RENEWING ELECTRICAL ENGINEERING

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Executive Summary

The program in electrical engineering at the School of Electrical Engineering has in a decade gone from being a mass-education program of 300 entering students a year to a program with 60 entering students. The future situation for the program is critical since the number of applications is steadily declining. Yet, the severity of the situation provides the urgency to radically renewing the program in order to provide a fresh start for electrical engineering at KTH. There is a tremendous opportunity to attend to undergraduate education at this time when most Swedish and European universities are concerned with making their research more competitive. The School of Electrical Engineering has strong research and is therefore well positioned for reforming its program and the way it is taught; this activity may provide the largest gains of the time invested. The renewal of the program may readily borrow from best practices internationally. Alternative models for teaching exists in the liberal arts colleges in the USA; institutions which have no counterparts in Sweden (or continental Europe).

The proposals herein are in summary:
Admission: Although admission to an educational program is part of the freedoms, we do not control it in Sweden. Our only control variable is the dimensioning of our program, the number of new students to admit. Hence, we need to better find out how the high-school grades correlate with performance in the program. We also need to initiate and engage in a public debate about the shortcomings of the centralized admission process.
Curriculum: The contents of the program must be designed to be more integrated, with consideration to both the longevity of the knowledge taught and the acquisition of practicable skills. A mandatory core curriculum would provide a common base and seek to define the identity of an electrical engineer. The curriculum must also be designed to provide intellectual stimulation and not be directly vocational.
Teaching: The curriculum is seen as the architecture of the educational program. This leads to a new structure of the teaching that takes its start from the whole and divides it into blocks that are best suited for instruction. A single block can be taught jointly by a group of teachers and the forms of instruction within a block may be chosen to best suit the topics taught (lectures, tutoring, self study, projects and laboratory). The education can also leverage on the research at the school to a much higher degree than today, for instance by engaging undergraduate students in our research projects in the groups. Contacts between faculty and students have been found to be vital for a good learning environment. We must hence improve this by assigning a faculty advisor to each student, to allow ourselves to tutor and coach students, and by engaging in tutoring of discussion groups as non-experts. The program should aim at learning for life and it may be complemented by a life-long learning program that maintains contact with former students and takes an interest in their educational well being throughout their work life. The end result of the teaching should be a certification of good to excellent knowledge, rather than a mere grading of the knowledge acquired. Such certification might be interesting for students from other universities as a gauge of their standing (with respect to KTH graduates).
Recruitment: A renewed program offers a wonderful opportunity to directly market the program to students. It should involve the professors as academic leaders to go out and tell young people personally about the program. The messages should target prejudice and misconceptions. A goal must be to attract more women to the program.
Financing: Our resources can be more efficiently used by engaging more teachers in fewer courses; we currently have many that are underfinanced. The income will increase when the performance of the students improves and when the attrition rate goes down. The renewal might attract enough attention to establish a foundation in support of its continuity.

The renewal of the program in electrical engineering requires the School's professors to re-assert their academic authority and to lead the change.

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Introduction

This report presents a *personal* view on the problems that electrical engineering faces and the opportunities that exists for rejuvenating the program at KTH. Most of the suggestions pertain to the *first three years of the current program*, which would constitute a Batchelor of Science in Electrical Engineering, if so decided. The structure of the report is the following. First a background to the current situation is sketched, with an eye to the American education market where there are interesting examples for how an educational program can be structured and managed. The following sections provide the proposals. The admission process is discussed with respect to the dimensioning of the program, the only control in the hands of the university. Then the suggestions to improve the teaching will be presented, starting from the curriculum, continued to teaching of the curriculum, followed by discussions on life-long learning and learning for life and on examination as a means to assure high standards in the retention and practicability of knowledge. The proposals end with ideas on how to improve the recruiting to the program and for how to finance the changes; then we conclude.

A SWOT analysis of the EE program at KTH is presented in Appendix A, a short suggestion for an English-language program is given in Appendix B, and a comment on last year's suggestion is in Appendix C.

Background

The modern research university is considered to have been created with the establishment of the Humboldt-Universität zu Berlin in Germany, based on the ideas of Wilhelm von Humboldt, whose name the university now bears. The university has been immensely successful and has had 29 Nobel Prize winners among its students and faculty (Falanga 2005). Humboldt's idea of a university was based on the *Lehrfreiheit* (freedom to teach) of the faculty and the *Lehrnfreiheit* (freedom to learn) for the students. Thus, students driven by their own curiosity, rather than by curriculum requirements, would meet the professor, charged by passion for his subject, in seminars. The Humboldt idea spread and was introduced in the United States by Johns Hopkins University in Baltimore, Maryland and the lesser known Clark University in Worcester, Massachusetts. The most distinguished research universities in the world have since been American.

