INFORMATION TECHNOLOGY IN ENGINEERING EDUCATION

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ABSTRACT
Engineering education at university level is a complex topic which includes all three components of mechatronics: mechanics, information technology and electronics. The change towards mechatronic products with a growing portion of information technology requires a holistic education approach to fulfil the requirements on engineers and their education. This paper suggests a potential solution for the interdisciplinary challenge of an information technology course for engineering.
Higher functionality and complexity of almost any kind of product do not only affect the product itself but also the product engineering process. Systems engineering is a promising way to successfully design a mechatronic product. A number of requirements arise out of the need to understand and operate with mechatronics and engineering processes, e.g. interdisciplinary teamwork or system-oriented thinking.
For a university one of the goals of education should always be the employability of all graduates. With only isolated knowledge of a few special disciplines the demand of the global job market for engineers is by far not met.
The educational vision is derived from all relevant requirements and tries to provide students with an interdisciplinary and holistic understanding of the engineering process. This includes technical and methodological expertise, social and communicative skills and decision making and responsibility. A concrete implementation of this vision in engineering education has to fulfil all technical requirements, prepare the student for the global job market and still keep the motivation at a high level. Integrating mechatronic products into the curriculum is a promising way to successful engineering education.

Keywords: Information technology, interdisciplinary education, product engineering

1 INTRODUCTION

Watching the product engineering during the last 30 to 50 years functionality and complexity increased dramatically. By stating "Things were so much easier back in the days" this development is not described sufficiently. Intelligent and technological high quality products appear much more complex to a mechanical engineer due to the high portion of interdisciplinarity which he experienced only insufficiently during his education. This is due to the fact that education concepts used to be old fashioned and narrow-minded with regard to surrounding disciplines and areas of expertise.
Chapter 2 addresses this issue by describing requirements on modern engineers and their education. In Chapter 3 an educational vision is derived from these requirements forming a concept as it is desirable in a perfect world. Obviously this state is unreachable in an ordinary curriculum today. Though in Chapter 4 the step is taken from vision to reality and an implementation at our chair is illustrated with the information technology course. Successful realizations are shown as well as deficits and workarounds. Chapter 5 offers a summary and an outlook on further improvements towards the optimal implementation of information technology in engineering education.

2 REQUIREMENTS ON ENGINEERS AND THEIR EDUCATION

The significant progress of mechatronic products towards a higher portion of information technology changes the requirements on engineering education. This mechatronic change is illustrated in Figure 1 and explains the increased demand of information technology know-how for any kind of engineer.
Designing such a mechatronic product requires understanding of complex, interdisciplinary systems and the interdependencies of technology, law, public policy, sustainability, the arts, government and industry. The increasing importance of systems engineering during the product engineering process

requires a "holistic engineer" with cross-disciplinary knowledge, as well as multicultural competence and global awareness. [1]
Systems engineering consists of a variety of tasks and components. This includes the coordination of different engineering disciplines and processes. It can also be thought of as the foundation for "technical leadership" during the design and product lifecycle of a modern mechatronic product. [2]

