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Training Engineers for the Future

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Society expects the engineering profession to solve problems that reach far beyond the conventional tasks of engineers. Training and education of engineers of the future must take these changes into account, at all levels. The challenges concern the number of engineers, but more importantly, their quality. All those present who devote themselves to engineering education are invited to undertake the necessary changes without further delay.

INTRODUCTION

IN THIS brief review I'll address 8 items:

- The educational system, with particular emphasis on continuing education
- Possibilities for improving highschool
- Possibilities for improving curricula leading to the masters degree
- Possibilities for improving curricula leading to the doctors degree
- Improving mobility
- Improving admission and transfer
- Engineers and politics
- The role of social sciences and humanities in the education of engineers.

Engineering professions are undergoing dynamic changes. For engineering schools at all levels, but indirectly also for highschool, this insight constitutes a challenge. Meeting this challenge might be decisive for an industrialized nation to remain competitive.

THE EDUCATIONAL SYSTEM

Acquired knowledge undergoes a rapid turnover in many disciplines, including the engineering sciences. Continuing education therefore becomes unavoidable. Think of the large number of engineers who completed their studies at the times of the electronic vacuum tube radio, then lived through the revolution of transistors, and later chips, and who are now confronted with the possibilities of microprocessors. Or think of chemical engineers, trained to apply sophisticated processes in high temperature and high pressure chemistry, who now must realize that one or the other of these processes is replaced by biotechnological processes. Continuing education will become increasingly important, particularly the kind that goes in parallel with a professional activity. If this development is left to itself, then the time spent on education would become longer and longer, the stay in production shorter and shorter. The same trend is also to be expected because of the tendency to earlier retirement, shortening of daily labor, increasing of leisure time and vacation time. Of course the reduced phase of productivity will be compensated to some extent by time-saving production technology such as factory-automation or computer aided everything, the efficiency of the workday will be enhanced by telecommunications, which will to some extent replace shuttling from home to work. Indeed, there are studies that show, that in certain industrial branches physical presence of the worker is not necessary for all workers; many activities could be operated by telecommunication from regional telecommunication-centers, or from home. But it remains to be shown whether the added value can be so increased that it compensates for the loss of work time. I feel one will have to shorten the duration of the primary education in view of the increasing importance of the time required by continued education. As far as the educational system of Switzerland is concerned, I feel that the time spent to the end of highschool should be shortened by 1 or 2 years, the time for the masters degree limited to 4 years, and the theme of the doctoral thesis should be so chosen that the doctors degree be obtained within 3 years. The goal of graduate studies is not to train young researchers. The goal of graduate education is to train young staff with the knowledge as to what research is. What is a scientific question? When may one speak of a method, when of a technique? When is it justified to regard a finding as scientifically proven? How are scientific findings discussed with respect to published material? Attaining expertise in such basic questions on research is independent of the topic of a thesis. From experience, I'm convinced that dissertations of today are too long and the time for their elaboration could be significantly shortened, simply by choosing an appropriate topic.

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IMPROVEMENTS AT HIGHSCHOOL LEVEL

I feel the ideal of the so-called general education ought to be rethought. I do not think that it is justified to speak of general education, when highschool students have received insights into classical and modern languages with the corresponding literature, sciences including mathematics, and history, philosophy, religion and other domains of the humanities. The teachers of all these courses in Switzerland are without exception scholars in the sciences or the humanities—that is, scholars trained in the dimension of understanding and explaining. But we are living in the technical era, and this is to a high degree characterized not by explaining and understanding, but by doing, realizing, and implementing. These are the dimensions for the engineer. Because young people are influenced more by personalities than by subjects, I think it is urgent to hire engineers with a background in didactics as highschool teachers, with a mandate of—for example—teaching physics. They would teach physics not from the viewpoint of the scientist with his urge of understanding, but from the viewpoint of an engineer with his urge of implementing. Understanding technology, understanding such issues as safety, security, reliability, economic aspects of engineering would be better understood by the educated youth and would in a lasting way influence the spirit of the ages, which paradoxically in the technical era often has become rather critical *vis-à-vis* technology. Technology would become a part of our culture again! And more young people would choose engineering studies. That this happens is very important. Let us remember that compared to Japan the number of engineers per capita in Western industrial nations are too small by a factor of 2. Increasing the proportion of engineers in society will be crucial for the survival of industry in the technical era. In a lasting way, the problem can be solved only if a larger proportion of highschool students choose technical professions, and this proportion ought to include female students.

IMPROVEMENTS AT THE MASTERS LEVEL

During their university studies, engineers ought to learn as a foundation of engineering sciences not only mathematics, physics, and chemistry as in the past, but also biology. I believe that it will be important for the development of technology to learn from nature. Let us keep in mind that biological evolution has had hundreds of millions of years time for trial and error, but intelligent man only a couple of thousand years. No wonder we all see, hear, smell, taste, and sense so much better than robots! No wonder that the G7 have launched, under the name of '**Human Frontier Science Program**', and initiated by Japan, an important program towards understanding the human brain. I feel that a similar program ought to be launched in educating engineers for the future.