Tertiary education underwent a big expansion following the Second World War both in United States and in Europe. Mass education is however at odds with the Humboldt model of higher education with the seminar as the joint forum for teaching and learning. As a result of the expansion, there has been an ongoing tussle within the research universities between the research and the educational activities. Joseph Tussman, a professor of philosophy at UC Berkeley, was disenchanted with the teaching of the first two years of undergraduate studies: the cafeteria menu of courses offered without solid counsel on how to compose an intellectually nourishing meal, and the competition for students' attention among courses taught in parallel that make time for reflection void. Tussman (1997) hence started an Experimental College Program in 1965 that consisted of a reading list of great works, without courses and exams. The program was taught by him and a few colleagues gathered from across the different departments of the university. The studies consisted of reading, discussing and writing. He had the possibility to make the program permanent after running it for four years, but declines since he could not see how to attract faculty to teach it.

North America has an educational market and where the research universities fail their students; there are colleges to provide alternatives. Pope (2006) makes a point of the perceived undergraduate failures of the research universities and he is rallying students and their parents for liberal arts colleges that care for the students' educational and intellectual needs. For instance, Tussman's model of undergraduate teaching still exists at the two campuses of St. John's College. The recently established Franklin W. Olin College of Engineering in Needham, Massachusetts, with the first class starting in 2002, shows that the alternative to the large universities are not limited to the liberal education. The situation is gloomier in Europe with its plan-economic university systems: all research universities, with the exceptions of the Universities of Cambridge and Oxford, are now also mass educational institutions. There is virtually no competition partly because of alleged equality among all public institutions; partly, and naturally contingent on the former, because of lacking comparative statistics, and partly on the centralized control and public financing that is opposed to differentiation among the universities.

The mass education has destroyed excellent academic environments and has cast the teaching and learning into a model based on that of a production system (Husén 1994 and 1986). Few warm to the thought of a European undergraduate program with hundreds of students in each lecture—with as little as five hours of teaching per week, little faculty contact out of class, and by certification of the learning by means of written

exams only (Hörisch 2006). With the exception of UK and Ireland, there are no liberal arts colleges that provide alternatives to the factory university and there a few universities that are governed independently of the political system. The debate about the universities and their faculties has been vocal in Germany and has targeted alleged improprieties among the faculties, such as absenteeism and laziness (Kamenz 2007). It shows how little trust remains in a system that once was the model for the whole world.

Sweden has taken a further step into the mass education by expanding the regional university colleges. There has not been a blue print for the growth, such as that laid out by Clark Kerr when he was chancellor of the University of California and oversaw its expansion (Husén 1994). The University of California system is structured into institutions of three complementary roles: the community colleges for adult and vocational training, the California State universities (23 campuses today) that provide undergraduate and Master's level education, and the ten campuses of the University of California, where research is being conducted. This is a system with a clear structure and with ample external competition, even locally, like Stanford to Berkeley and USC to UCLA. The Swedish system is unstructured and the different institutions do not have their roles well defined, neither from the University Chancellor nor from the governors of the universities and university colleges themselves. If anything, all institutions for tertiary education appear to aspire for becoming research universities. There are no alternative models, no colleges specializing and trying to perfect undergraduate teaching. The new Chancellor has voiced his opinion about this and suggests that today's fourteen universities become five. It might allow a structure such as Kerr's, but it would not create the competition by parallel and independent institutions, which is so vital for the American educational market's success.

A direct consequence of the Swedish expansion in general and the decline in interest for engineering among young people in particular, is the situation that prompts this report: Electrical Engineering at KTH is no longer a mass education. We have alas not returned to the situation some years ago when the admission in EE also was around sixty students. At that time, the students had both the aptitude and the attitude necessary to excel with their studies. Now we have sixty students about whom we know very little. This is the background to this report and the question that I will try to answer constructively is how the Electrical Engineering program at KTH can return from the mass education experiment and regain the reputation and the impact it has had for most part of the century that it has been given.

