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THE KARLSRUHE EDUCATION MODEL FOR PRODUCT DEVELOPMENT "KALEP", IN HIGHER EDUCATION

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1. Objectives of teaching product development

Product development is one of the most complex and important stages in the value creation chain. The objective of the university education of mechanical engineers is to impart the complex knowledge necessary for efficient product development in an industrial environment and to teach the students the key abilities required for their professional life. Industry is searching for engineers with a university degree as "problem solvers" and "creativity sources". Especially those engineers are indispensable that are at all times able to cope with new problem situations due to their well-founded basic training of the acquired methodical skills and their ability for abstraction and model design. Besides technical and methodical knowledge, so-called soft skills / key qualifications are also essentially important. But there exist a lot of deficits in the general engineering education, as shown by an actual study from the VDI (Association of German engineers). In this study, several companies were asked about deficits and reasons for detachment during the probation period: 55,1% of the companies criticize the social competence of entrants, 47% complain about personal competence and only 13,1% of the companies mention the professional competence as a deficit of entrants.
The main reasons for detachment are the disability of the entrants to transfer the theoretical knowledge into practice, furthermore the entrants' overestimation of their own capabilities as well as the want of social behavior.
With the aim to improve this situation of entrants in companies, the main requirement for the engineering education is the improvement of the key competences during the education.
Engineers have to be "team players", they have to be skilled in technical know-how and business management and they have to be capable of reaching decisions and implement them. In order to meet these requirements in the university education, KaLeP (Karlsruhe Education Model for Product Development) was developed at the IPEK (Institute for Product Development, University of Karlsruhe).

1.1 Comprehension of product development

The basis for this education model is the comprehensive understanding of product development. Product development is the process towards integral planning and prototype realization of new technical systems: beginning from determining the product profile, the concept and design of the technical system (e.g. the machine), until the building of prototypes and their validation during tests – considering to the manifold impacts on the entire product life.
The content of scientific work in the field of product development includes therefore methods, processes, management, design elements and partial systems for the creation of technical systems as

well as the methods and systems for the construction and testing of prototypes. Product development in this sense is certainly one of the core fields in enterprises and the innovation performance determines decisively the success of a company.
The constructing engineer/product developer is the central designer and "facilitator" of the product creation. The requirements for this position are a deep technical understanding as well as a high process and communication competence. Furthermore, designers have to distinguish themselves with methodological knowledge paired with social competence and the potential to realize ideas. The decisive success factor in product development is not the methodology, the management or the information technology, but the human being as an individual as well as a team. Here it is irrelevant if they are called designers, developers or product developers. What is important is the comprehensive competence for managing successfully the complicated challenges of product development. This competence consists of the fundamental knowledge about the comprehensive field of the general product neutral product development and the corresponding skills about the respective specific technical fields of product development.
Globalization and transparent markets require an increase of efficiency and innovation performance of the product development. Progress in information technology will allow totally new possibilities of applying virtual reality, simulation, and process management, and therefore considerably redesign the product development with its methods and processes. The future will bring a variety of challenges for the product development in which center is the human being – the development engineer.
The aim of KaLeP is to acquaint the actors in this complex environment of product development already in the engineering education with all aspects of the real working environment and to teach the best possible basis for managing the complex challenges of later professional life.
On the basis of these challenges for modern development processes and the comprehension of product development, the multi-stage education model KaLeP was developed.

2. Basis of the Karlsruhe Education Model for Product Development

The Karlsruhe Education Model for Product Development KaLeP was introduced in the year 1999 at the Institute for Product Development, University of Karlsruhe (IPEK), and since then further advanced. KaLeP is based on three approaches for imparting the taught knowledge in a possibly practicable form: the teaching units of the courses are divided into the three parts lecture, practice/workshop, and project work. This measure enables the effective teaching of theoretical matter (lecture), the demonstration of its application in example and practice (practice/workshop) and the intensive practice of the realistic work (project work). KaLep supplements these three elements of knowledge transfer with two additional columns: their embedding in a realistic, industry-near development environment and – in addition to the technical competence – the teaching of methods and process knowledge of different competence fields (see figure 1).

