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More than Professional Competence –The Karlsruhe Education Model for Product Development (KaLeP)

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ABSTRACT

The development of products is one of the most complex and important stages in the value creation chain. Besides professional competence and competence in methods, key abilities like social competence, the capability to make decisions and realize them are essential for future engineers to launch successful products in the market. The basis for the Karlsruhe Education Model for Product Development (KaLeP), started in 1999, is the above mentioned holistic understanding of product development.

For an education oriented on the demand of later professionals the courses are divided into three parts: the theoretical knowledge is imparted in lectures, in tutorials where the students train the practical appliance and implement it in a workshop with a complex project work. The courses are embedded in a realistic and industry-near development environment and in addition to the professional competence, method and process knowledge is taught in different competence fields.

The KaLep is part of an integrated education which is closely associated with materials science, manufacturing technology, engineering mechanics, etc. To ensure a methodical row the KaLep is separated into three education phases which are characterized through different fields of product development-specific knowledge: systems, methods and processes.

The first phase consists of the courses “Mechanical Design I, II and III”. Its focus is set on technical systems in product development. The students learn basic considerations of complex machine elements by means of the Element Model C&CM (Contact & Channel Model), process steps of product design, teamwork and elaboration capability as well as design and dimensioning regulations supported by engineering-specific software. In the second phase, in the course “Product Design”, students learn the basics of development structures und development processes in mechanical engineering and the appliance of product-neutral methods for support. In the third phase knowledge is deepened in the course “Integrated Product Development”, the core of the KaLep. In the lecture students are taught the field of product development processes in enterprises. Systematic planning, controlling and regulation of the development- and innovation process, the appliance of effective methods, strategy and team management are the main tees of this phase. The whole process is connected to a product development project with an industrial partner which generates a competition character between the student teams.

For gaining very important international experiences the students have the possibility to attend exchange programs with Purdue-University (Indiana) in the USA and Shanghai in China within the Global Engineering Alliance for Research and Education (GEARE).

INTRODUCTION

The industrial environment that alumni of universities are encountered with after graduation is characterized by high dynamic and enormous complexity. A very important aspect is the multidisciplinary product development. The combination of the classical mechanical design education with computer sciences and mechatronics requests a high degree of candidness and methodical proceeding. Further the integration of key abilities in the education is necessary.
The Institute for Product Development (IPEK, University of Karlsruhe, Germany) has developed an education model that conjoins these main aspects – the Karlsruhe Education Model for Product Development (KaLeP)

In the domain of product development it is essential to work on concrete examples with transferability to other cases. Of course students can't learn designing products in the first semester, but it is also important for the motivation of students in early stages of studies. The education must be executed step by step. Conceiving, Designing, Implementing and Operating are aspects which together represent a methodical process [4] and bring together essential "milestones" of product development. In the course Integrated Product Development the IPEK deploys these aspects.

An overview about the contents, the implementation in education and the tools we use in KaLeP is task of this paper.

THE RELEVANCE OF KEY ABILITIES FOR THE ENGINEER

In the application process engineers concentrate on explaining their professional competences. Key qualifications are often positioned in the background. [6].
A VDI (Association of German engineers)-study [5] shows this problem clearly: for 55% of the job entrants, reasons for detachment are social competences (multi-nomination was possible).

Thus, a sensitisation for these competences is necessary. Students must learn how important for success of a project a systematic proceeding is - and the right way for learning about this issue is that students do not only hear about it in lectures, they must experience it. These experiences must be collected in concrete project work and not in special "soft-skill"-courses – soft skills must be trained on the project, so that the important aspects of self-organisation, teamwork and methodical proceeding must be integrated in the product development education.

Especially regarding the multidisciplinary product development education the key competences are significantly important. Working together requires a high degree of teamwork, time- and project-management because the way of thinking and the approach to solve problems of engineers in other domains is completely different.

THE KARLSRUHE EDUCATION MODEL FOR PRODUCT DEVELOPMENT

This holistic understanding of product development requires a holistic education model. The Karlsruhe Education Model of Product Development (KaLeP), introduced in 1999, combines many of the main aspects for a great number of students in Product Development.