Admission

Husén (1994) itemizes the academic freedom as

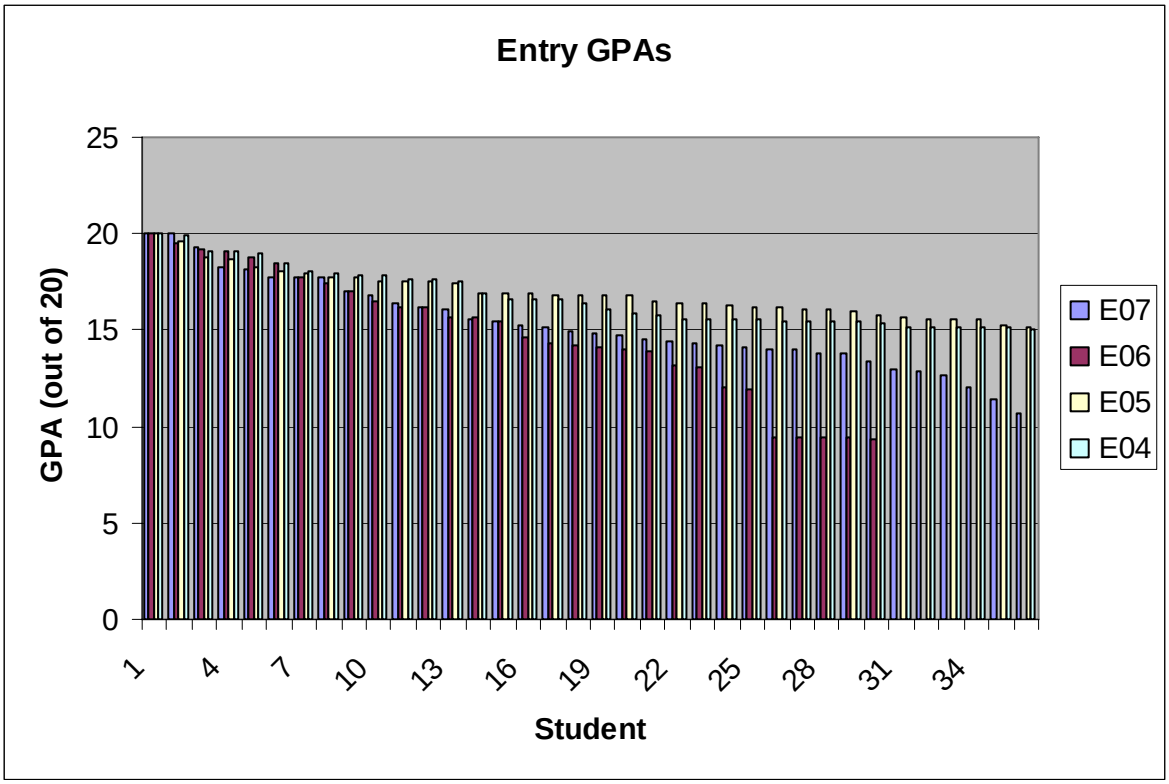
- Admission and selection of students.
- Developing and carrying out curricula.
- Establishing examination requirements.
- Planning of research programs.

The first item is entirely wrung out of our hands at the Swedish universities. Compare this with the American universities and colleges where the admission and selection is a careful process that frequently involves interviews, class participation on a trial basis (up to a week in some colleges), and essay writing on why she or he should be admitted and what the motives are from the student for the choice of program. Light (2001) describes the program that he has been responsible for at Harvard for finding out, basically, what make students succeed. The program is based mostly on interviews with students and thus it provides a deeper understanding for how to shape the time in college. Pope (2006) presents forty colleges that admit also students with weak marks from high school, but through their experienced admission process are able to turn out successful graduates, of which many continue to graduate school. The American admission process has been motivated by the widely different standards of the high school education. An interesting aside is that the Scholastic Aptitude Test that has been used to gauge high-school grades is falling out of favor and some universities and colleges do not even use it as a criterion for their admission decision. We have to recognize that the Swedish high schools do not provide a uniform level of education, especially since many more program provide eligibility for tertiary education. Yet our centralized admission through the National Agency for Services to Universities and University Colleges is highly standardized and impersonal and it is possible to enter university based solely on an entrance test ("högskoleprovet"), which is similar to the SAT.

By marked contrast to American colleges and universities, we know very little about the students that start our program. The reason is partly the centralized admission system that provides little detail and partly that we do not ask the students. We know the grade-point averages of those that have been admitted and those who finally start the program. We know nothing about their motivation for the choice of studying electrical

engineering, and we do not know how a GPA at entry correlates with the chances for succeeding in the program. What we know is that fewer and fewer are attracted to electrical engineering in Sweden, and that those students with the highest GPAs from high school usually apply to the most selective programs, irrespective of the field (such as all medical schools in Sweden; psychology, dental medicine and psychology at the Karolinska Institute, veterinary medicine and SLU, and business at Stockholm School of Economics; these programs all require GPAs of 20.00). For this year, the highest GPA at KTH is for industrial engineering with a minimum of 19.48; electrical engineering has a minimum entrance GPA of 10.71. The entry GPAs for EE is shown below for years 2004 to 2007 (it is truncated to 37 students, which this year entered based on high-school grades). A reduction of the number of seats to 20 would have given an entry GPA of approximately 15 this year.

Reducing the admission to the EE program might help in making the program more attractive, but it will not suffice to bring it in competition with medical and business schools. Also, we do not know how the dynamics work, and it might be a vain hope to reduce admission in order solely to increase the attraction for the program.



Discussion

A needed measure is to reduce the admission to a point were the GPA correlates well with students who are able to complete the program in a reasonable time, to institute a systematic study of our students in order to learn what they value in our program and what measures of their prior studies indicate their preparation to succeed with the program. This is basically unknown (a KTH-wide study from 1998 shows that the entry GPA is not an indicator for the number of credits passed by students during the first year of study). The EE program must then be further strengthened by curriculum design, new teaching methods, and better recruitment.

