Engineering Design Education: Practical Methods of Product Development

Hugo d'Albert[1,a], Udo Lindemann [1,b]

[1]Technical University of Munich, Institute of Product Development,

Boltzmanstr. 15, 85748 Garching, Germany

[a]dalbert@pe.mw.tum.de, [b]lindemann@pe.mw.tum.de,

Keywords: engineering education, product development, product design methods.

Abstract. One major issue in teaching engineering students is using of specific situation-oriented methods within the product development process. This topic has to be considered in technical education of engineers. The focus of this paper is on communication of design related aspects of product development to mechanical engineering students at the Technical University of Munich (TUM). The course "Practical Methods of Product Development" offered at Institute for Product Development can be attended by the students during their education in mechanical engineering at Technical University of Munich. The students are confronted with concrete tasks. They should develop innovative concepts for the existing products using specific engineering design methods. At the end of the courses they build models or prototypes and present their results be reflecting the used methods. The goal of this course is provide knowledge, design principles and develop soft skills related to the professional practice as engineers in the field of product development. Thus, the students are prepared to transfer knowledge from the theory to the practical applications.

Introduction

Mechanical engineers focus on designing and creating various mechanized devices, like tools, machines, and engines. Engineering as a process requires applying theoretical knowledge and cognitive processes to design, analyze, and troubleshoot complex systems in order to meet customer's requirements. The activities of design, analysis, and troubleshooting are what engineers do to develop new devices (e.g., cars, consumer electronics), processes (e.g., food processing, manufacturing, airport scheduling), and infrastructure (e.g., transportation, power distribution) and change existing ones that shape our lives [1].

Product development specialists must have not only background knowledge regarding mathematics, physics, or chemistry but also skills to handle multiple tasks in various stages of development process. The product development engineer ought to be a multifaceted engineer, knowledgeable and skilled in several fields. This engineer should work interdisciplinary, integrative and with the aim to be creative and innovative [2].

Their profiles may be conveniently sketched in terms of three components: (1) their knowledge - the facts they know and concepts they understand; (2) the skills they use in managing and applying their knowledge, such as computation, experimentation, analysis, synthesis/design, evaluation, communication, leadership, and teamwork; (3) the attitudes that dictate the goals toward which their skills and knowledge will be directed-personal values, concerns, preferences and biases [3].

The professional requirements on integrated engineering designers steadily increase and comprise not only subject-specific skills but also creative talents and social skills such as networked collaboration and intercultural behavior. These demands on young engineers have therefore also to be considered in university education. Therefore, besides specialist knowledge, the students should convey methodical, social and personal skills that make them able to work in teams [4].

Background

TUM founded in 1868 in Munich (Germany) is one of top technical universities in Europe. It is committed to excellence in research and teaching, interdisciplinary education and the active promotion of promising young scientists. The university also forges strong links with companies and scientific institutions across the world. TUM was one of the first universities in Germany to be named a University of Excellence. Moreover, TUM regularly ranks among the best European universities in international rankings.

TUM is structured in 13 academic departments that provide an excellent environment for research of 9,876 staff members and for the education of 39,081 students. The university has a budget of EUR 1,258 million [5].

The Department of Mechanical Engineering with 4578 students is one of the most successful faculties of its kind worldwide and occupies rank 19 in 2015, according the QS World University Ranking [6]. Institute for Product Development is one of the institutes within the Department of Mechanical Engineering. The research area of the institute is systematic product development and procedural modeling to support the design of innovative and competitive products. The institute offers a large variety of lectures, practical courses and seminars to the students focusing on product development and optimization of product development process. Students learn theoretical background of tools and methods for product development and can apply this knowledge in some practical projects. The practical courses offered at the institute are one of possibilities to use theoretical knowledge in practical context.

Concept of the course

The concept of the course implements design process bases on the Munich Procedural Model (MPM), which consists of seven interconnected elements (Fig. 1). The MPM offers a flexible set up that does not only support engineering-driven modification designs, but also provides a structure for the necessary clarification of requirements and successive resolving of uncertainties which is essential to more radical and hence uncertain innovation tasks [7]. The method oriented approach helps to plan and to determine direction in the development process and provide a framework for a structured analysis and reflection of the proceeding. Many situations in design projects require a combination of technical skills, problem solving and social skills: besides applying the technical knowledge of how to construct, test and produce a product, one also needs to be able to structure and systematically analyze a complex assignment and to communicate and negotiate constraints and ideas to other team members and the client [8]. Therefore, the integral part of engineering education must be development of interdisciplinary skills. These can be offered partly as own teaching programs or partly as seminars integrated in other available subject-oriented programs. Thus, the provided key and additional qualifications complement the professional competences towards the whole qualification of engineers [9]. In order to take account of this trend the cooperation with the Center of Key Competencies at TUM is forwarded. The Center organizes different seminars covering social skills, self-competence, and intercultural skills. Examples of courses are Teamwork, Rhetoric, Meetings, and Body Language.