Basis for the KaLeP are its three columns (Figure 1): the education, the environment and the key qualifications

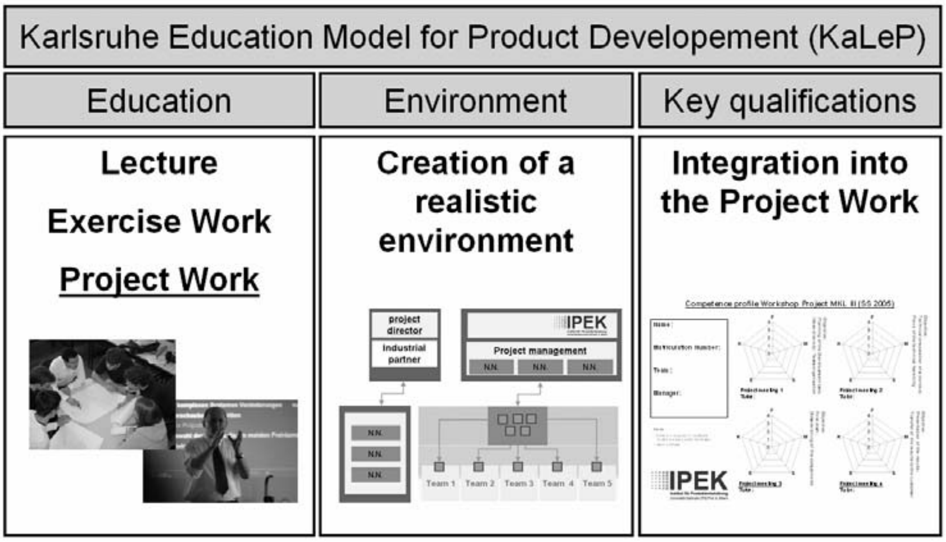


Figure 1: The three columns of KaLeP

The important aspect is that these three columns are toothed closely with each other. The education is divided into three parts. The theoretical knowledge is imparted in the lecture by an ex-cathedra teaching form. In the tutorials the students train its practical appliance by solving different tasks e.g. analysing technical systems, etc. The implementation takes place in the workshop. Teams of five or six students work together in a complex project task. So the KaLeP is based on the constructivistic learning process - the students must construct the knowledge for themselves to understand it correctly [2].

The education is integrated in a realistic and industry-near development environment. Reason for this is to motivate the students and to confront them with processes in the industry, e.g. leadership- and management systems.

Additionally the education of key qualification is integrated into project work, because it is very difficult to teach key qualifications separately. Seminars for key qualification work with abstract, less significant examples for illustration.
The KaLeP is part of an integrated engineering education at the University of Karlsruhe (TH) which is closely associated with materials science, manufacturing technology, engineering mechanics, etc. Thus a holistic and networked education is warranted for the students and different aspects of professional competences are combined, too.

THE THREE PHASES OF KALEP – AN OVERVIEW

By splitting the product development education into three phases we achieve a methodical row. This row is oriented towards certain fields of product development-specific knowledge: systems, methods and processes (Figure 2).

The first phase, Mechanical Design (MD), is placed in the first two years of the study. That is the reason for the huge number of the participant students (about 800).
The education of key qualifications is as essential as the education of professional qualifications in this phase because it is the basis for the further studies. For gaining clearness and a reference to use cases the fundament for MD are concrete systems.

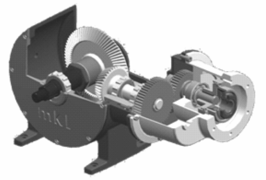
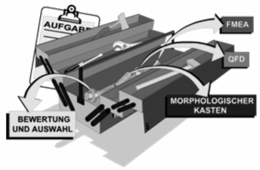
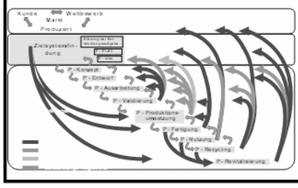
	Systems	Methods	Processes
Education	MD 	PD 	IP 
Rate key qual.	high	medium	very high
Topics key qual.	▪ teamwork ▪ self-organization ▪ articulation and communication ▪ elaboration potential	▪ method knowledge ▪ creativity technics	▪ team-leading ▪ team-development ▪ project-management ▪ presentation / communication ▪ self-management
number	800 students	400 students	30 students

Figure 2: Systems, Methods and Processes in the KaLeP

In the second phase, product design (PD) concentrates on the education of product-neutral methods, processes and creativity techniques. Constitutive on the basic systems of MD, the students operate on a more abstract level. Further they learn the basics of development structures.

The core of the KaLeP is the third phase. The course Integrated Product Development (IP) rounds off the engineering education. Here students learn intensively the coherences of development and management structures in industrial companies. Acquired knowledge about project management and the product development process is implemented in their project work directly.