Finally, we must, as a faculty, initiate a discussion around the centralized admission. It is now possibly to admit up to twenty percent of the seats of a program based on alternative selection criteria (other tests than the university entrance examination; knowledge, work experience or other experiences of particular value for the program, and other impartial circumstances). When our program regains it attraction and we know what makes our entering students succeed, then we should use this, albeit limited, means for controlling admission.

Curriculum

The liberal education has the grand goal of teaching students about human experience and to educate democratic citizens (Tussman 1997). The goal of an electrical engineering program must be more humble and focused. Yet we ought to remember that electrical engineers have been instrumental in the invention and development of telecommunication, electric power, computing, electronics, and electric traction. Electrical engineering technologies have radically changed the world. A goal of an electrical engineering curriculum is to connect young people into the tradition and heritage of the field and to prepare them for contributing to it. Another goal for the curriculum is to be intellectually stimulating and to provide learning strategies that are generally applicable. The curriculum could be loosely separated into three parts.

Core curriculum

The core curriculum consists of mandatory courses that are selected to provide a solid basis in electrical engineering and it seeks to define the identity of an electrical engineer. It includes fundamentals of mathematics and physics, electro-magnetics, signals and systems, electronics and circuit theory, communication and networking, and electric power systems. It is important that the emphasis is on fundamental principles that have longevity and may serve as basis for continual development and learning by the engineer during her or his work life.

Best practices

The electrical engineer must possess tools that are developed in other disciplines, such as mathematics, computer science, economics and management. The tools should be taught based on the best practices in order to ensure that they are the most modern and useful ones. These best practices are generally based on research done in other disciplines, outside the School of Electrical Engineering. The emphasis of this part of the curriculum must be on the acquisition of skills that can be productively used in solving electrical engineering problems. Examples are programming and software engineering, numerical analysis, simulation methodologies, optimization theory, financial analysis and project management.

State of the art

The research in electrical engineering meets the students in a plethora of courses, mainly on the graduate level in the fourth and fifth years of study. These courses are defining the state-of-the-art in the respective topics, and they are consequently characterized by a rapid evolution of the contents, by specialization in the treated topics and often by high demands in the skill-set required for the course exercises. The courses are given by the groups that conduct the research; the courses are often small owing to the specialization, and hence they form the modern instantiation of Humboldt's idea of the seminar-based teaching.

Discussion

A curriculum is not only a list of mandatory and elective courses: it is the architecture of an entire education. It is important to recognize that the curriculum will never be a finished product, but that it will be continually improved to pursue the vision of an electrical engineering education that best prepares for the engineering career and that provides intellectual stimulation and challenges to prepare for graduate education and for work in many areas outside engineering. The curriculum should represent the knowledge that the school's professoriate have decided fundamental for an electrical engineer, without consideration to admission, possible success for those who enter the program and the graduates' near-term job opportunities. The curriculum should be designed with an aim of learning for life.

The present curriculum can be seen to contain the three listed aspects of electrical engineering education. However there is no explicit information about the curriculum and the thoughts behind the selection of mandatory courses in the first three years. A better structure along with the motivations for the curricular design would provide more attractive information to the students. Also the curriculum is not evolving in conscious way; it rather evolves through changes in the constituting courses. There are two examples that should be studied carefully for their attention to the electrical engineering curriculum: Carnegie-Mellon University and Franklin W. Olin College of Engineering.

The curricular design also has a bearing on the finances for the program. The colleges presented by Pope (2006) offer curricula, all in liberal arts, that range from the four year mandatory reading list of great works, without electives, at St John's, to the entirely individual design of the curriculum for each student at Marlboro, Hampshire and New College. The latter means however that a curriculum is decided by the

student and her or his advisor and that it is then enforced. Hence, it becomes a mandatory list of courses. At KTH we do not have the luxury of individually tailored programs. The core and best practices curricula should indeed be mandatory in order for all students to share a common culture from the core and a common tool set from the best practice to allow easy change among the EE specializations. This avoids also the fragmentation of the resources, which instead can be invested in improved teaching and examination practices.

The state of the art curriculum provides choice, initially to the field of specialization, and later possibly to choice of courses within the field. It is important that electives are provided along with advice on how to choose and with the *approval* of the course selection by a faculty member. In general, the wide choice of courses and the lack of advise on how to choose pose problems both economically, since many courses become underfinanced, and personally, since some students make ill-informed, immature and unwise choices. This remark leads to the manner in which we teach the curriculum and the responsibility the faculty has for educating the students to become responsible, professional engineers.

Teaching

An education in electrical engineering is and always will be demanding. We should not lower the standards when the number of applicants decreases since that would be ruinous for the reputation of the program and would release graduates onto the labor market that alas may not be competent for the jobs in the field. Herein lays the dilemma: we admit students with weak high-school grades for a conceptually advanced and mathematically demanding education, and yet we need to maintain the standards for the education to be purposeful. Is there a solution?

