meet the students in groups of 8, we get to know them better. We can, for instance, examine them two by two, while sitting in front of the terminal, and they can tell us what they have done and why."

Not all lecturers, however, are happy about the changes in the course structure. The teachers also express different incitements for engaging in this developmental work. Some see it as an opportunity to develop a programme that makes use of the broad competence available at Chalmers, others express a milder interest in the venture:

"My participation is more or less a coincidence. Much of my teaching has always been allocated to the D-programme."

Two of the interviewees express the opinion, that maybe too many changes are introduced at the same time: changes in the content of the programme, in the course structure, and in the ways of teaching and examining students:

> *"It's almost a revolution. You change everything at the same time."*

The essentials of the programme

The teachers describe the changes mainly from a professional perspective, i.e. the changes are described in relation to requirements on engineers formulated by representatives of industry:

> *"It may be a coincidence, or maybe rather a tactical choice, or subconciously tactical, that we put forward such arguments. People will listen to us if we do. Lecturers for instance trust the arguments if for instance representatives of industry say that they need people who can communicate and cooperate. I'm not sure that they would believe the pedagogues, if they were to suggest that PBL is more effective than lecturing."*

In the interviews the teachers point to the following essential aspects of the programme:

- the project orientation, including group work (*"The students seem to know each other better. They function more like fellow-workers if you put it that way."*)

- the generalistic appoach (*"Even if you do not have the skills to solve a particular variant of differential equations you have a sense of what the subject is all about and what use you can have of it."*)

- the integration of subjects (*"One important goal that we have for this new D- programme is to create links between programming, discrete mathematics and computer engineering, such as how computers are designed. By not dividing the courses into separate subjects the subject boundaries will become less rigid."*)

- the free choice of courses (*"This is a 180-credit programme. Earlier 137 of these credits consisted of mandatory courses plus a degree project comprising 20 credits. One term, 20 credits, was optional. That's a very perculiar way of viewing what's important"*) and

- the training in communicative skills (*"It is striking how untrained the students usually are in writing and using Swedish and English."*)

By emphasising these areas the teachers hope to develop the five essential engineering skills: 1) a broad problem-solving competence within the field of computer science and engineering, 2) specialist knowledge within some area and an ability to aquire new knowledge i.e. flexibility in skills and competences, 3) constructional skills in engineering design, 4) a general ability to cooperate and communicate with other people, specialists within other fields or users of technology, and 5) competences in carrying out technical/scientific development or investigations.

Desired qualities in student learning

What qualities in student learning are linked to these competences, and how do the teachers hope to develop them by changing the content and structure of the programme in the ways described above?

By introducing projects the teachers hope to foster a professional attitude towards studying. The students are to view peers, tutors, lecturers and researchers within Chalmers as resources in the learning process. The teachers also express their belief in projects as means for developing a broad competence in problem solving:

- abilities to structure problems

- abilities to seek information and to judge what information is relevant for the advancement of the problem solving process

- abilities to go beyond established knowledge and, at the same time, to make the most of knowledge already acquired, which means that the students cannot just learn by reproducing facts but have to strive for a deeper understanding of the course content.

If such abilities are to be developed, the projects presented to the student must have certain qualities. The teachers do not all agree on how the projects should be designed:

> *"There is some sort of cultural difference between people involved in this programme. During the third year we all agree that we should have a major*

project. In my opinion it doesn't matter a bit if these projects are close to reality, in the sense that a company should have such a problem and would wish to have it solved. It should be a relevant problem, which, within our subject, could mean solving a substantial programming problem, specify and delimit the task and eventually design a program that can perform something. But the problem could be designed at our department. Completely internal. It should be interesting. It should be fun to work with. But the idea that you have to go outside of the University hunting for problems is nothing that bothers me./.../ On the contrary, it is easier to find good problems if you do not put such restrictions on the choice."

The project leader, however, expresses the opinion that by choosing projects from real-life situations the problems that the students work with, will, as a consequence, have the interdisciplinary character needed to develop an integrated view of the subjects within the programme.

By working in groups the students learn how to explore topics in cooperation with others, taking account of different perspectives and experiences, and they learn how to articulate their thoughts and ideas. The risk is, however, that group work becomes the dominant mode of learning, even when it is not functional. The students seem to have somewhat miscomprehended the situation, being, as they are, scheduled in group rooms for about eight hours a day. This was intended as a service to the students, but:

"Everything is done within the groups. I believe we will have to back off somewhat and reflect upon what should be accomplished by the groups, what should be left to the individual, or maybe to small groups of students to work out together."

The generalistic approach aims at developing broad competences in structuring problems, handling information and utilizing available knowledge. Such competences must, however, be balanced by a depth in knowledge within some area. The teachers all agree that students cannot become specialists within every field of interest and that such an ambition unfailingly leads to shallow knowledge. The generalistic approach is coupled with a focus on basics; the teachers hope that the students will develop sound knowledge that will last for a long period of time, maybe for life:

"The things you choose to concentrate on should be learnt in depth. We want to avoid all 'easy-exam-kits', cramming or reproducing standard examples and the 'clear-memory' that usually follows the exams."

The teachers have some problems, however, in agreeing on what constitutes knowledge to concentrate on if you have to make a choice. Since they also have the ***aim of integrating subjects***, 'basic knowledge' has to be defined interdisciplinarily. The mathematicians, for instance, stress different aspects of what constitutes basic mathematical knowledge for computer engineers, differences in opinions that shed light on D++ as a programme leading to different specializations, towards electrical engineering or computer science. One of the interviewees points to analysis as the most important field of mathematics for computer engineers, one that they really need to learn in-depth. Another interviewee stresses the fundamental character of discrete mathematics:

> *"Within discrete mathematics you can discuss the concept of 'mathematical proof' much more easily that within analysis, where you have to build on certain conceptions even for real functions. We have for instance the axiom that every set of real numbers bounded above, has a least upper bound. That is nothing obvious. It's an axiom. Other things you have to prove, things that seem just as obvious, or not obvious depending on how you view them. It is very hard for the students to see what the rules are: What do I have to prove and when can I just make assumptions? When can I just draw a sketch and when do I have to use epsilon and delta? Discrete mathematics deals with basic situations where these rules can be made very clear."*

Another complicating factor is that computer science is a young research field where 'basic knowledge' is not always easy do define. Students, some of them hackers, also hope to learn the hottest news, the latest applications, and hence they can find it a bit tedious to dig deep into things that, superficially interpreted, might appear to be simple matters. The teachers do believe, however, that defining basic knowledge is a possiblility, if teachers could only cooperate smoothly:

> *"But it's so darned hard. It really annoys me./.../We occupy the same building and we have known each other for twenty years and still there are cultural collisions."*

Even if some students are well aquainted with computers they do not always have the necessary knowledge nor the frames of reference needed so understand how, for example, a computer is designed and how it operates. Today, most computer components come in the form of integrated circuits and students never have the chance to develop an understanding of the hardware. Some of the developmental work within D++ concerns the design of laboratory exercises that will help the students to construct relevant conceptions, say, by actually building a computer, connecting wires in the old-fashioned way.

At the heart of engineering lies the ability to construct. The work demands creativity and skills in communicating.

> *"To construct is to be creative. You have to learn basic skills and problem solving but I believe that D++ should also develop the students' communicative skills and we must recognize the value of creativity."*

This means that the students will need a certain latitude to develop their personal interests, for instance the ***freedom to select courses***. Up to 39 academic credits in mathematics used to be mandatory. Within D++ the students have courses for 24 academic credits that allow no individual choices. Above this level the students may choose advanced mathematics courses that will suit their specializations. Each year the students also have the opportunity to choose freely from among the courses offered within or outside of the department. They can study English if they like, they can study the history of science, philosophy or environmental sciences. And during the last year and a half of the programme the freedom of choice is substantial.

Communicative skills are stressed by the teachers. This includes not only language and presentational skills, but also abilities to understand how the world appears from a different perspective. Some students seem to neglect the fact that every programme or piece of hardware will eventually reach a user:

> *"There exists a certain culture among young people, that you have to squeeze the maximum out of the hardware by devising smart transformations of the program. The program will be completely incomprehensable. You will not understand how it works, which some of them seem to view as an extra merit: Ah, you don't understand my program!"*

Communicative skills are often attributed to women. By encouraging women to take an interest in computer science new perspectives will enter the field:

> *"Today the challenge is to make systems that people can use and enjoy and that function in a way that makes you want to use them. They should feel natural to*

you, which means that the designer has to be able to understand the user's needs. Such qualities are currently required of a computer engineer."

The gender issue

Today, industry is more open to female engineers. The organizations are flatter, people work in project groups where competences, such as those mentioned above, are highly appreciated. The teachers have also noticed a change in the attitudes towards female engineering students at Chalmers. Today they are often accepted and welcomed. Nevertheless they are in minority, and when composing study groups, the planners of D++ made sure that the girls, even if not yet 50% of the students, should be 50% of the groups that they attend, which means that most of the study groups will have to do without women.