A THINKING MODEL NOT ONLY FOR THE EDUCATION – C&CM

Because of the variety and the different sectors the mechanical design education is a very complex issue. After graduation students should be able to adapt their knowledge to solve special problems in their industrial environment. To teach this holistically to students a methodical and structured process is the basis. The IPEK integrates a theory to abstract technical systems into the KaLeP for realizing this. The theory is a thinking model called the Contact & Channel Model" (C&CM) [3].

This model is easy to use because only three hypotheses form its basis. One of them is that every technical function is fulfilled in the contact between at least two elements – the Working Surface Pairs (WSP) and the structures linking them – the Channel and Support Structures (CSS).
Addicted of the use case there are many methods build on the C&CM. There are design rules and methods to analyze whole product architectures, e.g.

Figure 3 shows a simple example for the abstraction of a crane with C&CM. The model isn't restricted on mechanical systems, Electrical and systems based on information technologies can be displayed too. Because of its broad application area and its easy way to use it is very powerful in the engineering education.

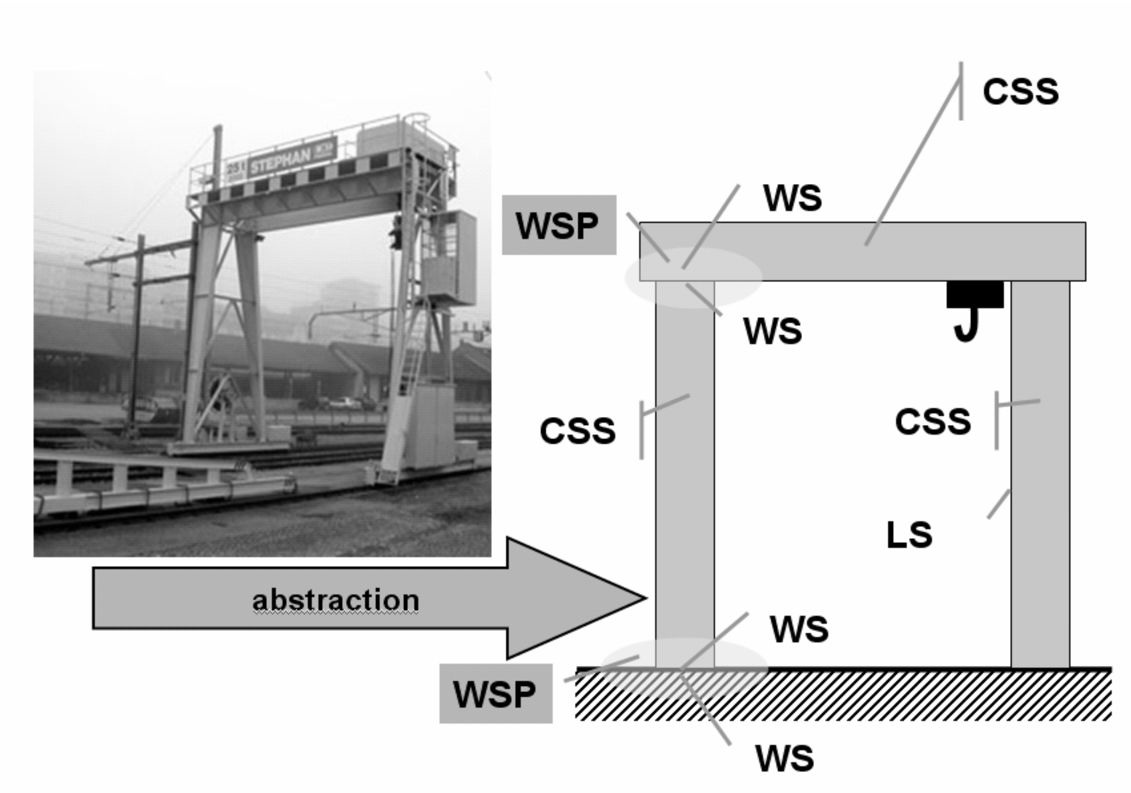


Figure 3: A simple example for the abstraction with C&CM

With C&CM selected machine parts are imparted to the students in very detail in lectures. And after having understood this model, they are supposed to analyze the function of very different unknown machine parts and systems better.

Further the C&CM allows not only to analyze systems but although to synthesize. This is very important for the constructive tasks e.g. in the workshop and of course later in the industrial environment.

An overview does not suffice; special examples do not suffice too. An abstraction and general description of technical systems is the key for an effective engineering education because the variety and complexity in the technical sector are increasing permanently.