Each element of MPM includes methods that allow solving specific technical problems during the product development process. The practically important methods for the effective and efficient development of innovative products are implemented during the course. Depending from the step in development process creativity methods, rating-methods or specific design methods can be uses by students. Each of these methods is used in team work. Thereby a strong focus is laid on development of soft skills like communication, discussion, moderation, or presentation. Teaching and learning methods are presentations and workshops. These methods support goal oriented activity and finding of solution. The maximal amount of participants is limited to 12.

The course is intended both for bachelor and master students and therefore previous knowledge and experience are not necessary. Although the language of the course is German, many of foreign students attend the course. Thus, intercultural aspects can be also regarded.

An online learning platform is available for the communication and for the exchanging of information between students and scientific assistants who take care through the course.

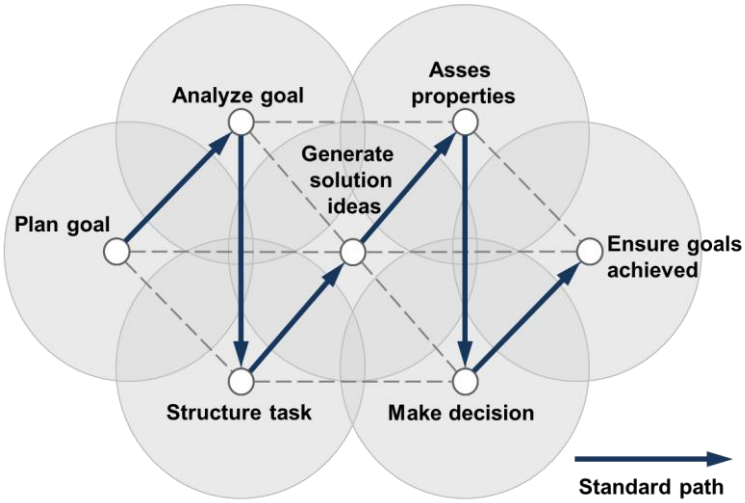

Figure 1. Munich Procedural Model (MPM) [10]

The course is divided in 8 events. These events correspond with the tasks within MPM. However, to emphasize the strong focus on soft skills competencies in summer semester 2015 an additional meeting was added to offer the students professional soft skills training in cooperation with Center of Key Competencies at TUM.

The first event is held by the scientific assistants. All other ones are prepared by students in form of presentations or moderations. The students are supported with advice by scientific assistants on the preparation. The appointments are arranged by prior agreement between regular events of the course. It is important that that students possess background knowledge concerning the methods before the event begins. To motivate the students and proof their theoretical knowledge they answer a set of short questions at the beginning of the event.

1st Event: Organization and Plan goal

The first event starts with introduction. The students get an overview of the research areas of Institute of Product Development and of the other courses offered at the institute. The organization of the course is presented and the content regarding individual events is described.

Main focus is emphasized in the approach. Students should be aware that the major aspect of the course is not a product that will be developed but systematical application of methods connected to development process. The product that should be developed by students is chosen by scientific assistants. This product should not been too complex. As examples from previous semester are to mention a cable roller, a bicycle carrier, a plant irrigation system, or an office chair. All these products are well known from daily life. How to make these products more innovative and distinguished them from already existing products.

The aims of presentation, moderation and feedback are explained. Each of students gets two tasks: preparing and giving a presentation and moderating of a workshop during the event. The students who give a presentation or moderate a workshop get a feedback from the scientific assistants and from other students. The feedback is seen as an essential part of learning and help to develop self-awareness and improve assessment performance.

Then the first methods corresponding with first element of MPM are applied. The students define objectives regarding the influence of the market, potential customers or competitors on product development. As methods are applied SWOT-analysis for an imaginary typical company, analysis of weak points and benchmarking regarding competing products.

2nd Event: Analyze goal

In this event specific and detailed requirements for the new product are formulated and documented. Using 635 method students collect possible and plausible requirements. Based on results from the first event and collected specific requirements a list of requirements is created. This list is binding and serves as orientation for the next steps.

3th Event: Structure task

The product is taken as a technical system and using Quality Function Development (QFD) structured in logical subsystems and components. The method functional modeling allows defining of relations within complex structures. The students learn to deal appropriately with complexity, identify the core problems and determine the most necessary actions.