The interviewees (all men) have great difficulty in discussing ways to attract female students. The lecturers do not seem to have entered the project with a specific interest in recruiting women. All of them are, however, positive to the general aim to increase the number of female students:

"And I think I can buy the common argument that girls are more particular about the social situation during the years they study. Boys can endure lectures and swing a pint in the evening, while girls are more selective."

As a rule, girls are less experienced in using computers than boys. By equipping every study room with computers with Internet- and WWW-connections and all the relevant software, the girls can practice regularly and at times of their own choice. This will, hopefully, give them a chance to overcome feelings of insecurity. It is a problem, however, for men to foresee what will be problematic to girls. The laboratory work, mentioned above, where the students were supposed to acquire knowledge about computers by connecting wires, seems to have introduced additional obstacles to the girls:

"Some of the girls in my group found the lab very difficult and trying. They were a bit unfamiliar with connecting wires, things that boys more often do. So they had an extra threshold to cross."

By stressing the importance of competences and perspectives that girls are more familiar with, such as language skills or social skills, the teachers hope for more gender-inclusive education:

”And the men we teach should have competence in applying perspectives traditionally associated with women, or that women, by large, are more acquainted with. It is of vital importance that such perspectives enter our programme. And that is exactly why we call this programme D++. The programme will be better for all.”

The IT-programme (Linköping University)

The philosophy of Problem Based Learning (PBL) forms the basis for the IT-programme. Inspired by teaching methods developed within the fields of health-care and medicine at Linköping University, the project leader drew up the lines for developmental work founded on the basic ideas of PBL:

”In fact, we are the only study programme in Engineering in the world, that I know of, that in its entirety is built on PBL. Aalborg in Denmark have it, but in Aalborg they mainly have a project organization, and we can discuss the extent to which that looks like PBL.”

The students work in tutorial groups, intended to support the individual members in their studies. Within the groups the students have the opportunity to aquire knowledge of the theme studied, and to broaden their communicative skills and their proficiencies in monitoring the learning process. Three subjects are integrated within the themes: mathematics, computer science and computer and communication technology.

The groups are tutored by a supervisor, functioning as a facilitator, mildly steering the process horizontally and vertically by posing questions to the students about the process (”Do you find this relevant to the subject? Is this something that will add to your knowledge?”). Horizontally so the students do not digress too much from the path delimited by the goals set up, vertically so as to assure that the students do not pose trivial questions or questions that will go too deeply for the students to handle.

Goals are defined for the programme as a whole, for each term and for each theme studied, and these goals frame the course, nothing else. Each theme is studied for a 5-6 week period. A written text is presented to the students, where the theme is introduced and the goals are made explicit. The students do not take courses and the lectures are optional and limited in number. Peers, tutors, teachers, researchers within the department and people with a competence in the subject outside of the university are viewed as resources for gaining knowledge. Group meetings are mandatory, and form the basis of the work and the students also have resource meetings with tutors and lecturers.

The first theme is introductory. The students are presented a 'scenario' out of which they are to formulate problems in accordance with the goals set up by the planners of the theme. One of the scenarios, presented within the first term, introduces the students to a real-life situation:

> *"A small club has discovered that they have problems with their internal information, the information about members' activities, needed for the secretary to be able to provide adequate information about club activities to people outside of the organization. Period."*

The scenario is presented to the students, to use in their learning process:

> *"And at the same time their task is to study databanks, information retrieval and mathematical logic and set theory. The situation is presented so as to serve as a realistic basis for their work. They are to think: Well, we are going to learn how to design a databank and what it is supposed to consist of and so on, and when they do so they are supposed to have the situation, the club, at the back of their heads, to refer to."*

The essentials of the programme

Two goals have been set up for the IT-programme. The first is the aim of recruiting 50% women to the programme and the second goal is to educate generalists, engineers with broad competences within the field of computer and communication technology. And PBL is the means chosen to reach both goals.

What are the essentials of PBL? The teachers differ somewhat in their descriptions of the philosophy, but the following characteristics are described in the interviews (alternative phrasings of the goals are given within brackets):

- the group work (the act of learning is viewed as a social process) (*"It cannot be a coincidence that three out of four advertisements, where companies advertise for engineers, request that they should have a degree and added to that a competence in cooperating and working in groups."*)

- the reality based examples as points of departure (the studies should be of relevance to society)(*"That's the whole point of this, that technology must be understood and handled within the perspective of the society and not as technology for its own sake."*)

- the self-directed learning process towards pre-defined goals (the students are responsible for their own learning)(*"Which doesn't mean that the students have to be totally responsible for formulating problems nor for defining the subject content or the direction of the work."*)

One of the interviewees described the goals as positions in three dimensions, always present in educational planning:

- the character of the work forms: the individual versus the collective approach to studying, where PBL could be viewed as close to the collective pole. The interviewee expressed, however, a second opinion about this. Tutorial groups sometimes split up. They may have tutorial meetings but afterwards they sometimes go home to commence their studies individually.

- the ways of organizing the subject matter: a subject- versus a problem-oriented point of departure, where engineering education traditionally has been subject-oriented, PBL builds on problem solving within interdisciplinarily defined themes.

- the responsibility dimension: a student- versus a teacher-governed process of learning, where PBL proposes to be near to the student-governed pole.

The teachers might, however, leave too little responsibility to the students:

> *"They define the goals and within these boundaries the students are allowed some latitude, and they govern by telling the students to have tutorial meetings where tutors are often present./.../ In my opinion much could be gained by giving the students responsibility not only for planning their own time between the tutorial meetings, but also for participation in the planning of the whole process, for instance time for and content of resource meetings of different kinds."*

The interviewee expressed the opinion that PBL has been somewhat uncritically imported from a field of university education quite different from engineering – the field of medicine:

> *"Engineers are not educated to treat or to take care of existing situations, but to create new ones."*

This would, according to the interviewee, call for more of self-governed learning, for example in the form of project works.

Other interviewees express similar views, but on the other hand most of them agree about the fundamentals of the PBL-philosophy, and since the project leader has a firm belief in PBL and has tried it out within his own subject field for a number of years, PBL has been broadly accepted within the programme and also, with some hesitation, within the Faculty Board. (*"Will they become engineers or will they become all woolly and vague?"*) The members of the Board were, however, reassured when they understood that the main idea was to change the forms of teaching:

> *"And that the changes were directed towards features that everyone is complaining about anyhow: that teaching is transmissive, that the students cannot handle problems that do not look like the ones in the collection of examples, which is a critique directed towards all technology students."*

In the interviews, PBL is put forward as the available, tried-out and accepted method to reach the two main goals: to attract women to the programme and to educate generalists.

Desired qualities in student learning

What qualities in student knowledge are linked to the notion of the 'generalist', qualities in student learning that the teachers hope to foster within their problem-based approach to engineering?

By working in groups the students are offered the opportunity to develop their communicative skills, to understand the importance of viewing problems from different perspectives, and to learn how to make use of experiences available within a group. They also have the opportunity to develop their self-confidence, by practicing their argumentative skills among friends and peers. They have a chance:

> *"...to feel that they have a situation well in hand. That they have the proficiency. Many students, not all but some, are genuinely insecure and do not dare to expose themselves to others."*

By using reality-base examples the students will, hopefully, develop their abilities to view technological problems within a broader context. This means that the students will have to abandon the narrow technological perspectives, often attributed to engineers:

> *"I would wish for them to leave the IT-programme with a different attitude. When they are presented with their first set of specifications and are told to construct such and such a gadget, they will, instantaneously, ask themselves: Why? Who will be the users of this gadget? What are they going to do with it? What implications will it have for their work? Have they checked other options? Are other actors, interest groups or effects on society involved? To pose all those questions instead of just locking themselves up in a room with a specification, closing the door and returning in a week or so, leaving the gadget to the users to make the best of."*

By emphasizing that the students are responsible for their own learning, the teachers hope to foster a professional attitude towards studying, not as an act of reproducing knowledge handed over by the authority, but as a way of learning actively within an atmosphere of critical reflection:

> *"... which means that they will solve problems, contruct things or analyze situations in such ways that do honour to the profession."*

The aim is, as mentioned above, to educate 'generalists'. In the interviews the teachers elaborated the meaning of this concept. Being a 'generalist' means to be able:

- to handle complex situations (*"There exist, broadly speaking, people with two different attitudes towards technology: Those who are interested in technology as such, who dig deep into the systems and who are not particularly interested in broader technological applications, and those who are interested in the complex contexts of technology, often referred to as problem solvers."*)

- to integrate subject knowledge (*"We hope that they will be able to see the connections between the various subjects we introduce them to."*)

- to have a broad technological competence, balanced by a depth within some field of interest (*"Sometimes we use the somewhat hackneyed metaphor of the drawing-pin. It should have a certain breadth in order to hold firmly and it should have a sharp point that will dig deep."*)

- to communicate ideas and results (*”To understand what communicative situations demand: ablilities to cooperate, to make yourself understood, to be able to argue for your ideas. Those are insights that I would want them to aquire.”*), and

- to be independent and creative (*”If I had the opportunity to wish for something I would like to be able to say: Look, here we have an example of a truly scientific attitude: they have an overview of the field, they can identify situations where their skills are adequate and they really do not have less knowledge of facts than traditionally educated engineers, not forgetting the memory lapses that always occur. These are ablilities that I would wish for.”*)

PBL proposes to develop all these qualities. But PBL is also a means to attract women to the programme. How do the teachers view PBL, and the qualities mentioned above, with respect to gender?