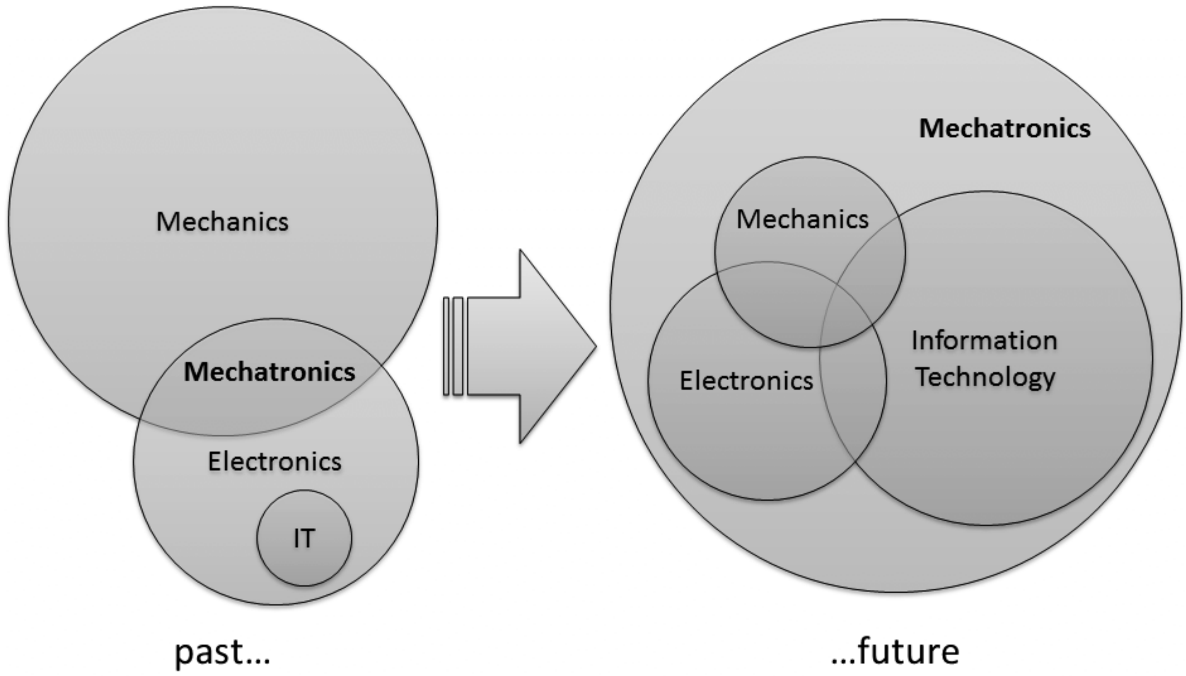

Figure 1. Change of products towards mechatronics [3]

Beside the need for an interdisciplinary education the job description of an engineer generally changed towards multidisciplinary knowledge and social and communicative competencies. A modern product engineering process requires readiness from the engineer to:

- Optimize the product not only for functional compliance during the product engineering process but also for subsequent phases of the product lifecycle (Design for X). A product has to be designed to suitably support the processes of manufacturing, assembly, maintenance, transport and recycling.
- To work in an interdisciplinary team during the early phases of the product development. New design methodology approaches are required to allow a functional product specification and description across disciplines.
- Be willing to collaborate in an international team supporting distributed product engineering and manufacturing with respect to worldwide supplier and customer markets.
- Use modern IT tools for systematically improved benefit. The objective is an earlier and deeper virtualization of the product engineering process to allow virtual simulations replacing real tests in the early development phase.

This results in a number of consequences for the education of a modern engineer:

- Setup of a solid basis, i.e. proper understanding and applying of fewer things is preferred over memorizing of as many facts as possible.
- Exemplary studying, i.e. not only theory but also implementation in exercises.
- System-oriented thinking, i.e. keeping an overview of the complete system without getting lost in details.
- Basic knowledge in data processing, modelling, simulation, controlling and optimization.
- Improvement of social skills including interdisciplinary teamwork and communication.

This can be achieved by a holistic teaching approach including theory and practice for information technologies aiming towards mechatronic products. Isolated knowledge of different disciplines does not sufficiently meet the demands of the job market for engineers.
An important legitimation for higher education is the improvement of the employability of engineering students. Therefore a modern education approach has to fit into the requirements of an engineer's day-to-day business. [4]

3 EDUCATIONAL VISION

In this chapter a holistic vision of modern and progressive education for engineers is presented. Information technology is an integral part for the successful education of a modern engineer. Therefore it is part of an educational vision forming the holistic education approach of a university of technology. Especially in high wage countries this approach is essential to enable the next generation of engineers to be competitive in a globalized market. This can be achieved by covering three areas of competency:

- technical and methodological expertise
- social and communicative skills
- decision making and responsibility

While addressing a single area of competency is easily covered by various lectures, lessons, exercises and tutorials, an education that combines and integrates these three areas of competency is hardly implemented nowadays. The vision tries to achieve this level of integration in all courses of the curriculum on a regular basis during the education of a young engineer.
Holistic education as described above is a challenging task for the lecturer as well as the student. It requires an enormous amount of flexibility on both sides. [5]
By merging the educational vision with the requirements on engineering education in Chapter 2, the resulting courses of the curriculum should consist of mechanical engineering, information technology, mechatronics and teamwork. Additionally students should gain learning outcomes by adopting the contents with concrete problems or products. This can be supported with a proper example product which ideally has to be continuously integrated into the course. Depending on the organizational situation it can be recommended to keep the example product through different courses and semesters. Studying with exemplary topics creates a much better relation to the actual problem and its solution. This has a direct effect on employability which is positively altered by the integration of examples during the education.
In summary the educational vision guarantees for a flexible, interdisciplinary and motivated graduate who is trained in hard skills as well as in soft skills.

4 IMPLEMENTATION IN ENGINEERING EDUCATION

An exemplary implementation of the vision presented in Chapter 3 is described below. The presented course is called "Information Technology for Engineering" and takes place at the beginning of the bachelor and diploma degree program of engineering students. In this course the focus is set on information technology with a small portion of mechanics and electronics. At the same time in the curriculum a corresponding course is offered with focus on mechanical engineering with a small portion of electronics and information technology. This course is called "IDEE" (Integrated Design Engineering Education) [6], [7], [8]. Both courses complement one another regarding the mechatronics and systems engineering paradigm. "IDEE" and "Information Technology for Engineering" also fit into the product design concepts of the V-model defined in VDI 2206 and the enhanced V-model as it is described in [9]. This model provides a guideline how to develop a product in context of the product lifecycle. For each step of the development the involved disciplines and processes are described. Though the V-model itself is quite complex the included components are well known and correspond to processes like mechanical product design, simulation or software development. For education purposes it is a viable method to locate the different courses of the curriculum inside the product lifecycle and identify relations and transitions between the numerous process steps of a realistic product engineering process.
During the lecture theoretical background is provided in the area of hardware, computer architecture, software development, programming languages and techniques, data structures and algorithms. Practice and implementation are realized in medium sized exercise courses at the computer.