There are two remarks to make and they lead to the same solution. The first is that the curriculum is not designed with all of the students we admit today in mind. Naturally some of the students we currently have in the program fulfill our expectations very well. The curriculum is designed for those students and those whom we will strive to attract. Central to that effort is our teaching and the way forward is to reconsider our practice in light of the end of the mass education.

The second remark concerns the fate of the students that we currently admit with low grades. There are clear examples from Pope (2006) and others of students who have lackluster performance in high-school for reasons of teenage problems, lack of motivation and stimulation, or simply sub-standard schooling, but who are able to rebound in their undergraduate education, given the right teaching. For example the College of Wooster in Ohio admits 80 to 90 percent of its applicants, which includes B and C student; yet it ranks 11 among the 900 American colleges in terms of students who go on to get a Ph.D. (Pope 2006). What Wooster knows about each of its students, but what we do not know about any of our freshmen, is that the student has a desire to learn and that she or he has a positive attitude towards the studies; the college probably also knows the reasons for the weak performance in high school. Despite our lack of information about the students we teach, we have to revamp our ways and we will then see more students prospering.

The first proposition is to attend to the teaching of a curriculum, as opposed to isolated courses. The second proposition is to maintain frequent and friendly contacts between faculty and students. The third proposition is life-long learning and the fourth is a different examination structure.

Curriculum teaching

While we collaborate around research projects, discuss our ideas and seek help from one another, teaching at a research university is a solitary activity. We rarely share experiences from class room teaching and to sit in unbidden on a colleague’s class would seem indiscreet (Tussman 1997). This is unfortunate and limits us from evolving in the craft of teaching and as a consequence exposes us to pedagogic consultants who willingly lecture us on all of our wrongs and who propose ideas for us to improve our ways, without regard to their practicability. Teaching has to become a more central activity for the faculty.

With a focus on the curriculum, the teaching can be structured in the manner most apt for conveying the knowledge defined for the program. This means that some blocks of the curriculum are best taught jointly by a group of teachers; some are based on self-studies followed by group discussions, paper writing and oral presentations; some are best taught in hands-on sessions in the laboratories. The current model with a course taught by a single teacher together with a few assistants should not have precedence over other models. The block model is practiced in many places. It consists of work that the student does full time, without

competition for attention from other academic activities. It allows the student to immerse her- or himself fully in the topic of study during the block. There will also be less fragmentation of related subject, which hopefully lead to a better overall understanding. If parallel activities are scheduled, then it is important to make sure that they are not in competition for the students' time and ideally also that they reinforce and complement each other.

The advantages of being several teachers for a block or a course is that it allows collaboration in defining the contents, flexibility with respect to the schedule since they can substitute one another, and allow a subject to be taught from more perspectives than what a single teacher is capable of.

A clear strength of research universities, such as KTH, is the well-functioning doctoral education, where the ideal of Humboldt may be considered to be realized. This strength should be leveraged to boost the quality of the undergraduate education. The following two examples show how it may come about.

- Research projects announce work tasks that would be suitable for undergraduates (programming, doing measurements from a given setup, plotting data). The student would then do the work for credits, for remuneration, or for his or her own sake. The student will make contact with graduate students and faculty; she or he will learn about the project area and take on responsibility for carrying out a task with quality and timeliness (Husén 1986). The value for a student could be tremendous, simply by being part in any small capacity of important research that will be published.
- The undergraduate teaching could increasingly be based on independent studies of the students in the manner of doctoral students. It would require coaching and regular follow-ups to ensure progression and quality. Working with students in this manner provides a more direct means for communication high expectations to every student, compared to lectures and recitations in group, followed by a written exam without personal follow-up.

Faculty-student contacts

We rarely meet our students during the first three years. We get glimpses of them during a few hours in front of a class, in an occasional recitation or Q&A session before the exam; we do not hold our doors open for scheduled office hours. This is in contrast to what has been found to be conducive to learning (Cross 1998) and what has been found valuable from the students time (Light 2002). Oxford and Cambridge have historically separated the teaching, offered by the university, from the learning that went on in the colleges (Rothblatt 1997). The learning was supervised individually or in small groups by a tutor. The examination was again offered at the university level to provide a common standard and hence allowed colleges to compete for best performance. Also the best American colleges pride themselves on the good learning environment, based on close faculty-student contacts and in many cases also cooperative student-student contacts. Light find this to be a key for students to achieve well also at Harvard (Light 2002).

We must improve our contacts with the students both in class, but also out of class. During my nearly ten years at KTH has there not been any social get-together between faculty and students. The teaching-related contacts are of course most important, but the value of the social contacts should not be discounted and they are easily arranged. The faculty contacts can be of at least three different types: guidance and monitoring, expert coaching and tutoring, non-specialist tutoring. We describe their roles briefly.