The gender issue

As mentioned earlier in this report, industry as well as engineering training programmes have recently opened their arms to women:

> *”Whatever views people have of female engineers, no one can be blind to the fact that there will soon be a lacuna within the recruitment groups and if girls were only to apply...Whatever views you have, it all boils down to pure and simple economics.”*

Two attitudes towards the recruitment problem are pointed out by one of the interviewees: Either women are given the benefit of special treatment within otherwise traditional programmes, or women are taken into account when the programmes are planned:

> *”We say that the traditional system is unable to benefit the girls. It does not make the most of their competences.”*

When planning the IT-programme, the project leader put a lot of energy into recruiting suitable lecturers. He applied, what he calls ’Noah’s Principle’, to the task of choosing staff, upholding the maxim that half of the teachers should be women. This meant that he had to seek lecturers and supervisors outside of his immediate circle of acquaintances, and he found, much to his own surprise, a lot of competent women that he did not even know of:

"We are, of course, aware of the fact that there exist deeper problems of equality, but such a simple, almost banal measure, has brought to the fore a range of hidden circumstances, for example how many competent women there are... this is a bit shameful to admit...but how many exceedingly competent women there are, that I have never noticed. Isn't it shocking?"

Among the teachers, responsible for the planning of the terms or themes, 50% are always women. Noah's Principle has turned out to be very effective in supplying the programme with many competent role models for the female students.

Another simple measure, pointed out by one of the interviewees, is the choice of words. You can describe technology using different vocabularies, some of which will have a greater appeal to female students:

"Rather than talking about how technology functions you can talk about its usage and applications in a social context./.../ You can talk about micro-chips or care of the elderly and security alarms, which is more or less, talking about the same matters."

Female perspectives on technology are important and should, according to one of the interviewees, be accentuated more within the programme:

"I think it would be more honest if the IT-engineers that we educate had some knowledge about the gender aspects of technology. That the ideology is not only manifested in the forms of teaching."

The form of teaching, PBL, is viewed as the principal instrument for attracting women:

"On somewhat shakey grounds we assert that PBL will suit girls. There are no investigations supporting our claims. We just have the intuitions. And I must say, that the observations I have made in my group definitely support them. Girls sometimes have a tendency to say: 'I'm not able to work this out', and the boys have immediately countered: 'What is it that you do not understand. Let me explain'. The result has been that the girls take a more active part in the conversation. They thrust themselves into the discussions, asking questions like: 'When you say this, what do you actually mean?'"

The traditional ways of teaching technology students have met with a lot of criticism that PBL might be the remedy for. On the other hand, not only women will benefit from the changes:

> *"Women are, statistically, associated with the traits that we want to support within our programme, but we are mainly interested in the traits./.../ We talk a lot about differences between the sexes, but mathematicians, statisticians and technicians know that these differences have to do with statistical means. The means may be different, but the bulges around the means can cover each other /.../ It might very well be the case, that what is expected to be a female view or a female attitude is observed among the boys in a group. And this would not be the least unexpected. Just the opposite."*

Until proven wrong, the teachers rely on the effectiveness of PBL and the general impressions, expressed by the interviewees, are that the groups function well within informal and supportive group climates:

> *"But at the same time we know that since this is a School of Engineering, we have to meet very strict demands. We have to be able to show that this programme really turned out fine."*

III The project within the new engineering programme

Women in Engineering Education (University of Karlstad)

General description

About ten years ago the first engineering programme was launched at the University of Karlstad, the energy programme, comprising 120 academic credits (three years of full time studies). Today about twelve different programmes are offered to the students, and among those, four are part of the project Women in Engineering Education: The Computer Engineering programme, Energy and Environmental Engineering, Innovation and Design and, since 1995, Structural Engineering

This whole concept of engineering education is new and has not yet found its forms:

"It has been stated that engineers with a Master of Science should handle technology on a scientific basis, while we educate theoretically oriented technicians. Our programme is supposed to be theoretical but we do not dig too deeply into the boxes, which is easier said than done."

This kind of education, largely equivalent to polytechnics or 'Fachhochschulen', colleges with long traditions in other European countries, is situated somewhere between the extrapolation of the secondary school and the academic Bachelor of Science:

"Both of them could be quite authoritarian./.../ In the old upper secondary schools, teachers tried to renounce problematizing. The students were chiefly taught methods. We pictured an education where we could find a balance between the quantity of content and the quality of learning and I believe that we can be localized near to the quality pole. Rather than losing in quality we choose to reduce the quantity of the content studied."

When the letter of invitation reached the University of Karlstad, the project leader saw his chance to start a developmental programme that would change praxis within engineering education:

"I wanted to change the forms of examination and the work-forms towards more project-based learning. /.../ My aim was not specifically oriented towards recruiting women, but to raise the general quality of engineering education. And, I must admit, that PBL was something... if we were to receive any fundings...that was forced on us. I knew practically nothing about PBL."

A project with many faces

The Karlstad project has many faces. It can be viewed as a **recruitment project**, a measure chosen to meet a future supply-demand crisis of engineers and scientists. In Karlstad, situated in a district of Sweden where young peoples' willingness to continue their studies at the tertiary level is somewhat lower than in metropolitan areas such as Göteborg and Stockholm and to some extent Linköping, the recruitment investments are not only directed towards recruiting women but towards new groups of students in general.

But the project can also be viewed as a **developmental project**, aimed at raising the quality of engineering education, moving in the direction of a more humanistic engineering practice. One example of this is a course addressing "The Language of Technology", comprising 5 academic credits, implemented in cooperation with the Department of the Humanities. Within the programme a general emphasis is put on communication, the writing process and oral presentations. One of the lecturers within the Environmental Engineering programme describes the interdisciplinary trend:

> *"Since this is a new programme which attracts girls we have the possibility to follow it up and to see how the female students view the different parts of the training. We have a course in environmental science which is also offered to the science students. Within this course we can introduce perspectives and discussions other than those that are common within a pure technological education. I believe that will be interesting."*

Linked to the aim of developing the curricula and the teaching methods is the aim of raising the quality of teaching by offering the lecturers **in- service-training**. During the first years of the project, pedagogical courses were held, seminars were offered to the staff on topics such as women's and men's language and male technology, books were distributed and the teachers were encouraged to reflect upon their own teaching methods.

The recruitment aspect

In the interviews the teachers, three male and one female, stress different aspects of the project. Perhaps not surprisingly, the female lecturer points to the equality aspect of the programme. Much effort has been invested into marketing the programmes. A video-film has been produced, where personal portraits of female engineers are presented. The video-film is used as recruitment material, shown to classes in upper secondary schools where students are about to choose directions for their continuing education. Other recruitment material has been distributed among prospective students, administrators from the university cooperate with secondary and primary schools for vocational guidance and female professional networks have been formed.

All these activities seem to have led to an increase in the percentage of female students. For the three programmes, Computer Engineering, Energy &

Environmental Engineering and Structural Engineering, the percentage has risen from an average 16% in 1994 to 23% in 1995. Some believe that the increase might be matched by a corresponding decrease within other programmes, e.g. Systems Analysis where the female lecturer teaches:

"I have my suspicions, since our decrease (from 40% to 25%) coincided with the increase within Computer Engineering. So it seems as if I have sold my soul to this project. But on the other hand, I have learnt how to market a programme. Showing what you have to offer can perhaps contribute more to the effects than the actual changes in the courses. We are in the limelight. We have shown that women are needed within the technology programmes. I think that is very important"

The lecturer also points to the effects of the project on the attitudes towards female lecturers within the university and to the overall effects that the meetings, arranged by the Council, have had on these attitudes:

"I have more of a commanding presence today that I ever had before. I have the knowledge. I have something to contribute to the discussions, whenever they come up. And people listen to me. Yes, I have certainly learnt a lot."

On the other hand, there is always the risk, that the marketing campaigns promise more than the programmes can live up to:

"But I really do not see the links between projects and courses being more attractive to women. I have never understood the connections. And that problem-based learning, the new ways of teaching, should be more attractive to girls? No, I don't know what the links are. But to recruit girls. We have tried to make our programmes better, but that is more of a side effect."

