RE-ENGINEERING ENGINEERING EDUCATION – IN THE LIGHT OF THE BOLOGNA PROCESS

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There have been many reasons to consider a re-engineering of engineering education. New materials, new design, new manufacturing and assembly processes and methods, new models, new tools, and new application areas. We will first focus is on the implication on regular university education from these factors and from the Bologna process initiated in Europe for university education in general. Then we will elaborate on what this means to the actors in continuing engineering education.

Background

Engineering education has slightly different traditions in different countries [1]. In Sweden, the roots are from the mining schools in the early eighteen hundreds. Initially the education was mainly practical but during the 20th century, there was a gradual shift towards theory and science. Today there is rather little direct connection between the academic curricula and the role of the professional engineer in industry.

Science and math are the core components of the first two years in the curricula. The rationale is that the engineer is expected to use equations and formulas to be able to compute dimension or values of beams, shafts, rods, columns, resistors, conductors, etc., for each component or system designed. Some decades ago, the tools were the slide-rule, pencil and paper, mathematical tables and engineering handbooks. Later desk and hand calculators replaced the slide-rule, but not even today, the math courses consider modern design tools.

The mental model of the engineer is, in the educational system, still mainly the computing person or inventor doing the task assigned mainly alone, and that the problem to be solved is clearly defined. That is, engineering education is mainly focusing on one person solving well-defined equations by herself/himself.

The conclusions in this paper are mainly based in a long experience from engineering education combined with findings in a number of case studies in industrial development projects [2]-[3].

Computing Tools

Today most of the formulas and heuristic rules in the engineer's handbook are implemented in modelling and simulation tools in the computer. There is no need to re-compute everything by hand for each new machine, each new amplifier, each new building, etc. Almost all the computations, that constituted the engineering professions a couple of decades ago, have now been fully automated. Hence the training spent on such computations in the engineering curricula can be replaced by *e.g.* training in understanding complexity, how different factors interact, and how to co-ordinate related complex activities.

Moreover, before the Internet era, it was convenient to know a lot by heart, or at least to know exactly at what page in the handbook to look for it. Today, it is in general faster to search the information on the Internet, than to stretch the arm to the bookshelf for the handbook. The need to remember all the details by heart is less important today than it was in the past. Hence, some more time, previously used for teaching things, can be re-allocated.

Globalization and Sustainable Solutions

Globalization has many dimensions. You can move or out-source production to countries with lower wages. You can transport goods and material fast and at rather low cost. It is now longer sufficient to be competitive locally. Information on the Internet is immediately accessible from anywhere. A harmonization of rules and standards is taking place within the European Union, and in many areas standards are accepted or even prescribed globally.

In this situation, it is important to understand foreign traditions and cultures, both to enable multi-ethnic development teams and to adapt products and services to expectations and needs on different markets. For the engineer it is quite different to act in a cross-cultural team compared to working as a computing person alone. Maybe social training and ability to communicate should be a cornerstone in the engineering education at the same dignity as mathematics.

There is another trend towards complexity and integration of different products, systems and services. One example is the amalgamation of the transfer of voice and pictures in cell phones and cameras. Another is the introduction of GPS navigation in cars. The boarders between radio and TV broadcasting and recorded music, books and movies on one hand and Internet distribution on the other is about to disappear. The holistic understanding required is in contrast to the narrow applied courses normally offered in engineering education.

Customer expectations and legal requirements on sustainable solutions, material recycling, environment conservation, acceptable working conditions in the manufacturing etc. all means that a better understanding of complexity and totality will be required.

Rate of Change

It would maybe be possible to handle most of the factors mentioned in the previous sections in case we had sufficient time to implement the change. Unfortunately, we have not. The rate of change in technology, in trade, and in politics is such that there will seldom be time enough to find the best solution. The winner will be the one who can first offer a sufficiently good solution, idea, product or system, not the one who, at the end, can offer the very best one.