4th Event: Generate solution ideas

The students learn problem solving by applying engineering design methods like synectics or morphological boxes to search for creative ideas. The aim is to foster the creativity and stimulate the thought process. As results the students generate a structured variety of alternative solutions for the specific technical problems.

5th Event: Asses properties

The available alternatives are analyzed for their properties. The students estimate functional relationships between the product components using Design Structure Matrix (DSM). The results are visualized in an influence portfolio and discussed.

6th Event: Make decision

The variety of available alternatives is analyzed and interpreted for their assessable features. This is a base for the evaluation of alternative solution and for the choice feasible and technical optimal concept. To make the choice the students visualized the results with sketches indicating the core technical solutions. By mean of weighted scoring list the choice of the most suitable concept is carried out.

7th Event: Ensure goals achieved

In this event the problems regarding risks are evaluated using Failure mode and effects analysis (FEMA) and Fault Tree Analysis (FTA). The aim is to secure safety and reliability of a product. The students identify and evaluate potential risk in terms of initiation of preventive measures. The Design for X method (DfX) is used to estimate the specific product traits including: manufacturability, power, variability, cost, yield, or reliability. The students discuss the problems in a role playing. The scenario is prepared by the scientific assistants. The students play the role of members of executive board of imaginary company and represent the opinion of different departments with their conflicts of interests. As result a final solution is elaborated as a feasible concept and translated in technical product. In the last step the models or prototypes of overall concept are develop by the students in our technical lab.

8th Event: Presentation

In the last meeting the results of development project are presented. The students make a critical analysis of their progress during the course and reflect their own problems and the advantages and disadvantages of the used methods.

Conclusions

The requirements on quality of academic courses in engineering education must meet the needs of the industry in the 21st century. Therefore, the consideration of practical relevance is important in course structure. This is the major objective of the described course. During the course “Practical Methods of Product Development” the students learn not only to implement a transfer of theoretical knowledge in operational practice and how to apply engineering design methods but also learn to work in a group and develop their social skills. Furthermore, they gain insight into project management and learn to coordinate multiple tasks in a complex project.

The ability to effectively present information, respond to questions from the public and conduct a debate is also emphasized in this course. The students get practical experiences and extend their capabilities to manage relationships and expectations with other stakeholders. One important issue is the project documents in accordance to formal request. According the schedule the students learn to define work plans, manage project activities and resources to deliver results in appropriate quality.

The quality of the courses is ensured by continuous feedback and exchange of experience between students and scientific assistants.

References

[1] S. Brophy, S. Klein, M. Portsmore, C. Rogers: Advancing Engineering Education in P-12 Classrooms, Journal of Engineering Education, July 2008.

[2] N. Adamsson, M. Grimheden: The Product Developer: Education and Professional Role, International Conference on Engineering Design, ICED’07, Cite des Sciences et de l’Industrie, Paris, France, 28 - 31 August 2007.

[3] A. Rugarcia, R.M. Felder, D.R. Woods, J. E. Stice: The Future of Engineering Education, Chem. Engr. Education, 34(1), 16-25, 2000.

[4] T. Luft, B. Schleich, S. Wartzack: Concept Development for Innovative Products - A Challenge for Engineering Design Education, International Conference on Engineering Design, ICED13 Sungkyunkwan University, Seoul, Korea, 19-22 August 2013.

[5] Information on http://www.tum.de/en/about-tum/our-university/

[6] Annual Report 2015: Mechanical Engineering, Technical University of Munich, Department of Mechanical Engineering, February 2016.

[7] M. Lorenz: Handling of Strategic Uncertainties in Integrated Product Development, Dissertation, 2008.

[8] K. Lauche: Measuring Social Skills in Design, In Bocquet, J.-C. (ed) International Conference on Engineering Design - ICED’07, Paris, France, 2007.

[9] VDI - Verein Deutscher Ingenieure e.V.: Stellungnahme zur Weiterentwicklung der Ingenieur-ausbildung in Deutschland, available: http://www.vdi.de/fileadmin/media/content/hg/VDI-Stellungnahme_zur_Ingenieurausbildung_2004 2.pdf, 2004

[10] U. Lindemann: Methodische Entwicklung technischer Produkte. Berlin, Heidelberg, Springer, 2009.

Authors' background

Your Name	Title*	Research Field	Personal website
Hugo d'Albert	Phd candidate	Product Development	http://www.pe.mw.tum.de/en/employees/hugo-dalbert/
Udo Lindemann	Full professor	Product Development	http://www.pe.mw.tum.de/en/employees/udo-lindemann/

*This form helps us to understand your paper better, the form itself will not be published.

*Title can be chosen from: master student, Phd candidate, assistant professor, lecture, senior lecture, associate professor, full professor