The in-service aspect

The in-service aspect of the project seems, by and large, to have been a disappointment to many of the interviewees:

"You have the two principles: On the one hand academic freedom, which allows teachers to do whatever the hell they like about their teaching. So what can we do? We can arrange seminars, we can give them books, we can encourage them to change their teaching. It isn't very effective. On the other hand we can use the management model and rule. It is not very effective either, but at least something will happen on the surface."

The interviewees do not wish to be too negative about the effects of the project, but more than one of them is tired of the lack of interest in the proposals to change the teaching. Much of the atmosphere and the attitudes within the departments have, however, changed and some teachers are interested in educational issues, but still there is much to be done:

> *"I believe that if you decide that it is important to make the changes and you get stuck in the same old ruts, you have to reconsider. We couldn't do it. I couldn't manage anyhow. And, being in this situation, we should appoint someone who sees to it that decisions are made, who tells people where to go and who follows them up. Link it to salary-increase or what the heck, but show that you are* ***serious****."*

The developmental project

The Council's letter of invitation implied a move towards more problem-based learning. The staff of the Department of Engineering and Technology attended an in-service training course in PBL during 1994 and 1995, but they were not all convinced that PBL was the solution to the teaching problems facing them:

> *"From the start I found it woolly and vague. And I attended a course in England, and that was really wishy-washy, which I wrote in my course evaluation. I did not like it at all. It gave me* ***nothing****. We had endless discussions over trivial matters and people were particular about guarding their special preserves: We do it this way, and it really works! But what makes it work, I asked. They did not know."*

Instead, the teachers have worked out their own teaching methods in cooperation with a pedagogue helping them to raise the fundamental didactical questions: What should I teach? How should I do it, and why should it be done in such a way?

Another developmental project has recently started at the Department of Engineering and Technology, its aims are to develop the students' abilities to problematize the fundamental phenomena presented within the courses and to create relevant frames of reference:

> *"Students do not have the frames of reference needed. /.../ During a lecture I asked how many of the students who did not know what a hydrophore is, since we were*

going to introduce them to the technique, and it turned out that 80% didn't. Only 20% knew and these had all grown up in the countryside. The lack of such frames of references is very common."

Study begins in the laboratory with the intuitions that the students have about the phenomena to be studied:

"And by posing questions to the students they are forced to reflect upon their own intuitions, at least this is how I interpret the situation. This will, hopefully, lead to a new level of understanding. And then we introduce some definitions: What you have just encountered we call The First Law of Thermodynamics."

The students are given assignments, texts to read that connect to the laboratory work:

"And then they reach a situation, which we call 'little f' for some reason. It is a lecture-like situation but it is not a lecture. We start out by giving the students a self-test where we pose simple questions about the texts they have read and about what has happened in the lab.'If I have read this, have I really understood the basics?'"

The questions are given back to the students to work out in groups. The teacher moves around in the study room, giving hints to students or posing new questions aimed at raising the students' awareness of their own understanding.

After about five such 'loops' (laboratory work and 'little f') the students are summoned to a lecture, which they are now well prepared for. The lecture includes periods where the students pose questions to the lecturer. One of the interviewees points out that the students sometimes ask questions that the teachers themselves have never been confronted with before. Many of the lecturers have been quite successful in their own studies, which means that many basic questions may have passed them without being noticed:

"There are many stones that I have never turned over to check what was underneath. The students have turned many stones that I never even knew of: Why is it so? I had no idea. /.../ In the long run we learn how students think within our own subject. We develop a humble spirit and a greater understanding towards why our subject might be hard to learn. It feels as if we are on the right track."

The teachers hope that such insights will gradually change the culture of engineering education by spreading to other teachers within and outside of the department. The process, however, is slow and the departments are not always willing to supply the necessary time-space for developmental work. A predicament for many departments and teachers at the University of Karlstad is the heavy work-load, sometimes caused by the fact that some lectureships are vacant.

> *"We strive to set aside time. Time to work under the guidance of a pedagogue posing questions. And if we had not had the project, the team would have existed but the pedagogue probably wouldn't. And we feel that we have to do something that we truly believe in. And this we do believe in, and we have enough substance to ground our beliefs. We have not merely started a PBL-project."*

A thematic discussion

In the previous chapter the five development projects were described on the basis of interviews with people enrolled in the programmes. Summarizing the results from the descriptions is not an easy task. From the interviews we gain a picture of a diversified practice, locally organized to serve particular educational needs. A follow-up study of the projects must take into account such variations in forms and content of the programmes. On the other hand, it would not be practically possible nor desirable to suggest five separate evaluations. The projects are, in fact, parts of one developmental endeavor, funded for the purpose of fullfilling two goals: to attract female students to science, mathematics and technology and to raise the quality of student learning by making use of more problem-based learning – in one or another interpretation. In order to form the basis for an integrated study of the programmes we need to see past the apparent differences in the organisation of the programmes, in search for some common rationales under which we can subsume the observed variations.

As mentioned in the introductory chapter, the aim of this study has been to describe the essential changes implemented within the projects, the desired qualities in student learning motivating these changes and the means chosen to attract female students to the programmes and hopefully make them stay. Would it be possible to find some common traits covering the variation of approaches to these themes, ideas that could possibly and relevantly be followed? Leaving aside for the moment the problem of relevance, I will discuss the possibility of finding such common traits, fundamental ideas that do not distort the overall picture of a varied praxis.

Changes in work forms

A common trait within all five projects seems to be the criticism raised towards the traditional ways of teaching, a criticism which has also been broadly articulated in the public debate within and outside of the university system. This does not mean that the lecturers and tutors generally distrust lecturing, but rather they problematize the generality of the teaching method and wish for a more varied praxis, adapted, for instance, to different educational needs and local university cultures. The teachers seem to be on the move **from** a culture-centric teaching praxis, relying heavily on standardized means in the form of lectures, exercises and tests, **towards** a more relativistic view of teaching, relative, for example, to variations in the process of learning.

The alternative perspectives are, however, somewhat vaguely articulated in the interviews. Some of the teachers describe how they have turned to colleagues, within or outside of the natural sciences, for inspiration, adapting alternative teaching methods (sometimes a bit uncritically) like problem- or project-based learning to their own local conditions. In Stockholm and Linköping this tendency is commented on, and in Karlstad it is straightforwardly criticized by two of the interviewees, who call for a more reflective appoach to the problem of teaching.

New trends and old

It might be appropriate to remind readers of the pedagogical debate from the 70s, when problem-oriented teaching methods as well as projects were severely criticized, not to say attacked, from among others a Marxist perspective, for being unrealistic, idealistic and generally wishy-washy (Callewaert & Kallós, 1976, cf. preface by the same authors in Illeris, 1976, pp 7-16). By this I do not wish to propose that the methods implemented within the five projects described above suffer from the short-comings ascribed to the so called ”pink wave pedagogy” (Callewaert & Kallós, 1976), but it may serve as a basis for reflection upon the current trend, to recall some of the voices from the past, articulated below in the preface to Knud Illeris book ”Problem-oriented and actor-governed teaching - prerequisites, planning and implementation” (Illeris, 1976, my translation of title). The book made quite an impact on the pedagogical debate in Scandinavia during the 70s. The preface to the book was, which may be seen as an expression of the tone of the time, written by two of the most voiciferous critics of the new progressivism:

> ”We have already mentioned that Illeris tries to deduce the development of an alternative educational praxis from the presumption that the labour market demands new qualifications of the labourers. Above all, Illeris purports to show the need for an increase in ”general” and ”intense” qualifications. Everyone must 'learn how to learn', to cooperate, to think creatively etc. In this connection it is important to underline that we are

> probably faced with not *one* but *two* trends. On the one hand we must take into consideration the possibility of an actual need for changes in the qualifications of the merchandize manpower, on the other hand we must discuss the ideological aspects of this trend. Is it, in other words, really the case that the new didactics, when applied, make all students better equipped, within certain limits, to think more freely, greater or to be more cooperative? Or do we rather transmit the illusion of the importance of creativity and cooperation? Is it a fact that the general qualifications are needed in a 'modernized' production system or is such a need only illusory? The problematic within this area is complex." (Callewaert & Kallós, in Illeris, 1976, pp. 12-13, my translation)

One basis for the criticism in the 70s was, as exemplified above, the argument that the educational reforms were based on superficial analyses of the needs of the labour market. The same criticism could be directed towards the projects presented in this study (and has in fact been raised by some of the interviewees, such as in Karlstad where one of the lecturers pointed out that such analyses by preference are based on the articulated demands of representatives from large companies rather than from small- scale industries). The interviewees seem to balance between three perspectives not always clearly separated: the demands of the students as independent learners, the demands of the local university culture (the departments, the faculties etc.) and the demands of the labour market. In some of the interviews this balancing act is described as a problem of taking into account both internal and external evaluations of the programme. This predicament makes the second question, the ideological issue raised in the text cited above, relevant and imperative: Do the teaching practices described in the previous chapter, when implemented, really equip students with the skills and knowledge emphasised by the interviewees, or are the criteria used still rooted in the traditional system, thus making the quest for alternative ways of learning the subjects only illusory? When designing a follow-up study of the five projects such questions have to be taken into account.