For evaluating the use of C&CM a reference task was created to acquire the student's ability to abstract and analyze an unknown technical system. It consists of questions that allow drawing conclusions from their way of thinking. A great number of students don't recognize the system on the first view. Through the methodical progress and utilisation of C&CM they learn more about the system and many more can describe the function completely at the end of the task. The results are amazing. Since the introduction of KaLeP with the embedded C&CM the number of students who could identify the function of the technical system increased enormously.

PHASE 1 - MECHANICAL DESIGN I, II AND III

Already in the early phase of the study key qualifications should be taught just as well as a technical knowledge base.

Mechanical Design I
The Mechanical Design Education starts in the second semester with MD I. That is why the number of students is about as high as 800. Besides teaching of key qualification it is important to offer the students a practical appliance of the theoretical contents.
In order to realize this, students have the possibility to participate in a “transmission workshop”
The students are organized in about 160 groups. Each group receives a gear box and the corresponding tools. Additional to lecture and tutorial different tasks must be handled. This starts with a simple disassembling and assembling of the whole gear box. During this the functional relevant working surfaces must be analyzed and described. At the next appointment the students prepare technical drawings and free hand drafts. Tutors discuss the achievements in the groups. Also here the C&CM plays a central role. The main functions of gear wheels, bearings and screws are known by the most students but what about distance-rings and fits? By analyzing the working surface pairs and channel and support structures awareness for the existence and function is growing.

Mechanical Design II
In MD II (third semester) the main focus is not any more on the analysis of technical systems but on the synthesis. Lectures and tutorials include principles of design, tooth systems, dimensioning, etc. In the workshops the students solve constructive tasks beginning with simple bearings to a complex angular gear. The results are presented to the tutor at certain milestones and new tasks are defined.

Mechanical Design III
In the fourth semester, in MD III, the students must develop a complex system. To accomplish this, teamwork is essential. Because of the extensive task the work must be unitized and each team member has its own division and must work in cooperation with the others. The tasks in the past were e.g. a ball bearing assembling machine, a carousel placed on a car trailer, etc.
Figure 4 shows an overview about the Mechanical Design education.

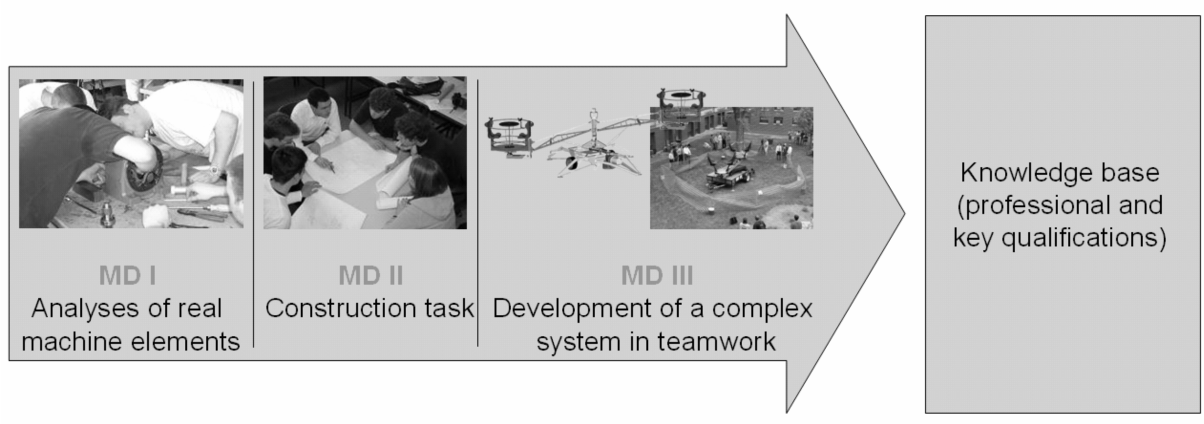


Figure 4: Mechanical Design education as methodical row

After each workshop meeting the students are evaluated concerning five different competences and potentials in the so called competence-spider (see Figure 5):

- F - professional competence (basic knowledge, machine parts, foreign language, …)
- M - methodological competence (development methods, FMEA, QFD, CAD, …)
- S - social competence (communication, teamwork, leadership, presentation)
- K - creativity competence (problem sensitivity, creativity techniques, courage for new solutions, …)
- E - elaboration potential (power to put something in practice, cost awareness, systematic work style, …)

Students are also integrated in the evaluation process. The team-members have the possibility to evaluate each other. After a discussion the tutor fills in the competence-spider. In this way the students learn to review other work in relation to their own performance.

