RESTRUCTURING OF MECHANICAL ENGINEERING EDUCATION

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ABSTRACT

The paper presents the restructuring of the Mechanical Engineering education at KTH. The organisation of the comprehensive work is discussed in relation to the challenge of including many school members in the change process. The work is based on a strategic decision where the need for renewal of the programs was acknowledged. The work was managed from the Deans´s office with the purposes both to better fit the education into new industrial demands and to the European development according to the Bologna process.

The first students started their studies in the autumn 2003. The new programs showed a significant higher attractivity than the former Mechanical Engineering programs. One of the programs, Design and Product Realisation, is described more in detail.

The work is still in progress and will be for several years to come. The purpose with this paper is to participate in the international engineering education development discussion.

Key words: Mechanical engineering education, Design and Product Realisation, Change process, EC harmonization, Bologna convention, Bologna process, CDIO methodology.

1 INTRODUCTION

The objective with this paper is to describe the process of changing traditional Swedish engineering programs into new programs that meet future expectations from both the student and the society, but at the same time fulfill the requirements of the European harmonisation. The focus is on Mechanical Engineering programs; Design and Product Realization, classical Mechanical Engineering and Vehicle Engineering.

Mechanical Engineering is one of the oldest and most traditional disciplines in engineering education. The roots are from Christopher Polhem (1661-1751) and KTH started mechanical engineering programs in 1869**.** The traditional program was appropriate during the 20^{th} -century when the society transferred from agriculture to an industrial society. In the 21^{st} -century the focus is on a global market, where a holistic view on services, products and processes is central. The work presented here is the transformation to a curricula corresponding better to future needs of engineering competencies. The three programs addressed, hold close to 360 freshmen every year.

This paper focus on the academic leadership process of changing the comprehensive traditional single cycle and four and a half year Master of Science program in Mechanical engineering into a Design oriented engineering program into a 3+2 structure aligned with the Bologna convention. [1].

2 METHODS

The key challenge with such a change in a large organization that holds long traditions and is committed to its current assignment is to overcome the natural resist for change. The method used is based on a consensus model within the school organisation. In total 17 departments have been involved with over 100 university faculty professors taking an active part in the reform process. From each of these departments one professor was selected by the Head of the Department to be the communicator and facilitator between the Departments and the School level i.e. Deans office.

Specified project appointments given to the faculty staff and students included in the old programs have managed the process of change. The tasks given required several interactions and "killing of your darling" – operations. Eight internal committees were appointed with a total of 30 members. Each one of these committees was asked to handle eight different areas of individual and professional skills that have to be included in the curricula. This topic is described more in detail in this paper. A group of external advisers was also appointed to give the view from the industry and the society.

Several general activities took place during 2001 to 2003 with the purpose of making the design of the new programs as "right from the beginning" as possible. The work or the development could be compared to the development of a new product by following a generic product development process [2]. Many of the activities took place in parallel; as in a "concurrent engineering" model.

2.1 Defining the customer need

A group of faculty staff and students was appointed to define external and internal demands and line-up a structure of objectives. The members of this group were not appointed to any formal positions in the existing organisation. They discussed with industrial partners, students and organisations concerning their demands of quality and quantity of engineers. The findings are reported in a report 2001. [3] The report was treated as the product definition.

2.2 Comparison with competitors and existing solutions

Information was collected and discussions were held with several national and international universities, (Chalmers University, University College of Arts Crafts and Design Stockholm, Umeå University, TUDelft, NTNU Norway, MIT Boston, Stanford University). [For example see 4,5]

2.3 Conceptual design

During the preceding phase it became clear that the new programs should be adapted to the two-cycle system and to ECTS defined in the Bologna process. This concept acted as the structural base throughout the coming work.

The most important factor in order to succeed was to express the program objectives. The authors have their roots in Mechanical Engineering with a focus on analytical, research based and disciplinary organised subjects. Traditionally our graduates had been employed as design engineers and manufacturing engineers in major Swedish enterprises (Scania, Atlas Copco, Ericsson, ABB, Sandvik, Volvo and others). The new programs emphasise more sharp on a holistic view of product development and on a conceptual creative design phase. One strong focus was to position the programs between the Art and Design based education programs and traditional Mechanical Engineering programs.