Project-oriented and problem-based learning – are the differences crucial?

Twenty years have passed since the dabate about "pink wave pedagogy", and much has changed in the views of teaching and learning. The didactic explosion of the 80s has resulted in a multitude of studies of learning processes as they occur in classrooms and lecture rooms (for summaries of some recent qualitative studies within the field of higher education see e.g. Marton, Hounsell, & Entwistle, 1984; Ramsden, 1992). PBL and project-oriented teaching methods as well as laboratory methods with roots in the progressive movement (see e.g. Dewey, 1980; Kilpatrick, 1918; Perry, 1902) and the new progressivism of the 70s (Illeris, 1976; Berthelsen, Illeris, & Poulsen, 1979), have been futher developed in the 80s and 90s (Barrows & Tamblyn, 1980; Berkson, 1990; Egidius, 1991). Today, advocates of PBL often emphasize the differences between PBL and project-based teaching methods.

What are the differences? The reader can compare the following definition of "project work" with the descriptions of PBL presented previously in this report, by teachers at Linköping University:

> *"Project work here is defined as a teaching method whereby the students – in cooperation with teachers and possibly others – explore and handle a problem in close contact with the social reality in which it occurs. This means that the work should result in a constantly broadened perspective and an increasingly profound insight, that the problem is viewed from a range of different perspectives that cut across the traditional subject boundaries, that the choices of theories, methods and other facilities are made with reference to the problem. The role of the teacher is not only to transmit knowledge, but he or she should primarily give the impetus, inspire, "frame" the work and be a consultant. The work should result in a concrete product, which can have the form of an oral presentation, a written report or be expressed through other media or actions."* (Berthelsen et al, 1976, pp 16-17, my translation, italicised in original)

One difference between a project-oriented approach and PBL is the view of the results of the learning process. While the former approach emphasizes the concreteness of the results, PBL puts less emphasis on such products, with the argument that students, if requested to present reports or presentations, will spend a lot of futile time on the administration of their work. Rather than investing energy into the content and process of learning, thoughts about the end-product will frame the act of learning. Administering a project can, on the other hand, be viewed, not as a means for learning but as a content in itself. Within D++ and the Project Programme for instance, some of the teachers point to the necessity of developing a **know-how** or design-oriented approach to problem solving as well as a **know-why**, or theoretical stance (cf. Kjersdam & Enemark, 1994). An engineer or a scientist must be able to take up a position as a project-leader and must, therefore, learn how to distribute time and effort, how to cooperate in work-groups and how to present results in oral or written forms.

There are other differences between the approaches, and there are arguments for each of them, often well-founded in theories of learning or theories of practice. PBL and project-oriented approaches can, together with laboratory-based methods such as the ones implemented within one of the programmes in Karlstad, be argued for in some context or another. Focussing on differences may be crucial when discussing pedagogical practices. To polarize perspectives can be a fruitful way to highlight subtle but important nuances of a certain approach by contrasting it to approaches that are similar but not the same. But the aim of this study is not to discuss the teaching methods chosen within the programmes nor to compare their merits. The aim is rather, as mentioned above, to examine the possibility of finding fundamental ideas common to the five programmes.

A common rational

Two traits seem to link the five developmental projects:
(1) the idea of the self-directed learner and
(2) the notion of the social character of learning

(1) ***The idea of the self-directed learner*** is manifested in many forms, for example in the emphasis on learning as an act of acquiring a personal understanding of the course content rather than as an act of reproducing knowledge handed over by authorities. The notion of the self-directed learner also implies a breakaway from a view of learning as a linear process in which knowledge and skills are acquired in bits and pieces hierarcically organized, towards of view of learning as a process of getting aquainted with the subject matter in an experience based, spiralling process, in which students formulate and re-formulate their own frames of reference. The idea of the self-governed learner also implies a notion of learning as an activity, a creative process in which students seek information relevant to their own inquiries, where they work in the laboratories trying out and testing assertions about phenomena. The free choice of subjects or tasks to explore is another manifestations of the overall idea, a way of organizing the studies which would not be possible if the teachers did not firmly believe in the students as active individuals striving to adapt to the social environment.

(2) ***The notion of the social character of learning*** is manifested on three different levels. On a personal level we find an emphasis on dialogue as a way to exceed the limitations of personal and idiosyncratic perspectives. The collective work forms, the stressing of argumentation in written and oral forms bear reference to the need for the individual to try out ideas of her own and test them in cooperation with others.

On a cultural level we find an emphasis on dialogue as a strategy for surmounting single subject perspectives. The students are not only expected to acquire knowledge of subject areas within mathematics, physics, computer science and the like, but to gain knowledge about their interfaces: to distinguish between questions asked from a mathematical perspective, a physical perspective, etc. and to see their interconnections.

On a social level we find a breakaway from the notion of university subjects as isolated ivory towers where students are socialized into limited perspectives, recruited to research rather than adapted to practices outside of the university. Many, but not all, of the teachers stress the use of 'real-life'-examples or 'scenarios' as bases for instruction. Such tasks introduce students to a range of perspectives, some of which may be alien to a scientific or technological culture (humanistic, linguistic, social, etc.), or to the literate culture of the university in general (praxis oriented perspectives).

Some teachers, however, seem to have problems with the issue of integration on a social level. They suggest that the tasks presented to the students should be meaningful and interesting on a personal level and relevant on a cultural level, i.e. relevant to the subjects presented within the programme, but they have their doubts about the notion of relevance on social level, i.e. to demands that the tasks presented to the students should be relevant to local practices outside of the university. Such hestitations could be interpreted as expressions of an awareness of the complexity of the problem of integration.[2] If teachers themselves, representing different subjects or subject areas, have problems seeing the links between their own research field and the interests

---

[2] Such an awareness has strong theoretical support within recent research in education. A multitude of research results point to the difficulties of transferring knowledge from one subject domain to another or from one context (e.g. theoretical) to another (e.g. practical). For discussions of research within this field, see e.g. Pfundt & Duit, 1991; Säljö, 1991; Caravita & Halldén, 1994.

of others, how will it be possible for them to design tasks that will help students to discover interdisciplinary links and, in addition, engage practical perspectives in society. A follow-up study of the programmes should, in some way, address this problem.

Qualities in student learning

How do we know that the learning activities implemented within the programmes really equip the students with abilities to be independent of but sensitive to the social contexts of learning – self-directed and socially aware? And are we not faced with a conflict of ideals when we request both autonomy and dependence from the students, a request expressed in the interviews as a balance between critique and acceptance?

The professional and scientific attitude

A balanced, reflective approach to learning can be described as the hallmark of a scientific or professional attitude. Such an attitude is, however, not possible to develop in solitude since science and engineering are collective enterprises. Knowledge may be personal in the sense that only I know what I know, but a collective is always needed to prove and disprove assertions, to hold knowledge in trust and transmit it. The students must enter scientific, mathematical or technical traditions in order to develop knowledge which is both personally and culturally genuine and relevant. To be independent is to know the limitations of personal perspectives and to be able to judge the relevance of facts and assertions within different cultural contexts. In the interviews the teachers point to several qualities that can be linked to such a scientific or professional attitude:

On a personal level the attitude is described in terms of a striving for understanding of the content, not taking for granted facts presented. The student can cooperate with others with a readiness to relativise his own ways of thinking. Competence in expressing thoughts so as to make them understandable to others together with the ability to listen and make use of other people's arguments are other qualities pointed out.

On a cultural level the interviewees talk about developing a 'sense' for the subjects and for the effectiveness of abstract reasoning. The students are able to shift from one subject perspective to another, aware of the limitations of each.

On a social level depth within some area and an openness to alternative perspectives are pointed out as important qualities. The students can model complex situations or 'scenarios' and are prepared to broaden limited professional perspectives. The students pose questions about the relevance of a specific professional perspective to a local practice. To express scientific knowledge in a language understandable to laymen is also a quality attributed to the true professionals.

These views are, of course, descriptions of ideals, qualities of learning to strive for rather than to expect as outcomes of the study programmes. Within the field of education, researchers have found that scientific attitudes take both time and effort to develop, and far from all students form such attitudes during their undergraduate years (Perry, 1968). It has been shown, however, that the development of certain attitudes is heavily dependent on social demands. In a cultural environment, where students are encouraged to reproduce facts, they tend to develop conceptions of knowledge as something absolute (see Marton, Dahlgren, Svensson, & Säljö, 1977; Säljö, 1982). The designs of tasks and tests also bear reference to and transmit conceptions of what counts as knowledge within a specific cultural environment (see Säljö & Wyndhamn, 1988, 1990).