We need a project organization that is much more flexible than those we present in the textbooks in our engineering courses. They may be appropriate for building roads, houses or bridges, but not for the development of systems or services in consumer electronics or telecommunication systems. In a study within Ericsson [4], it was observed that even in the short subprojects of 8-12 months, despite careful screening of the requirements before the projects started, normally about 30% if the functions initially required, were discarded during the project, and about 30% of the functions delivered at the end were not considered when the project started. The changes were due to better understanding of the technology or to adaptation to competitor moves.

It is quite clear that the traditional waterfall model with its distinct phases and delivery of items is not appropriate. An organization where the development teams have themselves the responsibility and the power to act and take decisions is required. Therefore, tools and methods for a dynamic co-ordination are needed to enable the desired flexibility.

Resistance to Change

The academic system is designed to be robust and to resist influence from religious and political forces. The selection of professors and leaders has for many generations been based upon excellence within each discipline, and the disciplines have split and become more and more narrow. It is rather clear that the changes argued for in the previous section will not be initiated from within the current departments or disciplines. So, could such a change be controlled and managed by the university board or vice chancellor? Not very likely. One popular phrase is: “to manage a university is like herding cats”, and another one: “to change anything at a university is like trying to move a grave-yard – you will not be supported by those involved”.

One kind of change that is likely to occur, however, within the universities in Europe, is along the agreement on the Bologna process, since such changes will not challenge the current structure of the disciplines.

The Bologna Process

In the Bologna model there are three levels, 3 + 2 + 3 years, devoted to something similar to the B.S., M.S., and Ph.D. levels, respectively, used in U.S. One objective is to increase the mobility, to encourage students to look for another university often in another country, for the master's level after finishing a B.S. Enabling such mobility will however require some re-thinking and re-engineering of the current engineering education systems in many countries.

Currently the engineering degrees in Europe are awarded after 4-5 years of studies in a coherent curriculum, where the courses have been designed to build upon each other over the whole program. The total group of students is assumed to be the same all over the 4-5 years. So, one implication of the Bologna process is that the first three years at one university can't be design mainly as the basis for the M.S. program at the same university. They must prepare for M.S. studies at any other university in the "Bologna community". There is also a requirement on *employability* after the first three years. Hence, in engineering the first three years must lead to some kind of capability appreciated and paid for by employers. An engineer "*able to understand and use modern models, methods and tools in the engineering profession, but not necessarily trained to develop new such models, methods and tools*" is a possible interpretation of employability after three years of study. One can assume that most students will apply to the first three years in their home country.

Another implication of the Bologna process is that the students starting the master's program can't be assumed to have a B.S. from the same university. Some kind of general acceptance and selection procedures have to be used. As most universities seem to be aiming at master's students not only from the member states of the European Community, but from the whole world, it will not be possible to base the selection upon paper applications only. Some kind of qualifying exam will be unavoidable.

A third implication might be on continuing engineering education. It is likely that graduate schools will offer only master's programs based upon their strong research profiles. This means that there will be a need for continuing update courses for the professionals engineers (B.S.E.) in terms of the use of new models, methods and tools, and maybe new materials, new components, etc. Such updates are not natural components of master's programs, but will rather be offered as a set of short courses over a couple days or weeks each.

Implications on Continuing Engineering Education

The need for a re-engineered engineering education will not be met by the regular academic curricula. The shift of focus from the cornerstones of mathematics and science to a more balanced holistic profile, where methods and tools for innovation, human communication, and integration have the same dignity as those for computation, will not be accepted by the current departments of science, engineering and mathematics. In the Bologna structure, universities, in the design of new master's programs, will mainly offer contents in line with their strong research profiles.

Hence, there will be a market demand of two kinds on continuing education from professional engineers in industry. First, in the non-technical area, there will be a need for training in innovation, in understanding multi-ethnical communication, in flexible co-ordination of complex heterogeneous projects and integration of complex heterogeneous systems. Secondly, in the technical are, courses with updates on new design, modelling and simulation methods and tools ready for practical use, will be needed

As the existing universities and institutes of technology will have difficulties to meet the demand, both by means of regular programs and extra-mural courses, there will be a market opportunity for independent actors. Professional organisations like IEEE, ASEE, IEE, IACEE, SEFI, etc., can play a major role in defining the needs and by contributing to the supply of courses offered over the Internet.

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