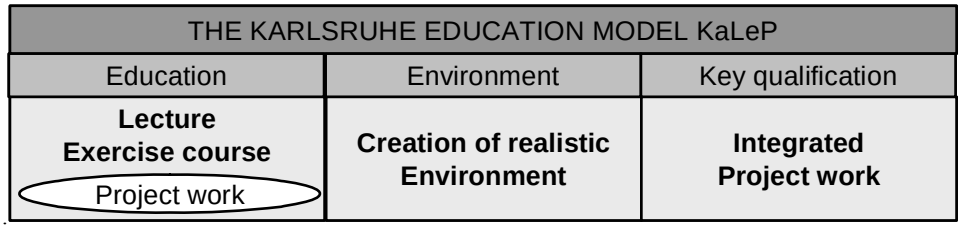

Figure 1. The three columns of KaLeP

KaLeP consists of three education phases in the engineer training. The first phase begins in the second semester with the courses MKL "Mechanical Engineering I,II,III", the second phase begins in the sixth semester with the course PE "Methods of Product Design", the third and last phase aims at students specializing in product development and design in the ninth semester with the course IP "Integrated Product Development". The three education phases are characterized by their focus on certain fields of product development-specific knowledge: system, methods, and processes. (Figure 2).

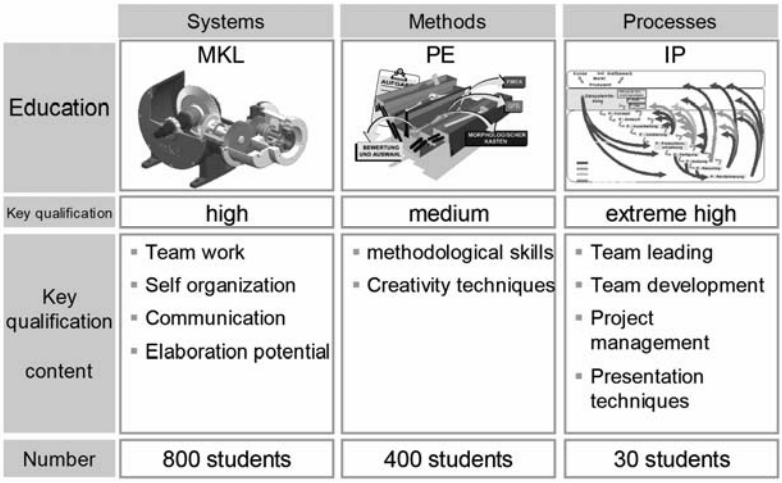

Figure 2. The three elements of education: systems, methods, and processes

2.1 Mechanical Engineering – systems of product development

The focus of the course is set on the technical systems of product development and Team oriented development processes. The main objectives of the course are:

Professional competence:

- design process steps of product design by means of complex assembly groups
- examine machine elements with the help of the contact & channel model (C&CM)
- apply norm-appropriately the design and dimensioning regulations of assembly groups
- apply basic considerations for complex machine elements used in mechanical engineering
- introduce the software used in engineering

Team competence

- promote the capacity for teamwork, elaboration capability, and the ability to assert oneself in performance –related, supervised workshop project meetings

Self organization

- the Students have to assess the expenditure of time and the technical effort of the delelopment task and split the work package in team on their own

Communication

- the Students present the results of their task to certain milestones and the tutor gives a detailed feed back

Elaboration potential

- the development task is extremely complex, it can only be solved in the team.

Self-assesment

- beside the professional competence, the Students are assessed in 4 other competence fields, and every student gets an individual feed back of his work (Figure 3 and Figure 4)

1. Professional Competence - F
2. Methodological competence - M
3. Social competence - S
4. Elaboration potential - E
5. Creativity potential - K

2.2 Methods of Product Design – methods of product development

The aim of this course is to display the importance of methods in the product design process and to teach the most important methods. The lecture aims at building up the professional capability of

students with respect to the basics of development structures and development processes of mechanical vehicle engineering and at imparting the knowledge of product neutral development methods that can be directly used in practice as tools for product development.