Guidance and monitoring: Each undergraduate student would have a faculty advisor from the start of the program until the specialization is started in the fourth year (where ideally another advisor would take over). The advisor should meet with the student often enough to follow the progress with the studies and to build a trustful relation. The advisor will hence monitor that the student is doing well and may provide advice for any encountered problem. When the curriculum offers electives and the choice of foreign study programs then the student must have the advisors approval in order for the choice to be official. The contacts provide a continuity over the curriculum and allows each student to been seen as an individual amidst the flock of students in a class. The idea is to spot problems early on when it comes to poor performance, to provide the student with a sparring-partner concerning choices and the meaning of the studies, and to communicate the high expectations of the faculty on each and every student in the program. This role cannot be handed to a student counselor.

Expert coaching and tutoring: This role is similar to a normal teaching setting since the teacher is an authority in the subject. It provides teaching on a more personal basis that is more open for discussions, questions and reasoning around the subject at hand. It provides the possibly best environment for conveying

knowledge from the teacher to the students. This is also the role that we assume towards our doctoral students. The role can be applied to particularly difficult parts of a teaching block, where the individual attention helps the student across.

Non-expert tutoring: The tutors at the colleges of Oxford and Cambridge, or at Reed, St John's and many other intellectual colleges, are not experts in the fields that they tutor. Hence, a professor of mathematics may tutor a group in biology, or a classics professor may be tutor for a computer science class. The idea is that the group tries to learn together; the tutor brings discipline to the group along with learning strategies from her or his own field of specialization. The role can be very stimulating since it allows the tutor to learn new subjects, but it can also be uncomfortable to be only a primus inter pares and not an authority.

Of these three roles, the first is necessary to ensure that we reduce the attrition rate from the program, but also to have the empathy and trust to recommend a student to leave when the program clearly is ill suited to the abilities, prior knowledge or interests. The second role is desirable and might fit the instruction of certain topics or for a part of a block, for instance a section known to be hard to grasp. The third role does not exist at KTH today. However if all faculty would be involved as non-expert teachers across the curriculum, which is possible since almost all have an EE degree, then we would learn about each others subjects and it might promote collaborations and also to create a more unified faculty.

We may also enroll senior students as advisors, as the Meiklejohn advising at Brown University. The student advisors are referred to as "Meiklejohns" (named after Alexander Meiklejohn, 1872—1964, a philosopher, university administrator, and free-speech advocate who served as dean of Brown University and president of Amherst College; Tussman (1997) has an essay on Meiklejohn, who also was Tussman's mentor) and their role is explained as follows to the entering students:[1]

> *Meiklejohns are carefully selected and trained. They provide a student perspective on the curriculum and often serve to broaden the knowledge of the curriculum that can be accessed by the first-year student by complementing the knowledge of the faculty academic advisor. The combination of the faculty advisor and student peer advisor has proved to be a powerful one. Each offers insights the other cannot. To make this work for you as an incoming freshman talk with your Meiklejohn advisor on a regular basis and get to know how they can help.*

We have here a tried-and-true example that we readily could incorporate in our program.

Learning for life, life-long learning

The way we teach is not necessarily conducive for retaining the knowledge in the long term. Final exams at the end of a course are passed after intensive cramming, and the material will never be re-examined before the diploma is issued, unless, of course, the course has a sequel. Instead of focusing on life-long retention of knowledge, the zeitgeist is on the life-long learning. I believe that these are two separate issues and that both are vital for EE: learning for life implies that the value of the education is lasting, while life-long learning means that the lasting knowledge can be continually complemented.

Learning for life is addressed by the careful design of the core curriculum and by examinations that test long-term retention of knowledge, and not only swiftness in acquisition through cramming. This will be discussed in the next section. The life-long learning provides an opportunity to maintain life long contacts with the graduates of the program and to retain a loyalty with the institution. Some initial ideas for this would be to offer whole-day courses to graduates twice a year based on the state-of-the-art curriculum, which needs to be refreshed most regularly. The courses could include laboratory sessions and exercises. The graduate would also be welcome to take any exam for the curriculum as a diagnosis of the retention. The principal idea is that the School maintains an interest for life in the graduates with respect to their knowledge from the education.

Examination

Examination today takes place at the end of a course and the student will not again have her or his knowledge tested on the subject (unless the student fails). This means that we know nothing of the retention of the knowledge. Another problem with the current system is that we grade the students based on the

[1] http://www.brown.edu/Student_Services/Meiks/mission.php

examination result for a course and the student will then compete for jobs based on a listing of course grades. This is a disservice to the labor market since it is hard, nay, impossible for a prospective employer to know what an assortment of grades indicate: is the student capable of working as an electrical engineer? Only the GPAs approaching A are clear indication of a good performance.

The idea of examination came late into the nineteenth century at Oxford and Cambridge and it took several decades to introduce it (Rothblatt 1997). There was a concern that many of the virtues of the education would be lost and that the examinations would lead to cramming rather than learning and that cooperation would perish. It is therefore interesting to note that many premier colleges do not rely on examinations and provide student assessments based on a wider portfolio of indicators than the mere result of a written or oral exam. The written exam has simply become the most rationalized check-point in mass education: as the grades are recorded, the student progresses in the pipeline from entry to exit.