A two-dimensional pedagogical model was chosen as a base for the curricula design. The first dimension is a traditional disciplinary dimension in terms of the fundamental engineering subjects. The second dimension is the engineering professional and the individual professional skills. Both these dimensions are integrated in each course to build an integrated program. The CDIO methodology was used and adopted. [5,6]

2.4 Contacts with suppliers

In this phase of the curricula development, all the KTH Departments acted as the suppliers. A working group at the Dean's office defined a core curricula based on 50 courses for the first three years of studies. The 50 courses should serve as a base for four programs within the School of Mechanical and Materials Engineering. These courses are listed in Table 2.

2.5 Detail design

The phase of detail design was conducted within the development teams in interaction with the general project management (the Deans´s office). All courses were designed in detail and the general goals and purposes concerning learning outcomes for the programs. The CDIO concept was adopted for integrating individual and professional skills into all courses. [6]

2.6 Production planning

In parallel with the detailed design, the work with planning of staff resources for development and delivering of subjects contributing to the general goals was performed. The KTH Learning Lab [7], the pedagogical development unit, was appointed to give direct individual support but also provide pedagogical courses, workshops and seminars.

2.7 Production

The programs are built up by a set of courses. Each course has a formal specification. This specification was developed in close interaction between the school and the departments. The single most important factor was to coordinate the development of the new courses so the fit into the learning objectives for the whole program, not only for the course itself.

2.8 Reflection and evaluation

During the design phase we had an intensive interaction between the school level and the departments. For all courses we have a formal course analyse and reflection system in place. In this specific situation we have appointed a quality assurance group. This group consist of faculty members, students and an external chairman. They performed formative and summative evaluations and reported on every school meeting to the school board.

2.9 Documentation

Several forms of documentation had been compulsory to deliver. All formal documentation, but also informal documents was continuously published on the Web for information sharing.

3 EIGHT AREAS OF SPECIAL INTERESTS

We have selected eight areas of special interests. For each of these areas a committee of three to four faculty members, one to two students and in some cases an expert was appointed. They were engaged for approximately six months.

1. Committee #1 addressed the questions of learning objectives related to learning outcome and assessment. The learning objectives were formulated on both a program and a course level. It was known to the committee that the students would focus on examinations. It's very important that the forms and procedures for examination will relate to the learning objectives. To introduce an external committee to evaluate the relation between learning objectives and assessment procedures is one way to ensure the meeting of learning objectives on a program level.
2. In an engineering program leading to a professional degree the links and interrelations between courses are essential. Committee #2 had to evaluate the formulation of prerequisites formulated in the course description. They were also interested in the progression of knowledge and skills in the program.
3. There is always an intensive debate about mathematics in engineering programs. A group was assigned to be responsible for evaluating the mathematical content. It was important to take into account both the content given by the Department of Mathematics but also the content giving in the applied engineering sciences courses.
4. Experimental and practical skills are crucial. Some courses were defined to include experimental skills, and others were defined to be more theoretical. The last decade modeling and simulation had increased and real physical laboratories had decreased. It was needed to ensure that the graduates achieve at least a basic understanding and training in real experiments.
5. Life long learning has been on the agenda for more than a decade now. Learn-to-learn, active learning, deep learning and constructive learning were defined as important pedagogical methods to adopt. Committee #5 was looking into different pedagogical methods.
6. Engineering Education needs to include humanities. Focus must be on to how ethics, history, cultural perspectives, internationalization etc. are integrated into the curricula. It is important that all courses integrate more or less of humanities into the technical subject. We need to ensure that this had been done in a proper way.
7. English have been introduced as the professional engineering language. Swedish is still our mother tongue and social language. The bilingual situation has to be treated in a proper way to ensure the quality of the learning outcome.
8. Problem based learning, PBL, had been introduced in engineering education over the last 30 years. The new curricula are not based on the PBL philosophy, but include real projects, teamwork, active problem solving etc. Committee #8 was addressing the balance between PBL philosophy and traditional based courses.

The use of committees was one way of increasing the program view of the curricula. The members of the committees, a total of 30 faculty members, got the opportunity to learn and reflect on different issues of an engineering program. They got a program focus instead of a focus on their own course only. The students were very active and gave a lot of valuable input.