On this foundation of scientific knowledge, the emphasis of engineering education ought to be oriented towards problem solving. Although knowing facts will always be necessary and useful, knowing how to help oneself will be increasingly important. Knowing how to help oneself means having the ability to muster knowledge from neighboring disciplines. I would not exclude that in this process conventional borders between disciplines will vanish or at least become weak, for example the border between mechanical and electrical engineering, where electronics and computer science become common denominators. Problems do not appear bundled according to disciplines!

IMPROVEMENTS AT THE GRADUATE LEVEL

Requirements particularly for small and medium sized enterprises in high technology becomes intellectually more demanding. Many of these companies will be dependent on staff with an understanding of research, that is with an understanding of scientific questions, choice of methods and techniques, interpretation of scientific findings and literature. This is what one learns when working on a doctoral thesis. In Switzerland, today almost all chemists and chemical engineers go through the doctoral program, but only about 1/6 of all engineers. Accordingly, our chemical industry employs large numbers of staff with a doctors degree, while in all other branches of engineering this proportion is correspondingly small. One experience at ETH Zürich might illustrate the problem. The main library of this university years ago offered technical access, for small and medium sized enterprises, to international data banks. It became clear very soon that many small and medium sized enterprises did not have staff with the ability to articulate a problem in a way as to obtain sensible answers from data banks. Furthermore, it became clear that the representatives of such companies very often were not in a position to interpret the data obtained. Had such representatives been in contact with research, for example during graduate education, such difficulties would not have arisen. This does not mean that young engineers would have to be kept overly long at university, because, doctoral theses can be finished within 3 years.

MORE MOBILITY

University students should, as in the past, change universities during their studies. It is true that many young people these days travel around the world as hitch hikers in one phase or another of their education. But it is equally true that a tourist does not really get to know the foreign country.

From my experience mobility would be increased substantially by introducing the credit system, which works as follows: it is defined which combination of branches and hours will lead to a masters degree, for example, independent of the university at which, or the country in which the corresponding curricula were completed and intermediary exams passed. Such credits are transferable to other universities. The system has been working successfully in the United States. In Europe, as a part of the so-called Erasmus program, a broad pilot study has been launched in this direction. It would be wrong however to limit such exchange programs to the European countries. It remains important to exchange academic staff with the North American and Far Eastern countries. Probably it will be necessary to support such efforts by fellowships.

REMOVING BARRIERS FROM UNIVERSITY ADMISSIONS

Switzerland suffers, as many other Western nations, from a considerable shortage in engineering staff. I have already pointed out that the situation could be improved by exposing highschool students to engineers as teachers. But this will hardly be sufficient. Other measures should be considered also. I am thinking of facilitating exchanges between different kinds of institutions of engineering education. In Switzerland, highschool graduation ought not to be considered as the only basis for entering universities. Rather, admissions to technical universities ought to be made easier from our technical colleges, that is, from institutions, whose curricula are based not on a general education, but on an apprenticeship. I feel that a bit more courage for removing barriers to university curricula would be in order. Of course, students too ought to be more courageous in carrying the risks involved in such transfers; evidently, the risk of flunking exams increase when the barriers to admission are removed. On the other hand, living with risks is characteristic for the successful engineer; experiencing it already during the educational process would seem to be positive.

ENGINEERS AND POLITICS

Society demands, and rightfully so, to be informed about the consequences of novel technologies. Who could assess such consequences better than engineers? Technology assessment has been on the agenda for some time now, and it is permitted to conclude that it can hardly be taught in an isolated form. But it is important to sensitize future engineers in the course of engineering education for the problem, for example using nuclear technology. When the safety of nuclear power plants is treated in a course, the teacher would be well advised to discuss two questions of technology assessment, based on a solid foundation of engineering knowledge: What could happen, when nuclear technology is used for energy conversion? And secondly, what could happen, when nuclear technology is not used for energy conversion? The answer to the first question would be that as in all cases of accumulation of energy, failures can not be excluded with absolute certainty. The answer to the second question will be that with high probability a further warming of the planet will occur with the corresponding changes of climate, and migrations of people. I feel it is of fundamental importance to make sure that questions of technology assessment are phrased symmetrically rather than one-sidedly.

BUILDING SOCIAL SCIENCES AND HUMANITIES INTO ENGINEERING EDUCATION

It is interesting to know that already the law that founded the Swiss Federal Institute of Technology, in 1854, demanded that scientists and engineers receive, during their curricula, a complementary education in the humanities. As a consequence, the Swiss Federal Institute of Technology Zürich has not only a large division of humanities and social sciences, with chairs for various languages and literatures, but also in history, philosophy, psychology, law, economics, etc. Every student signs up in a course of this division each semester and furthermore has the right to be examined in one of these subjects in the final exams.

On the research side, there is a tendency to include specialists from the humanities and social sciences into current research programs. I mention the example of the American 'Human Genome'-project, which is to be accompanied by research on ethical questions. I also mention research programs on telecommunication and environment that are accompanied by economists, sociologists, and psychologists. It is important that colleagues from the humanities and social sciences work on such questions not only in isolation, but also in contact with their colleagues from the engineering sciences and natural sciences. Researchers with this kind of experience will find it particularly easy to give a dimension to their teaching that reaches far beyond their respective basic discipline.