Connection to the area of engineering and further motivation is created by the introduction of a mechatronic robot at the beginning of the course. In addition to the medium sized exercise groups, small groups of students are formed to assemble or solder their own robot. Self-organization and teamwork are required to accomplish the task in time. In the exercise courses the students are assisted to practice the theory right at their own assembled robot. This includes programming of the robot, testing of the created software and adjusting the robot's physical components.
The continuous integration of various issues of the product engineering process allows a deeper insight into the full product lifecycle and supports interdisciplinary thinking according to the new challenges of modern product engineering.
Former courses used construction kits which had to be soldered by the students themselves. Two different kits are shown in Figure 2. The main disadvantage of those construction kits is the soldering and assembly process which is time consuming and often results in inaccurate and defective robots. Uncomfortable software solutions are another source of errors. Both mechanics and software handling are not focus of the course and quickly lead to frustration which is the exact opposite of what was intended.

Figure 2. NIBObee (www.nicai-systems.com) and Asuro (www.arexx.com) assembly kits

Upcoming courses will be provided with Lego Mindstorms and a third-party interface for Mathworks Matlab. The interface has been developed by the RWTH Aachen University and provides a real-time connection between Matlab and the Mindstorms robot. With this setup the variance on the physical assembly is reduced to a minimum and does not interfere with the software and programming part anymore. The usage of Matlab as software development environment offers quick and easy access to model-based design and object oriented programming. Additionally it is a flexible and powerful tool during the whole engineering degree program. Additional toolboxes in Matlab allow for countless enhancements which go far beyond plain programming and controlling of the robot. Control systems can be integrated and even a simulation of the hardware is realizable. Depending on the number of participating students it is recommended to provide a simulation of the hardware to save resources, money and increase flexibility as it is done for example by the DiK at the Technische Universität Darmstadt [10]. The simulation can also be realized inside Matlab to allow testing of software code without using real hardware.
An exciting side effect of the integration of real hardware like robots is the possibility to organize competitions between student groups. Competition increases learning outcomes due to higher motivation and involvement into the content of the specific course. On top a competitive situation reflects the working environment in reality. We organize a robot competition some weeks after the end of the lecture as addition to the regular schedule. A number of tasks have to be accomplished before and during the competition to get a reward. The construction and programming of the robot has to be prepared prior to the competition and creates additional motivation and learning effects.

Altogether motivation, attendance, participation and evaluation of the students are significantly higher since the implementation of the holistic vision and the continuous integration of programmable robots. Comparing the different attempts to optimize the course it is evident that the exemplary and focused concept has the following advantages compared to former approaches whose main content was restricted to theoretical computer science:

- One integrated development environment during the whole semester enables the student to focus on the educational objective rather than struggling with multiple tools.
- A modular and reusable robot like the Lego Mindstorms is preferred to a robot which has to be soldered and assembled and the higher price of such a reusable robot is easily compensated in the long run.
- Reaching mechanical engineering students is a lot easier by programming a physical robot than teaching plain math and algorithms with only little relation to other topics of their curriculum.
- Continuous and integrated courses which are embedded into the whole degree program turned out to be the better teaching strategy compared to highly optimized and advanced but autonomous courses.

Figure 3. Lego Mindstorms assembly kit and assembled robot (www.lego.com)

5 CONCLUSION

The presented holistic educational approach and its implementation offer a potential basis for current and future education concepts. Industry and job market ask for flexible and highly qualified workers with interdisciplinary competencies. To satisfy this demand and guarantee employability for future generations of students, education has to be flexible as well. Both the vision and the implementation are thought of as dynamic and highly adaptable. Therefore the concept is considered as work in progress to keep up with the rapid internal and external progress. Internal progress means changes in the curriculum, related courses or availability of software and hardware. External progress consists of changing requirements of the job market and industry.

Improvements and changes are part of the concept which benefits from evolving degree programs. Adaptions and updates are also required whenever the content of a related course is updated.

Although this paper mainly deals with bachelor courses an extension to master courses is easily achievable. In fact various courses and seminars at our institute already successfully integrate the concept as well.

In summary the education approach presented in this paper describes a potential way to sustainably improve the engineering education of a university. Although an implementation requires rather low financial resources, a fairly high amount of flexibility and time is necessary to introduce the concept and maintain it properly. Especially the continuous integration of a holistic concept with matching examples in different courses is not a trivial task. From our point of view it is always worth the additional effort no matter if a light version in single courses or a fully integrated curriculum is desired.

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