> ”Where knowledge consisted of facts in a single frame of reference, the teachers' primary duties were to make the facts clear and to so correct his students in respect to the right or wrong of each fact as to allow of no error. The student, in turn, collected correct facts and procedures. Where knowledge is contextual and relative, the teachers' task is less atomistic as the student's is more integrational. The good teacher becomes one who supports in his students a more sustained groping,exploration, and synthesis. His acts of evaluation must subtend more than discrete rights and wrongs, and extend through time to assist discrimination among complex patterns of interpretation.
>
> Where the extent of this difference is not clear and explicit in an instructor's mind he may attempt to serve both sets of values at once in ways that are conflicting rather than complementary.” (Perry, 1968, p. 211)

Have the teachers been able to make such clear cut distinctions between different value systems when developing the programmes? Some interviewees point to the problem of reconciling different demands, such as requests from the students, from collegues, from the faculties, or from interested parties outside of the university, and we have every reason to believe that the value systems and qualitative criteria of these groups differ significantly. We know, however, that the teachers have put a lot of effort into designing open-ended tasks that will allow the students to integrate subjects and to be reflective and creative in their problem solving. Are the students, despite of the teachers' intentions to design alternatives to a transmissive pedagogy, confronted with conflicting views of knowledge and learning?

Such questions could be answered if we investigated the students' understanding of the latitude for learning within the programmes. How do they interpret the cultural meaning of knowledge? Can we find traces of the qualities in student learning, identified as ideal by the teachers when students carry out given tasks? Such questions could be addressed in a follow-up study, and the answers could render a picture of the changes implemented as either thorough or illusory.

Attracting female students

Two approaches to the recruitment problem

There exist, broadly speaking, two approaches to the problem of recruiting women to science and mathematics. One is to offer women pre-programme courses or a 'female entrance' to otherwise traditional study courses (see e.g. Slater Cavallo & Bibelnieks, 1993), with the aim of preparing them for their studies and building up their self-esteem. The other is to argue that if women are to be recruited to science, mathematics and technology their participation must affect the pedagogy and even the epistemology of the subjects presented within the university courses (Burton, 1995, Fennema, 1993; Solar, 1993). The latter position can be ascribed to the Council's offer to support the development programmes. In the letter of invitation to apply for fundings two aims were linked together: the political goal of recruiting new groups of students to science studies and the pedagogical aim of raising the quality of teaching to meet the demands of these new groups of students. The teachers and tutors interviewed, however, do not always relate their pedagogical intentions to gender. The interviewees, who stress the equality goal, seem to view the pedagogical changes more as side-effects of the recruitment endeavour, while those who view the changes in teaching methods as the primary aim of the projects do not specifically relate these changes to gender.

Stressing female competencies

On a more general level, however, the two aims seem to be closely linked. The teachers express beliefs in the alternative ways of teaching, offered within the programmes, as serving the interests of female learners or the interests of male learners with communicative competences or other qualitative traits often ascribed to women. By stressing such competencies, qualitatively new ways of thinking and communicating will enter the degree programmes and new perspectives on the subject matter will hopefully be introduced. When working in small groups these students can rely on and further develop their abilities to communicate and to solve problems in close cooperation with others.

Such beliefs about the relationship between certain work forms and female competences can find support within the feminist literature, where researchers often call for collaborative modes of working that will stimulate dialogue between students and between students and teachers (see e.g. SOU 1995:110, p. 260):

> "Female students react differently than male students in the social context of the classroom. They seem to favour collaboration over competition in learning." (Cordeau, 1993, p. 127)

Some feminist researchers argue for the existence of female ways of knowing (Belenky et al, 1986), female ways of thinking (Gilligan, 1982), and female ways of reasoning:

> "Psychologists have observed that women have a tendency to prefer socially interactive processes, in contrast to men who yearn for the complete isolation of private thought. In this respect feminism offers a methodology, a methodology for female reasoning: enhanced awareness starts with personal experiences, focussing on specifics within the experience and continuing towards a broader, collective analysis. Generalizations occur when a number of particular cases have been presented. This activity is interactive and not the kind of private process that Descartes visualized." (Sherwin, 1994, p. 21, my translation)

Other feminists have, however, argued against such generalized views of female ways of thinking and acting. Generalising from some women to all, is, they argue, a mode of thought alien to the feminist alternative to male dominated research, which has been criticized precisely for making unwarranted generalizations, for drawing conclusions about Man from studies about men.

> ”Time and time again we have discovered that we have missed or misunderstood some truths in the experiences of certain groups of women and that we even have been overlooked or misinterpreted ourselves by some other faction or other school of feminist thought. We have had great difficulty accepting the differences among women – differences linked to race, social class, ethnic background, religion, nationality, sexuality, age, physical ability and even female variations associated with the particulars of personal life histories.” (Frye, 1994, p. 3, my translation)

The interviewees in this study also question their abilities, even their rights, to express opinions about the preferences of female students in general. When designing the programmes, however, such notions seem to have guided their choices of methods. Some truth is ascribed to notions of women as more collaborative than competitive, more dialogical than adversary, more communicative and more sensitive to the social environment than male students.

That women have more experience in communicating in small groups in their daily lives (see e.g. Coates, 1988), does not, however, imply that they automatically benefit from group-work when confronted with problems of a different kind in an educational setting. The problem of transfer of abilities acquired in one setting to another is well known within the field of education (see e.g. Larkin, 1989; Säljö, 1991). Assumptions about the fruitfulness of collaborative methods and small-group discourse for the development of alternative ways of learning subjects like mathematics and physics cannot be taken for granted but have to be addressed in a follow-up study of the programmes described in this report.

Intergrating female students

Integrating women into study programmes within subjects dominated by men and male perspectives is a delicate matter. Women sometimes express a well-founded hostility towards being looked upon as a special group demanding special treatment. All of the female interviewees in this study express such a view and so do most of the male interviewees. A minority perspective easily becomes a perspective focussing on shortcomings (Kelly, 1987). Furthermore there are reasons to believe that an educational programme designed to fill the needs of female students may be viewed as inferior to the traditional study programmes and, therefore, be regarded as low-status. Pedagogical innovations, even if well meaning, can easily turn against women, for example when they seek advancement within the academic system or when they compete for jobs on the labour market.

Integration, when discussed in the context of integrating minorities into a majority culture, is often categorised into four different forms. The integration can be merely **physical**, as when people of a different culture are allowed to be physically present at a formerly restricted site, as when women once were allowed to visit and listen to academic lectures at the universities without being offered the benefit of taking part in the events. In order to join the activities the minority needs to be **socially** integrated, which means that they have equal rights, for instance to express their views in seminars and discussions. Passing the examinations, however, requires **functional** integration, which means that they not only receive the benefits of the system but they are also expected to contribute to the community, thus viewed as rightful members, with views worthy of consideration. Another form of integrations is **cultural**, a term referring to a broader acceptance of competencies acquired within a specific social setting. In the case of integrating female students into university studies within the fields of science and technology, a cultural integration would mean that the students, after receiving their degrees, are accepted into the society as true professionals, equal to students leaving traditional study programmes.

To be merely physically or socially integrated into an academic system does not seem to be sufficient modes of integration. To be allowed to stay within the university programmes you have to pass the examinations, otherwise you will eventually be excluded. It is possible, however, that social integration may be a step towards a functional integration. In collective forms of work, such as the ones implemented within the five programmes described in this report, some students may contribute to the group work in ways that are acceptable to the other members of the group, even if the qualities of their contributions do not fill the demands of the academic system. A group member could, for instance, be totally immersed in a supportive role, encouraging the other group members to communicate with each other, or absorbed by the role of being a secretary, administering meetings, taking notes, typing up reports and the like. Such roles may be very important to the functioning of the group, but when taken on by one single member they may be dysfunctional and interfere with that member's learning. Listening to discussions could, however, develop into a more active mode of participation which, in turn, may lead to a functional integration. In the interviews we can find accounts of such shifts in student activities, as in a case where a lecturer in Linköping reports of female students shifting from a passive to an active mode of participation in the group discussions.

Furthermore, there may exist different forms of functional integration. The whole idea of adopting alternative teaching methods implies a shift from standardised criteria for evaluating student knowledge to assessment methods that are more sensitive to alternative ways of knowing the subjects. Qualitative aspects of knowledge, neglected or overlooked within the traditional study programmes, are emphasised by the interviewees and pointed out as functional to a professional scientist or engineer. Whether these qualities will also be praised within a broader cultural context is, however, still an open question.