I believe that we graduate students from EE who have passed their courses but who are not qualified to work as electrical engineers. Hence we fail them by releasing them without necessary skills and we might fool employers who believe that a KTH graduate in EE has passed a rigorous education and will be able to perform. The idea of examination for grading students should be rethought and examination should instead aim at certifying acquisition of knowledge. It may be accomplished in the following manner.

The teachers of a block determine what they want to convey to the students and may then design a set of tests to verify that the students have learned that material. The tests could be of many different types for a single block. The tests result in a pass or a fail; a failure, in turn, lead to further study of the material. The level for a passing grade should be high, so that any student who has passed has fundamental understanding of the material. The block or course tests is followed by curricular tests that are graded and that test both retention and integration of knowledge. For instance, there could after the first year be an examination on the material from the first semester. The examination does not consider how the material was partitioned and taught across blocks or courses. After the second year, the first year and a half is checked. The complete program is checked after completion of the master's thesis. These exams would not carry any credit but would be mandatory and would provide the final grades for the student.

The advantages with this model are that the teaching can be focused on the acquisition of the course material, without attention to ranking of students. The comprehensive exams force the student to study for the long-term and with an emphasis on the understanding of a topic in context of other topics. A further advantage is that the comprehensives could function as certification examinations. For example, a student from a little known university, or from one with unclear standards, could take the comprehensives to show her or his knowledge in the field (such students often take a full MS program today); a graduate might re-take the comprehensives after a few years to ascertain that the knowledge is still there (to show when applying for a new job, for instance). The results from the comprehensive exams for graduates and external students could be in a form of a certification that the person has the equivalent knowledge to a student who has passed the EE program at KTH. Certification has become important in the financial industry and there are universities who target their programs to prepare the students for the Chartered Financial Analyst certification as the end goal, rather than the universities' diploma (Economist 2005). We have an opportunity here to define the KTH certification in electrical engineering. Note also that it might be possible to charge for certification even when tuition cannot be charged.

Discussion on teaching

The concept of learning communities encompasses the aspects that are presented above (Cross 1998). The changes in teaching clearly hold great opportunities for a renewal of the electrical engineering program in order for it to regain its status as a program that prepares for important contributions to our society, for rewarding careers and that stimulates the intellect. With the successful international recruiting to the MS level programs, we have a clear benchmark on how the KTH students fare in the competition with students who have received their undergraduate exams from other places.

The studies at KTH should include a mandatory semester at one of a set of selected international partner universities.

Recruitment

It has not been within my task to get a complete picture of how the recruiting for the electrical engineering program has been conducted. The program is presented along with the other KTH programs in a common catalog. The School also uses student ambassadors for visiting high schools before the students make their applications to the centralized admission process.

Here are some ideas that may be considered. First, we know or can find out which the best high schools are in the Stockholm region; they can be targeted for recruiting. A campaign would include professors going to the schools, talking about the education and taking questions. The students would then be invited to our School for special seminars and meetings with current students in order to get a glimpse into the life as a student. Prospective employers could also participate to such visits and tell that electrical engineers are important to them.

A recruiting beside the central KTH campaign would allow our program to be more visible, especially if we use clear messages for choosing EE. Common misconceptions and prejudice shall be met by turning them around: if you want to change the world (EEs have done that), if you want to work with people (EEs do that, but young people might not know it) and if your want to be creative (what engineering is about). Our campaign could also draw on interesting profiles such as Billy Klüver (researcher at Bell Labs and creator of electronic art; collaborator of John Cage, Jean Tinguely, Andy Warhol and others), Kurt Atterberg (patent engineer and composer), Conny Palm (telecommunications researcher and the man behind the first Swedish computer) and Rowan Atkinson (MSc from Queens College, Oxford, and comedian). Or Hedy Lamarr, actress and co-inventor (with composer George Anteil) of spread spectrum communication, who said: “Films have a certain place in a certain time period. Technology is forever.”

The main point for recruiting is to announce that there is a new program in operation and that it attends to the students learning in a manner that is not provided elsewhere in Sweden. By integrating the undergraduate teaching with our research activities, we could credibly label the program as “the research program in electrical engineering.” The electrical engineering program has very few women among the students. It is not evident how to change that, but the revitalization and a direct marketing of the program would allow women to be addressed explicitly.

Financing

It is evident that our education can be run better with more resources. Yet, we will have to live with the means that we have. There are two clear ways to improve our resources within the current allocation system (HÅS/HÅP). The first is the reduction in the number of courses to eliminate the teaching time in all of our under-financed courses. (The teachers freed up in this way may not be from the areas where more resources are needed; the gain is therefore contingent on their willingness to work as non-expert tutors in other subjects.) The second is the increase in income that we can expect from a higher examination rate and a lower attrition rate from the program.