4 RESULTS

Table 1. Syllabus for the first 3 years of the 5 year Design and Product Realization program

Year 1

4F1811 Perspective on Design and Product realization K40	5C1130 Mechanics I K10
5B1132 Mathematics I K01	5B1133 Mathematics II K02
5A1226 Physics K08	2D1212 Numerical methods & Programming K05

Year 2

<table>
<tr><td colspan="2">4C1010 Solid Mechanics
K13</td><td>4F1813 Design of Products B
K 21a</td></tr>
<tr><td colspan="2">4F1812 Design of Products A K20</td><td rowspan="2">4F1816 Electrical Engineering
K15</td></tr>
<tr><td rowspan="2">5B1206
Math III
K03</td><td rowspan="2">5C1140
Mechanics II
K11</td></tr>
<tr><td>4A1112
Appl. Thermodynamics
K27</td></tr>
</table>

Year 3

<table>
<tr><td colspan="2">Design of Products C
K21b</td><td colspan="2" rowspan="2">Short thesis
Advanced
Project
K46</td></tr>
<tr><td rowspan="2">Materials Technology
K18</td><td rowspan="2">Industrial Economics
K23</td></tr>
<tr><td colspan="2">Sound & vibrations
K42</td></tr>
<tr><td>elective
6 credits</td><td>elective
6 credits</td><td>elective
6 credits</td><td>elective
6 credits</td></tr>
</table>

The result presented in this paper is the development of new integrated, two-cycle engineering programs. A three-year undergraduate basic program in Industrial Engineering Design, followed by a graduate program leading to a Masters degree and opening up for further studies to Doctoral degrees within different specializations.
The four new programs, with core-curricula of 32 courses and with 360 enrolled students, were started in September 2003. In table 1 the structure of 18 courses in the Design and Product Realisation program is presented.
The core curricula for the Design and Product Realisation program consist of 18 compulsory courses and 4 electives. Table 2 shows the compulsory courses for the entire Mechanical Engineering program M, Vehicle Engineering program T and the Design and Product Realisation program P. Thirteen of the eighteen courses are shared with one or both of the other programs which makes the education cost-effective. It also opens up student mobility between our programs within the first undergraduate cycle.
In the two final years, to a full Masters Degree, four areas of specializations are planned; Engineering Design, Integrated Product Development, Production Development and Mechatronics.

5 STATUS

The three new engineering programs started in September 2003, and showed to have a significantly increased attraction for students. The new programs had more applicants than years before. In total 145 students was enrolled in the Mechanical Engineering program, 128 students in the Vehicle Engineering program and 106 students in the Design and Product Realisation program. The drop out level the first semester has clearly decreased as compared to the former years.
Still, there is a lot of development work to be made on a program level, on a specialisation level, on an individual course level and on staff development, but at this stage the process of change as can be seen as successful.

Table 2. Core curricula courses. (Credits are ECTS, Level is a Swedish system)

Course Name	**C#**	**Credits**	**Level**	**M**	**T**	**P**
Mathematics I	K01	12	A	X	X	X
Mathematics II	K02	12	A	X	X	X
Mathematics III	K03	6	B	X	X	X
Numerical methods and basic programming	K05	9	B	X	X	X
Physics	K08	9	A	X	X	X
Mechanics I	K10	9	A	X	X	X
Mechanics II	K11	6	B	X	X	X
Solid Mechanics	K13	12	B	X	X	X
Electrical Engineering	K15	9	B	X		X
Electrical Engineering	K16	6	B		X	
Materials technology	K18	6	B	X		X
Design of Products A	K20	9	B	X		X
Design of Products B,C	K21	9	B	X		X
Product Development	K22	9	B		X	
Industrial Economics and Organization	K23	6	A	X		X
Technology and Ecosystems	K24	6	A			X
Computer Science/Programming	K25	6	B			X

Table 2. (continued) Core curricula courses.

Course Name	C#	Credits	Level	M	T	P
Applied Thermodynamics	K27	9	B	X		X
Thermodynamics	K28	6	B		X	
Fluid Mechanics	K30	6	C		X	
Automatic Control	K32	6	C		X	
Mathematical Statistics	K33	6	C		X	
Signals	K34	6	C		X	
FEM for engineering applications	K35	6	C		X	
Linear and quadratic optimization	K36	6	C		X	
Perspective on Mechanical Engineering	K38	9	A	X		
Perspective on Vehicle Engineering	K39	9	A		X	
Perspective on Design Product and Realization	K40	9	A			X
Sound and vibrations	K42	6	C		X	
Advanced Project, Mechanical engineering	K44	15	C	X		
Advanced Project, Vehicle Engineering	K45	15	C		X	
Advanced Project, Design and Product Realization	K46	15	C			X

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