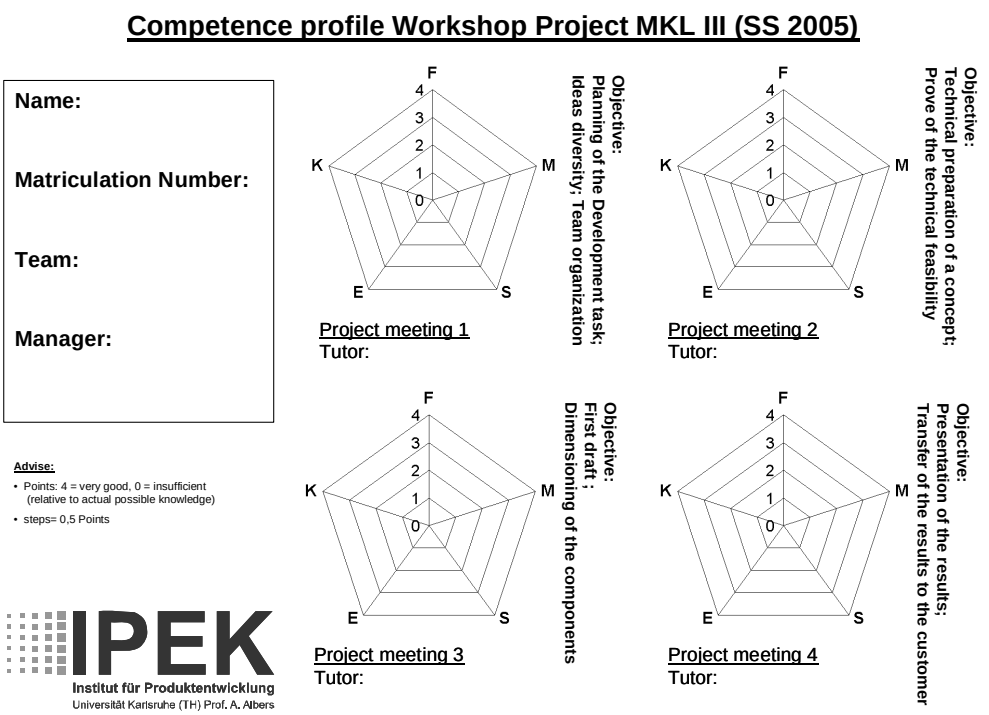

Figure 3. Competence assessment sheet

2.3 Integrated Product Development – processes of product development

The lecture introduces the students systematically to the product development process of enterprises. On the basis of practical experience and examples from industry, the theory of systematical planning, testing and regulation of the development and innovation process and the team-oriented implementation of effective methods are demonstrated. Strategies of development and innovation management, of technical system analysis and team leadership are discussed and trained in workshops accompanying the lecture. The focus of the main subject is on product development projects.

2.4 Competence profile

The aims and requirements of a modern engineer training are defined from the environment of the product development. The broad competence profile demanded by industry goes far beyond the pure professional competence of the classic university education. Besides professional competence, social competence, teamwork, methodical competence, creativity, and elaboration potential are of equal importance in today's working environment. The impartation, teaching and promotion of all competence areas are one of KaLeP's essential goals. In the workshops and projects, the students are continuously assessed with respect to their professional competence as well as their four other competence fields (see Figure 4). With this approach, the students reflect at a very early stage not only about their professional competence but also about their other competence fields and have therefore the possibility to improve their single competence fields in the course of the studies.

3. Integrated Product Development IP

The core of KaLeP is the major course "Integrated Product Development", in which 25 students in five teams realize independently a product development within four months. Besides lecture and workshops, the students are given a product development order from an external cooperation partner that the students work on full-time. This constellation is a win-win-situation for the university, the students, as well as the cooperation partners from industry or research.

The IP lecture discusses the theoretical procedure of a development process in a company from the profile stage to the construction of the prototype. In addition to the lecture, special contents are practiced and enhanced in workshops. The acquired basic knowledge from the lecture and the practiced methods from the workshops are then independently applied by the students in the development project to be realized.