A radical re-design could pick enough interest to establish a support foundation for the EE program. Support could be sought from Knut & Alice Wallenberg foundation, the Axel and Margaret Ax:son Johnson Foundation and from companies who are reliant on the supply of well-educated electrical engineers. The foundation ought to remain outside KTH under the jurisdiction of the supporting companies and foundations. That provides them the control to withdraw the support from the program, should the endeavor fail. Support from the graduates could over time be the main source of income for the foundation, similar to the alumni support for many university and college endowments in the USA.

The current system of sharing the income from teaching over the courses taught has the negative incentive that course givers compete for students and that there is little incentive to see to the whole curriculum. The allocation must instead reward cooperation and it must compensate activities that are for the common good, such as developing the curriculum and certification examinations. Such ideas are moot in today’s system since the work does not generate income.

Conclusion

There are two general conclusions that I have drawn from my consideration of the declining electrical engineering program. One is that teaching has to be re-asserted as an important activity that spans widely

outside the already well-functioning course instruction. The practice of teaching and the contents of our program must be as natural and common topics for discussion as our research topics. The problems in marrying research and undergraduate teaching are made more acute when the entering students do not have the stellar scholastic records as those who enter the premier American research universities or the Swedish medical schools. Yet by making our teaching more personal with more student-faculty contacts as well as the design of a curriculum that is more than a course listing, I firmly believe that many of the admitted students can be made into clever, well-functioning electrical engineers who can have rewarding careers and contribute to both their employers' and our society's best. As stated in Pope (2006), in analogy with a hospital, an educational program should be judged by the (academic) well being of those who graduate rather than on that of those who enter. The School must provide economic incentives that are in line with a vision to renew our undergraduate teaching.

The second conclusion is that the professoriate has to re-establish its academic leadership. The responsibility of implementing any changes necessary for the undergraduate programs survival rests with the professors. It is hence our responsibility to combine the three roles at the university of undergraduate and graduate education, research, and service to the society. Even though the roles appear to clash at times, we should attack that problem with the same open mind as any problem within our fields of research. The initiative is ours and we have to lead the change (Kotter 1996). Support functions, such as the Learning Lab, may assist but we have to remain in command (which has not always been the case). I am convinced that there is not any other academic activity where we have such an opportunity to make a difference and to get recognition for it. All of Europe's universities are concerned about making their research more competitive. By addressing undergraduate teaching, we pursue a challenge that will get wide attention, and, most importantly, that will have positive consequences for the young people who enter our program.

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Appendix A: Strengths, weaknesses, opportunities and threats

Strengths: Well educated teachers; strong research environment; KTH brand name; excellent job opportunities; impact on society; good industrial contacts; successful alumni; good representation of minority groups.

Weaknesses: Little student-faculty contact; no influence over admission and poor statistics of student performance; little integration of courses in curriculum and of research in courses; low attraction of program; void incentive structure for more effort on teaching; weak representation of female students.

Opportunities: Revamp engineering education in Sweden, gain attention; certification as main quality indicator, rather than course grades; create the strongest undergraduate engineering program in Europe; out-compete Swedish alternatives; bigger profit from time spent than on alternatives.

Threats: Little motivation for change in faculty; no sense of urgency in the reform; formal (regulatory) limitations; external forces and entrenched interests; insufficient financing, lack of incentives.

Appendix B: An undergraduate program taught in English

We have received an indication from Ramon Wyss, vice-president of internationalization, that there is demand for an English-language entry program at KTH. The School of Electrical Engineering would be well suited to develop and offer such a program. Since it would be the first program of its sort at KTH, it would be wise to make the program as broad as possible in order to serve as preparation for many of the specialized programs on the master's level. That would be accomplished by defining a mathematically oriented program in system engineering. The curriculum for the program could draw on the competences within the school on various types of systems and system design, and it would also involve theoretical computer science and system theory.

When setting up the program, it would be desirable to keep control over the admission. A proposal to the University Chancellor for allowing local admission for all seats in the program would be needed in order to select the students with both the right aptitude and attitude for the program. Scholarships would allow students from Eastern Europe to attend the program.

Appendix C: Comments on last year's proposals

I have been asked to consider the proposals from last year.

1. No admission 2007.
   This proposal would in my view signal defeat. The School of Electrical Engineering cannot do without an undergraduate program. It is far too important for our society to give up simply because the interest is waning. Who would we rather see educating the students during the first three years? What do they have to offer that we do not?
2. Effort on recruiting for the graduate levels (year 4 and 5).
   I only note that such an effort is not in conflict with a rejuvenation of the education for the first three years. As mentioned above, the admission of students to year 4 allow us to compare the results from our undergraduate program with those of programs elsewhere. This provides us with benchmark of how good our own program in comparison to other programs.
3. Effort on new or common entries in year 1.
   This has been evaluated separately by Stefan Östlund. Remark that we have authority over the EE program and may implement any change to it. Changes to a common program require consensus across schools.
4. Study the contents.
   This has been the primary purpose of this report.