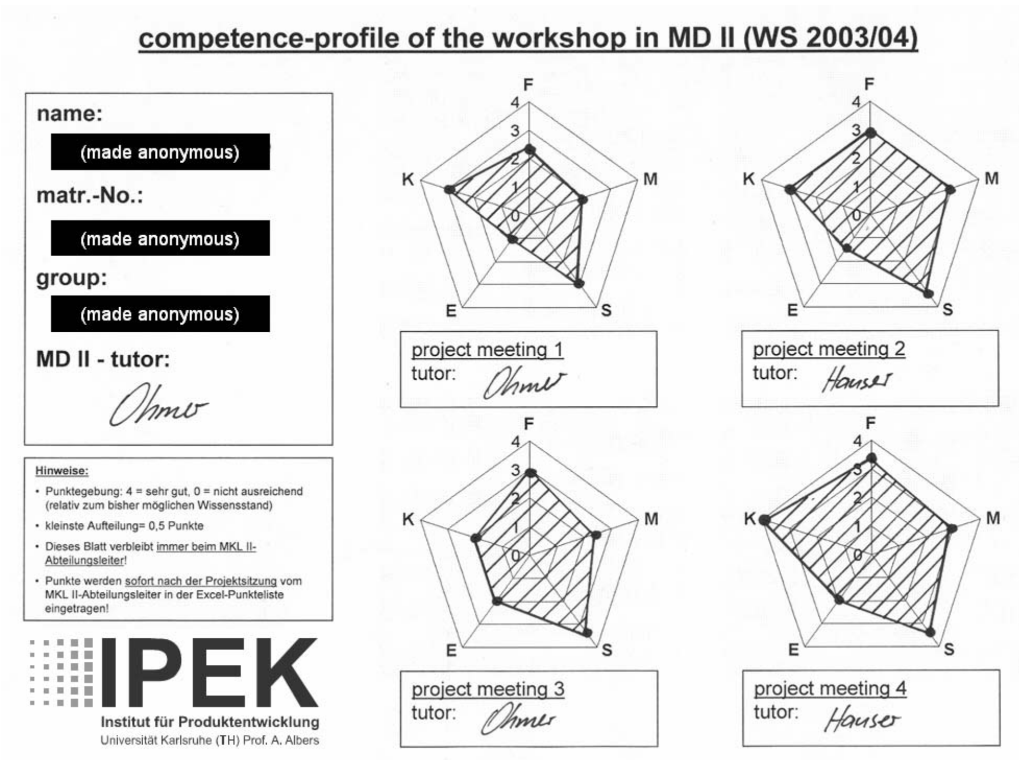


Figure 5: Evaluation with the competence-spider

Finish of the MD - education is the exam which is split into the theoretical part and the practical part. Students are given a very complex constructive task. It demands a structured proceeding, creativity and time management to solve the task within three hours - all the aspects they have learned in the workshop in addition to professional competences.

PHASE 2 - PRODUCT DESIGN

The course Product Design is the conjunction between Mechanical Design and Integrated Product Development. In the industrial environment engineers often only know that development methods exist but do not use them because knowledge about how they work is missing or they think that a lot of time is required for a low benefit.
At this point Product Design is deposited. Starting with the basics of the product development process and product neutral methods the students get an overview which methods do exist,

which methods are applied when and how to use them. The amount and the effectiveness the students learn by applying some selected methods in concrete examples.
Important is that the course Product Design is split up in three parts: development methods, manufacturing techniques and materials science so that a high degree of toothing between the three domains exists.

PHASE 3 - INTEGRATED PRODUCT DEVELOPMENT

The third phase consists of the course Integrated Product Development. A complete product development process until the prototype phase is run through in close cooperation with an industrial partner.
Because of the very high degree of supervision only selected students can take part in this course.

At the beginning of the course an industrial environment and development concept is created in cooperation with the partner. The development tasks are purposely formulated very broad. Each team gets an own office with accordant infrastructure in the Product Development Centre (PEZ) of the IPEK. The structure of the project work in which the teams are embedded is shown in Figure 6. Additional students take part in lectures and a workshop where they deepen their knowledge about development processes of enterprises; systematic planning and controlling and the practical adoption of complex creativity methods, presentation techniques, etc.