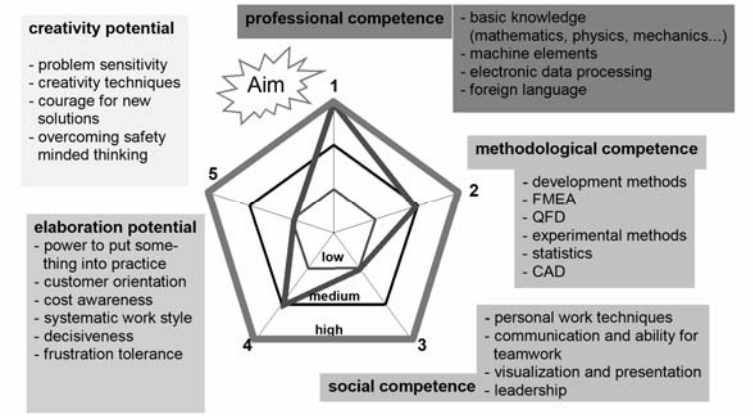

Figure 4. Competence profile

At the beginning of the project, a cooperation and company structure is designed together with the cooperation partner that integrates the five student teams. Each team is assigned a proper office in the Product Development Center (Produktentwicklungszentrum PEZ) at the Karlsruhe University, where the teams have access to all infrastructural resources of the institute. The five student teams lead self-dependently the development project; the results are presented to the project partner and the company management at certain presentation dates (milestones). At these milestone presentations, the further procedure is decided on together with the cooperation partner and the management.

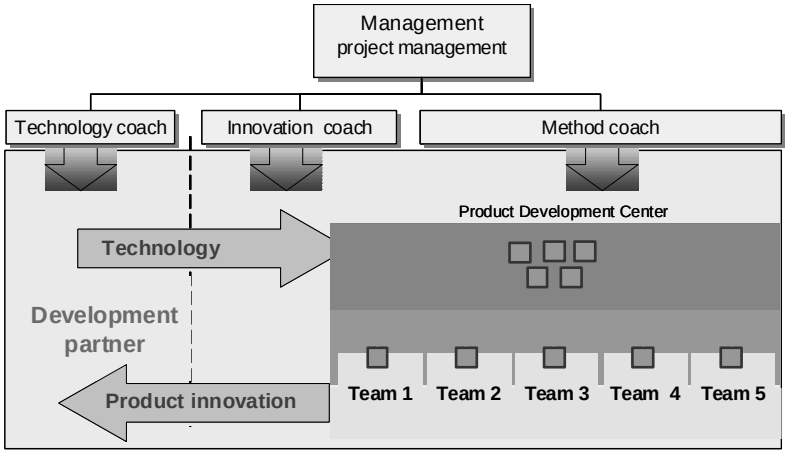

Figure 5. IP – Project structure

3.1 Structure and procedure of the accompanying project

3.1.1 Project initiation

One of the elementary teaching aims is the impartation of team competence and team management. The team composition plays a vital role for the success of a project. In order to demonstrate the students the importance of team composition and team development, the team is given a central role in the project. Before project start, all participants fill out a personality test that is based on the MBTI (Myers-Briggs typology indicator) and are assigned to one of the eight different types: “maker”, “realizer”, “organizer”, “problem solver”, “theorizer”, “creative person”, ,”visionary”, and “analyst”. On the basis of this typology, the five development teams are composed in a way that distributes equally all types into the different teams.
This team composition creates homogenous groups and supports in an optimal way group-dynamical effects and team development.

3.1.2 Presentation of the development task

After allocating the teams, the development task is presented to the participants. The development task is very broadly defined and is not based on a specific technical development task but begins at an very early stage of the strategical product profile determination. A development task could be e.g.: “The project partner intends to open up a new market segment or to expand the existing product line with a new product and searches for this purpose new innovative products that have a high market potential”. With this general aim, the students begin with the development of their products.

3.1.3 Milestone 1: Profile presentation

On the basis of the general development task, the student development teams begin with market analyses, market scenarios, and customer- and advertisement analyses. Workshops for the single methods take place that train the special methods of market analysis or scenario technique so that the students can apply this knowledge in the second step for their own project. In the first 1½ months, the teams concretize the task given to a technical task formulation. After this first stage, each development team presents several possible product profiles to the management and the project partner in a presentation lasting 20 minutes. The focus in this presentation is on the identification of the market demand, the competition advantage, and the affinity to the cooperation partner. From the presented profiles, the cooperation partner decides then together with the management and the single teams which product profile will be further advanced.