Outline of a follow-up study

When designing a follow-up study of a developmental project, you easily get entangled in a discussion of teaching practices in general. The range of questions to be asked of the programmes are numerous, and there are numerous ways of designing a follow-up study. We have to make choices about what fundamental questions to raise and about what topics can be investigated within a restricted time and with limited research rescources.

In some sense we can rely on the teachers to evaluate the outcomes of their teaching practice, as indeed they will, since assessment of student knowledge is an important element of the everyday activities within all university programmes. Students who do not fill the requirements will not be left unnoticed; students who do will receive good grades and will eventually get their degrees. On the other hand, we have to be sensitive to and critical towards the criteria used in the day-to-day assessment of student knowledge. We still know very little of what is involved in the daily practices of higher education, in terms of student learning and understanding and in terms of criteria used to distinguish between valuable knowledge and trivial (Marton et al, 1984). We have little knowledge of what is involved in learning subjects like mathematics and physics at the tertiary level (Crawford, Gordon, Nicholas, & Prosser, 1994), much less of expanding subject perspectives into interdisciplinary domains (Leinhardt, McCarthy Young, & Merriman, 1995).

This brings us back to the issue of relevance touched upon in the previous section. What problems would be appropriate to follow up in connection with this particular developmental endeavour?

As mentioned above, two goals guide the projects: the aim of attracting female students to science or engineering studies and the aim of raising the quality of student learning in ways described above. A follow-up study should address these goals, that is focus primarily on the women studying within the programmes and on qualitative aspects of their understanding of the subject matter.

In the following sections I will present an outline of a three-step follow-up study that addresses the questions posed in the previous section, and that takes into account the variety of teaching practices described above. The mode of evaluation could be called dialogical, since the design of the study presupposes close contact with teachers and lecturers within the programmes as well as with interested parties outside of them, people who are not directly involved in the development work but who may have an interest in the outcomes of the projects – people within the university faculties and representatives of the labour market.

An overview

A first step in a follow-up study would be to establish an overall picture of the women enrolled in the programmes: where they come from in terms of previous studies, their age and vocational interests, their motives for applying to the programmes and their previous levels of success within the educational system in terms of grades (average grades and grades in mathematics and physics from the secondary school). There are about 60 female students in all attending the five programmes, which means that a survey could be undertaken in the form of a census. Much of the data needed will be available within the departments. Supplementary data could be gathered through interviews or questionaires.

In order to establish a picture of how the female students succeed in their studies within the respective programmes, data about their previous studies could be complemented by data about their results from the ordinary assessments in mathematics and a supplementary core subject within each programme (such as physics), covering the first three terms. The results would give us an overview of how women, with various backgrounds and interests, are received and assessed within the study courses.

Special interest should be directed towards those who choose to leave the programmes. When do they leave? What reasons do they have for leaving and what do they choose to do instead? Are their reasons in any way connected to the content of the programmes or the work forms applied and if so, in what way? Data should, in these cases, be gathered through interviews, a way of obtaining information that will allow some probing into the answers given.

An in-depth study

The crucial part of the follow-up study will be to describe and characterise qualitative aspects of student learning and alternative ways of knowing the subjects presented. Could we find traces of the qualities mentioned by the teachers in the interviews, summed up in the conception of the scientific or professional attitude, when students address tasks presented to them? In what ways do they express a 'sense' of the subject matter brought to the fore when carrying out the tasks? How do they go about integrating knowledge from different subject domains? Are they cooperative and communicative and if so, in what ways? Do they take into account alternative interpretations of the tasks and if so, how do they utilize knowledge presented by others? Are they critical and reflective and if so, how do they balance critique and acceptance in the problem-solving process?

The ideal situation for addressing such questions would be to follow groups of students when they interpret 'scenarios' or work with projects in everyday situations that naturally occur within the programmes. This would provide the study with a strong ecological validity (House, 1980). Such a design would, however, be too costly in time and research effort (cf. Wistedt, 1987). It would not be possible to follow more than a few groups in depth, which means that the variations among the programmes and among the students attending them will not be fully taken into account. Another option would be to design tasks that could be presented to groups of students for the purpose of elucidating the qualities of learning mentioned above, carefully designed tasks that could be carried out within a limited period of time (about one hour). Such tasks have been presented to students within a research project "Ways of learning mathematics in gender-inclusive higher education" (Wistedt, Brattström & Martinsson, in press), and the results show that accounts of how students address such tasks can shed light upon qualititative aspects of learning and upon alternative ways of approaching problem solving (cf. Wistedt, 1994a,b, Wistedt & Martinsson, 1994a, in press).

Choosing tasks that presuppose the use of different subject perspectives could highlight the students' use of interdisciplinary ways of thinking and reasoning. The choice of subject content should be made in close collaboration with teachers within the five projects and should be sensitive to the particulars of each programme. Aspects of the content of the tasks or the concepts involved should, however, be common to the tasks presented to students from different programmes, in order to make the results of the analyses comparable and compatible.

It would be possible to carry out such an in-depth study within reasonable time limits and with reasonable rescourses. Covering three study groups (of 3-5 students) from each project would give us the opportunity to capture the variation among all five programmes and among about 60 students. A fairly rich variation in ways of approaching the tasks could be expected as a result.

The in-depth study should not be restricted to female students only. As pointed out by one of the teachers in the interviews 'female' traits, such as communicative and cooperative skills, are not expected to be reserved for women but are supposed to be encouraged in all students, male or female. In order to be able to say something about female ways of handling the tasks presented, we need to know something about male views of the tasks as well. As mentioned above, little is known about alternative ways of learning mathematics, science and technology at the tertiary level of education, which calls for a descriptive and comparative approach.

The in-depth study should result in thick descriptions (Geertz, 1991) of how students handle the tasks presented to them. Such descriptions could render pictures of how students understand phenomena and concepts encountered when solving the given tasks – how they contextualize the subject matter and how experiences are brought to the fore and utilised in the problem-solving process (Halldén, 1995; Halldén, Hansson, & Skoog, 1994; Wistedt, 1994a; 1994b). Recent research within the field of education has shown that learning in institutionalised settings generally entails challenges to naive and everyday notions of scientific phenomena (see e.g. Driver & Easley, 1978; Pfundt & Duit, 1991). The cultural conventions and speech genres applied within different subject domains often differ substantially from ways of thinking and reasoning applied within everyday settings (Perry, 1968; Marton, et al, 1984; Halldén, 1986). Within the natural sciences the differences are often radical (see e.g. Driver & Easley, 1978), which also seems to apply to mathematics (Wistedt 1994a; 1994b). Learning within a specific subject domain presupposes a cultural awareness, a readiness to relativise the frames of reference used to interpret phenomena (Caravita & Halldén, 1994). The analyses of the descriptive data obtained from the in-depth study could render a picture of variations in ways of interpreting the tasks presented to the students, in the students' awareness of the applicability and fruitfulness of such different interpretations, or in their usefulness in a more pragmatic sense, variations in approaches to the tasks given that could then be discussed in a gender perspective.

A dialogic evaluation

As mentioned above, the in-depth study will result in narratives that give rich accounts of how students approach tasks to be carried out in groups. The descriptions will form the bases for further analyses of alternative ways of learning, but they could also be used as a basis for discussions with interested parties, over desired qualities in learning. In a final step of the follow-up study the descriptions will be used to open a dialogue with people within and outside of the programmes, focussing on the criteria used to assess aspects of student knowledge.

People within the programmes, within the faculties and within the labour market, i.e. people with a central position within the respective cultures, could be asked to read through the narratives and to comment on the students' ways of carrying out the tasks. In interviews, following the reading of the accounts, people could be encouraged to express their attitudes towards the various ways of approaching the subject matter presented in the texts, feelings, aesthetics, values judgements and other reactions brought to the fore while reading the accounts.

The in-depth study will provide descriptions of various ways of understanding the academic culture and the latitude for learning when performing tasks presented within such a culture – student comments on the academic demands. The interviews with the teachers, faculty members and representatives of the labour market will provide responses to such student notions of what counts as knowledge, evaluated within the respective cultures. If we add the possibility to correlate data from step one with the in-depth descriptions of alternative ways of approaching tasks obtained in step two, we could gain a picture of culturally acceptable ways of knowing the subject matter, of experiences valued and of qualities of learning praised. Conflicting views could be uncovered and discussed in relation to gender-specific aspects of learning. The dialogue between the parties involved could result in an interesting debate over the possibilities of opening study programmes to new groups of students and of the readiness to adjust teaching practices to meet with changing demands.

References

Barrows, H.S., & Tamblyn, R.M. (1980). *Problem-based learning. An approach to medical education*. New York: Springer Publishing Co.

Belenky, M.F., Blythe McVicker, C., Rule Goldberger, N., & Mattuck Tarule, J.(1986). *Women's ways of knowing*. New York: Basic Books.

Berkson, L. (1990). *Critique of problem-based learning: A review of the literature*. Chicago: University of Illinois, Graduate College Thesis.