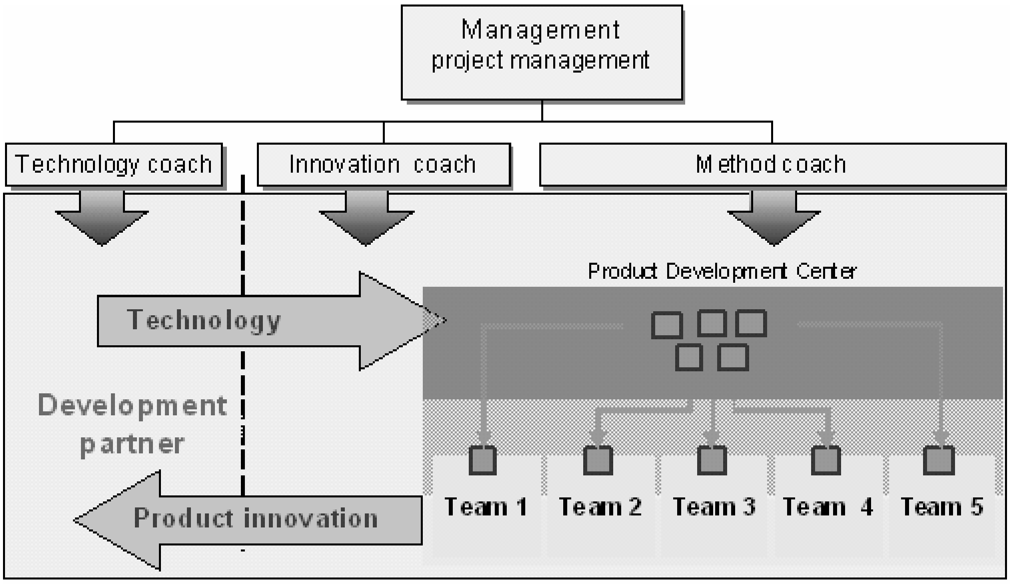


Figure 5: Environment and structure of IP [1]

The first step for the IP-Teams is to build up a project plan with concrete work-packages and milestones. After that because of the broadly formulated task the students use market analysis, scenario analysis, etc. to define their product profile.

At the first presentation the students and the project management discuss the profiles and the development of concrete ideas and concepts begins. A competition character is created between students and thus each team develops another product.
After two other presentations – the concept-presentation and a spontaneous presentation – the final presentation in front of many industrial representatives is taking place. Here the students demonstrate their prototypes and deliver the project documentations and idea storages to the project partner.

A product developed in cooperation with the STIHL Company, e.g. had its market entry on January 1st, 2006. Many other products were applied for patents. Thus a WIN-WIN-Situation for the students, the industry and the IPEK is created. In Figure 6 there a few impressions of the IP projects.

Figure 6: Impressions of the IP projects

INTERNATIONAL COOPERATIONS

Closely associated with the key qualifications are international experiences. The IPEK collaborates in several programs (Figure 7).
Students have e.g. the possibility to attend exchange programs with Purdue (USA) and Shanghai (China) within the Global Engineering Alliance for Research and Education (GEARE). Here in a foreign country internships can be absolved or courses can be attended.
Further there exist cooperation with Bulgaria and South Eastern Europe. The University of Sofia e.g. has adapted the KaLeP and the mechanical engineering curriculum of Karlsruhe for their mechanical design education. In South Eastern Europe the IPEK gets involved with development help, for example.

Figure 7: International cooperation of the IPEK

EVALUATION

By means of an Online Evaluation System it is possible to react quickly on the statements of students during the semester.
In order to sensitize the students for the importance of key qualifications the IPEK has created a special questionnaire. It consists of two parts. First the students must estimate how important the different key qualifications are for the engineer generally. Further they have to evaluate their own knowledge and competences in this domain.
Thereby it is possible to compare the estimation of the tutor with the estimation of the students. Because of a permanent controlling we have the potentiality to move focal points in the education.

Another aspect is the evaluation of alumni. To optimise our processes we analyze how important the several competences are in the real professional world.

CONCLUSIONS

Looking retrospectively to the last 10 years the IPEK can say that it is on the right way concerning engineering education. Feedback of industrial companies and alumni clearly proves this development.
Today many companies advance the opinion that key qualifications are the very weak point of entrants as well as methodology and a systematic proceeding.
Because of this the KaLeP must be optimized and accommodated permanently. In 1999 the IPEK cognized the situation and *conceived* a concept. After that KaLeP was *designed* and *implemented* in education. Now it is time to *operate* to fine tune the model so that the Institute for Product Development can offer such an education to the students also in the future. An exchange of experiences is very necessary to realize this.

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