3.1.4 Milestone 2: Concept presentation and milestone 3: Final presentation

In this phase of the project, the students have 2½ months in order to elaborate on their product profile, specify requirement lists, build prototypes, conduct technical and economic feasibility studies, and to build a digital and hardware-based prototype. The aim of this phase is to develop the product as far as possible and to create a complete development documentation to be passed on at the end of the project to the cooperation partner for a seamless further development. At the end of the project, a final presentation is held in front of a group of industry representatives, in which each student team presents their product development from the product profile to the functioning prototype in a presentation lasting 20 minutes. The teams will try to convince the management and the development partner from the superiority of their solution and to win the competition against the competing teams.

3.2 Overall integration

The overall concept of the major course Integrated Product Development enables the students to experience independently a product development from the definition of the development task to the construction of the first prototype. The participants are selected by a selection procedure, only 25 students are admitted for the project. The students are demanded a very high time commitment, the project is for the participants a four-month full time job. Besides the 2 lectures per week lasting each

1½ hours and the workshop with 3 hours per week, an additional 40 hours per week are estimated for the development project between mid-October to the end of February.
Besides the lecture, the modification of the workshops with respect to the given project is one of the decisive success factors of the project. For each project, the workshops are individually tailored to the demand of the respective project and the students. A variety of workshops were developed for this reason that can be held on demand in order to give the students the necessary training for solving the given development task. The contents of the workshops are: scenario technique, product profile determination, project planning, evaluation of technical systems, solution determination, patent search, presentation techniques, moderation techniques, synectics, and many more.

4. Exemplary projects

The lecture with workshops and accompanying development project takes place since 1996. During this time, the concept and the content have continuously developed and the complexity of the development task has increased year by year.

Figure 6. IP projects

4.1 STIHL Green Keeper

In 2003/2004, the project IP was carried out together with the development department of the STIHL Company. 24 students elaborated in competing teams product concepts for STIHL. The task for the IP project "Innovation with STIHL" was the development of an innovative new product that was to successfully extend the product range of the Stihl target market "Lawn & Garden". The boundary conditions of the product to be developed were very broadly defined and were adjusted to the core competences of the existing products of the Stihl Company, i.e. the technology. One of the central core competences of Stihl products are hand-operated two-stroke engine-driven devices in lightweight construction. These Stihl devices are used for such different areas of application such as e.g. motor scythe, hedge shear, high pressure cleaner, sprayer- and blower devices, universal suction devices, cut-off grinders, and drilling devices. The development task for the IP project 03/04 included all stages of a product development. It began with a market analysis with product profile- and product idea determination and ended with the creation of a digital mock-up and functioning prototypes.

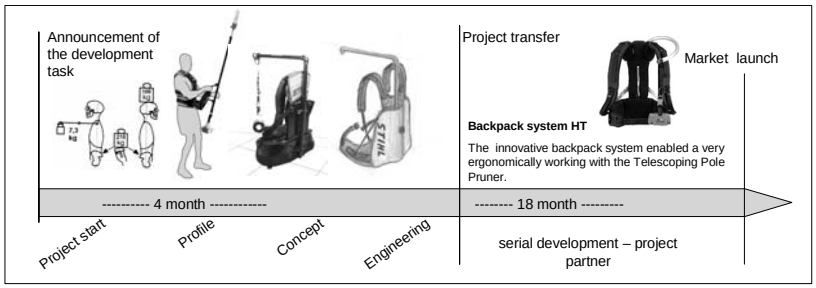

Figure 7. IP - STIHL Project "Green Keeper"

Within the scope of the project with STIHL, students developed four promising product concepts. One of the four products, a "bearing system for a motor saw with shaft" was realized right after the termination of the IP project in the serial development of the STIHL Company and had its market entry on January 1st, 2006.

5. Summary

With the help of the ten years experience that the Institute of Product Development of the University of Karlsruhe has in implementing the education project Integrated Product Development and the continuous improvement of KaLep, it was achieved to meet today's requirements for a successful engineer education. Evaluation results and interviews with graduates show clearly that the KaLeP approach improves systematically the key qualifications for engineers. In the meantime, the education model of the Integrated Product Development was transferred to other special fields such as e.g. electrical engineering. It demonstrates that the integration of aimed training of soft skills in a practice-near environment in combination with the university education of Humboldt is a very successful model.

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