Berthelsen, J., Illeris, K., & Poulsen, S.C. (1979). *Projektarbete* [Project work].Stockholm: Wahlström & Widstrand.

Boud, D. (1987). *Problem-based learning in education for the professions*. Sydney: Herdsa.

Brenner, P., & Jacobsson, C. (1994). *På jakt efter en främmande fågel. Innovativ matematikutbildning i Europa* [In search for a strange bird. Innovative mathematics education in Europe]. Stockholm: Council for the Renewal of Undergraduate Education.

Burton, L. (1995). Moving towards a feminist epistemology of mathematics. *Educational Studies in Mathematics*, **28**(3), 275-291.

Callewaert, S., & Kallós, D. (1976). *Den rosa vågen i svensk pedagogik*. [The pink wave in Swedish pedagogy]. Forskning om utbildning, **3**(1), 31-38.

Caravita, S., & Halldén, O. (1994). Re-framing the problem of conceptual change. *Learning and Instruction*, **4**(1), 89-111.

Coates, J. (1988). Gossip revisited: language in all-female groups. In J. Coates & D. Cameron (Eds.), *Women in their speech communities* (pp. 94-122). New York: Longman.

Cordeau, A. (1993). Empowering young women in mathematics: Two important considerations. In B. Grevholm & G. Hanna (Eds.), *Gender and mathematics education* (pp. 121-128). Lund: Lund University Press.

Crawford, K., Gordon, S. Nicholas, J., & Prosser, M. (1994). Conceptions of mathematics and how it is learned: The perspectives of students entering university. *Learning and Instruction*, **4**(4), 331-345.

Driver, R., & Easley, J. (1978). Pupils and paradigms. A review of literature related to concept development in adolescent science students. *Studies in Science Education*, **5**, 61-84.

Dewey, J. (1980). Individ, skola och samhälle [The individual, the school, and the society]. Pedagogiska texter av John Dewey. Stockholm: Natur & Kultur.

Egidius, H. (1991). *Problembaserad inlärning – en introduktion* [Problem-based learning – an introduction]. Lund: Studentlitteratur.

Fennema, E. (1993). Mathematics, gender and research. In B. Grevholm & G. Hanna (Eds.), *Gender and mathematics education* (pp 21-38). Lund: Lund University Press.

Franke-Wikberg, S., & Lundgren, U.P. (1980). *Att värdera utbildning*, del 1 [To evalutate education, Part 1). Stockholm: Wahlström & Widstrand.

Frye, M. (1994). Den feministiska teorins möjligheter [The possibilities of feminist theory]. In E.J. Emt & E. Mansén (Eds.), *Feministisk filosofi* [Feministic philosophy] (pp. 1-13). Nora: Nya Doxa.

Geertz, C. (1991). Tjock beskrivning. För en tolkande kulturteori [Thick description]. *Häften för kritiska studier*, **3**, årgång 24, 13-33.

Gilligan, C. (1982). *In a different voice*. Cambridge MA: Harvard University Press.

Halldén, O. (1985). *Koncentrationsläsning. Utvärdering av en idé.* [Concentrated studies. Evaluating an idea]. Stockholm: Pedagogiska institutionen.

Halldén, O. (1986). Learning history. *Oxford Review of Education*, **12**(1), 53-65.

Halldén, O. (1995). Constructing the learning task in history instruction. In J. Voss & M. Carretero (Eds.), *Cognitive and instructional processes in history and the social sciences*. Hillsdale, NJ: Lawrence Erlbaum.

Halldén, O., Hansson, G., & Skoog, G. (1994). *Evolutionary reasoning in answers to two questions used to measure the development of university students' understanding of evolutionary theory*. Working Paper Series, No. 4. Stockholm University: Department of Education.

House, E.R. (1980). *Evaluating with validity*. London: SAGE Publications.

Illeris, K. (1976). P*roblemorienterad och deltagarstyrd undervisning – förutsättningar, planering och genomförande* [Problem-oriented and actor-governed teaching – prerequisites, planning, and implementation]. Stockholm: Wahlström & Widstrand.

Jacobsson, C., & Elvin-Nowak, Y. (1994). *Kvinnor i matematiken. Ett trevligt inslag eller på lika villkor?* [Women in mathematics. A pleasant contribution or on equal terms?]. Stockholm: Council for the Renewal of Undergraduate Education.

Kelly, A. (Ed.) (1987). *Science for girls?* Milton Keynes: Open University Press.

Kjersdam, F., & Enemark, S. (1994). *The Aalborg experiment. Project innovation in university education*. Aalborg: Aalborg University Press.

Kilpatrick, W.H. (1918). The project method. *The use of the purposeful act in the educative process*. Teachers College Bulletin, Tenth Series, No.3.

Larkin, J.H. (1989). What kind of knowledge transfers? In L.B. Resnick (Ed.), *Knowing, learning and instruction. Essays in honor of Robert Glaser* (pp. 283-305). Hillsdale, NJ: Lawrence Erlbaum.

Leinhardt, G., McCarthy Young, K., & Merriman, J. (1995). Integrating professional knowledge: The theory of practice and the practice of theory. *Learning and Instruction*, **5**(4), 401-408.

Marton, F., Dahlgren, L-O., Svensson, L., & Säljö, R. (1977). *Inlärning och omvärldsuppfattning* [Learning and experiencing the world around us]. Stockholm: AWE/Gebers.

Marton, F., Hounsell, D.J., & Entwistle, N.J. (Eds.) (1984). *The experience of learning*. Edinburgh: Scottish Academic Press.

Perry, J. (1902). The teaching of mathematics. *Educational Review*, **23**, 159-181.

Perry, W.G. (1968). *Forms of intellectual and ethical development in the college years*. New York: Holt, Rhinehart & Winston.

Pfundt, H., & Duit, R. (1991). *Bibliography: Students' alternative frameworks and science education* (3rd ed.). Kiel: IPN

Prop. 1992/93:169. *Högre utbildning för ökad kompetens* [Higher education for higher competence]. Stockholm: Utbildningsdepartementet.

Ramsden, P. (1992). *Learning to teach in higher education*. London and New York: Routledge.

SCB, Statistiska Centralbyrån (1995). *Utbildningsstatistisk årsbok 1995* [Yearbook of educational statistics 1995]. Stockholm: SCB.

Sherwin, S. (1994).Är filosofisk och feministisk metodologi förenliga? [Are philosophical and feministic methodologies compatible?]. In E.J. Emt & E. Mansén (Eds), *Feministisk filosofi* [Feministic philosophy] (pp. 15-30). Nora: Nya Doxa.

Slater Cavallo, L., & Bibelnieks, T.A. (1993). Enhancing female participation in mathematics through pre-program intervention. In B. Grevholm & G. Hanna (Eds.), *Gender and mathematics education* (pp. 101-111). Lund: Lund University Press.

Solar, C. (1993). From a feminist to an inclusive pedagogy in mathematics. In B. Grevholm & G. Hanna (Eds.), *Gender and mathematics education* (pp. 327-334). Lund: Lund University Press.

SOU 1995:110, *Viljan att veta och viljan att förstå. Kön, makt och den kvinnove tenskapliga utmaningen i högre utbildning* [The will to know and the will to understand]. Stockholm: Utbildningsdepartementet.

Säljö, R. (1982). *Learning and understanding*. Göteborg Studies in Educational Sciences 41. Göteborg: Acta Universitatis Gothoburgensis.

Säljö, R. (1991). Piagetian controversies, cognitive competence, and assumptions about human communication. *Educational Psychology Review*, **34**(2), 117-126.

Säljö, R., & Wyndhamn, J. (1988). Cognitive operations and educational framing of tasks. School as context for arithmetic thought. *Scandinavian Journal of Educational Research*, **32**, 61-71.

Säljö, R., & Wyndhamn, J. (1990). Problem solving, academic performance, and situated reasoning. A study of joint cognitive activity in the formal setting. *British Journal of Educational Psychology*, **60**, 245-254.

Wistedt, I. (1987). *Rum för lärande* [Latitude for learning]. Stockholm University: Department of Education.

Wistedt, I. (1994a). Everyday common sense and school mathematics. *European Journal of Psychology of Education*, **9**(1), 139-147.

Wistedt, I. (1994b). Reflection, communication, and learning mathematics: A case study. *Learning and Instruction*, **4**, 123-138.

Wistedt, I., Brattström, G., & Martinsson, M. (in press). *Ways of learning mathematics in gender-inclusive higher education*. Stockholm University: Department of Education.

Wistedt, I., & Martinsson, M (1994a). *Kvaliteter i elevers tänkande över en oändlig decimalutveckling* [Qualities in pupils' reflections upon infinity]. Stockholm University: Department of Education.

Wistedt, I., & Martinsson, M. (in press). Orchestrating a mathematical theme. *Learning and Instruction.*