INTERNATIONAL ENGINEERING AND PRODUCT DESIGN EDUCATION CONFERENCE
2-3 SEPTEMBER 2004 DELFT THE NETHERLANDS

THE CONSTRUCTIVIST ASPECT OF DESIGN EDUCATION IN THE KARLSRUHE EDUCATION MODEL FOR INDUSTRIAL PRODUCT DEVELOPMENT KALEP

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ABSTRACT

Since 1999 the Institute of Product Development of the University of Karlsruhe (TH) *IPEK* (until 2003: Institute of Machine Design and Automotive Engineering) teaches students of Mechanical Engineering with a newly developed education model called *KaLeP* (Karlsruhe Education Model for Product Development – Karlsruher Lehrmodell für Produktentwicklung) which has a significant advantage in supporting the learning process in the human brain opposite to the "conventional" way of academic education. A large quantity of team-oriented project work supports the natural way of "learning by doing" and motivates the students to advance their own learning process.
Very positive feedback of students and industry as well as an evaluation of students' performance indicates that KaLeP has a great potential for an effective education.

Keywords: design education; constructivism; thinking model

1 INTRODUCTION

In times of an accelerating growth of mankind's knowledge – especially the knowledge of technologies - it becomes more and more fundamental for engineers to understand important interrelations instead of memorising a big amount of facts. So for their education it is important to know the process of understanding exactly and to form the education in a way that supports this process as well as possible.
Modern theories of education say that the taught knowledge cannot be cloned into the brain of learners but they have to construct this knowledge individually and embed it into their previous knowledge to understand it.
The Institute of Product Development of the University of Karlsruhe (TH) *IPEK* created an education model that agrees with these special needs of the students based on these considerations. It is called the Karlsruhe Education Model for Product Development (Karlsruher Lehrmodell für Produktentwicklung *KaLeP*).
This paper shows why KaLeP is particularly suitable for the support of learning based on the new theories of education.

2 MODERN UNDERSTANDING OF EDUCATION – CONSTUCTIVIST ASPECTS OF UNDERSTANDING

In the last couple of years considerable progress has been made in researching the processes in the human brain during learning. New insights and a new interpretation of yet existing knowledge brought forth modern theories for education. One that is accepted largely is the theory of constructivism.

2.1 Theory of Constructivism

Constructivism is a model of the human learning and understanding process that bases on the acceptance that any knowledge of people is not a thing that ca be learned as facts but it is a result of the own interpretation of the entirety of each persons own sensations. This involves that it is hard and almost impossible to understand a big amount of facts without having the chance to bring them into an individual context. So any kind of teaching should permit phases of individual construction of the handled learning matters.

Constructivism is not a new theory. Yet Xenophanes and Sextus Empiricus thought about similar theories. Vico, Kant and other important philosophers accepted these considerations and advanced them [7]. But not only after the publications of Watzlawick [12], Holzkamp [8], Siebert [11] and further advocates of modern constructivism this theory was accepted by a multiplicity of educationists.

Based on constructivistic theories several methods for teaching were developed. Some of them are abstract and can be used for almost every topic, some are specified for very particular fields of knowledge such as natural sciences, jurisprudence, medical science or – as described in this paper – Engineering sciences. All of them have in common that in the learning process a great (channelled) freedom is needed for having a chance to construct the taught facts in the own brain and to embed them into the yet existing knowledge.

3 KALEP

Applicating these theories into the concrete learning process the Institute of Product Development of the University of Karlsruhe (TH) has developed a new method for the education of a great number of students in Product Development. This method includes the needs of students to construct the teached topics for themselves as described in chapter 2.1. It is called the "Karlsruhe Education Model for Product Development" (Karlsruher Lehrmodell für Produktentwicklung *KaLeP*). [4; 5; 6]

3.1 Overview over KaLeP

KaLeP was introduced into the education of IPEK in 1999. At this time it was a new approach to academic education in the sense of Humboldt.

KaLeP is based on the division of education into the three sections

- lecture,
- tutorial and
- workshop.

The lecture contains the teaching of basic knowledge. This is expanded in the tutorials where the application of the taught knowledge is shown. Yet here Students have to solve first engineering problems themselves. But due to the great number of students and the resulting lack of time there is no chance to allow each student to construct all of the new knowledge in their mind in these both "classical" parts of education – lectures

and tutorials are held in a great lecture hall with momentaneous more than 500 students per semester.
As described in chapter 2.1 “Theory of Constructivism” the students must get a possibility to think about the taught subjects in a very individual way that allows them an embedding into their previous knowledge. For this reason the main lectures of IPEK contain a workshop where the students have to solve a problem of Mechanical Engineering in small groups of 4 - 5 students. The tasks in these workshops are quite open, on a high level and accompany the students during the whole semester. A solution of the tasks is often only then convenient possible if the students work engaged in their team. The have a quite big – in higher terms even increasing freedom in designing their product as there is no pre-modelled solution they have to reach. If possible, the tasks come from industry so that there is no existing or satisfying solution for the task at all when students begin to work at the problem. This is a very motivating situation as students are involved into real product development projects.
A typical task for undergraduate students was in the last years e.g. designing a carousel for garden-parties with little certain, pre-defined bundary conditions. Students of higher levels designed new machine tools, made completely new concepts for refrigerators or were embedded into high-level basic-research-projects and designed parts for humanoid roboters and micro-systems for absolutely new patterns of application.
The supervision of the students in the workshop is organised very extravagant. Each group has to present the progress of their project 4 – 5 times each term. Each presentation is examined by an employee of IPEK and discussed with the team for at least 4hours. After this meeting where problems and the further progress of the project are discussed the students have to plan and organize their project themselves until the next presentation (every employee of the institute has at least two consultation hours a week if unexpected problems should occur).
At the end of each presentation the students get an elaborated feedback about their strengths and weaknesses. So they have the chance to identify their weaknesses and concentrate their further learning on them. The tool for this evaluation of students’ performance is a diagram in which five criteria (professional competence, competence in methods, potential of creativity, social competence and potential of elaboration) are evaluated.

3.2 KaLeP Supporting the constructivist education concepts

As described in chapter 2.1 “Theory of Constructivism” it is important for every learning process that the knowledge that is taught is not only lectured but the learners have to get a chance to re-construct it in their own context for understanding it. KaLeP allows this by its special composition of education that implements the above described parts lecture – tutorials – workshop and the C&CM theory. The following sub-chapters describe how the elements of KaLeP are adjusted to the special individual needs of learners.

3.2.1 Project work

All tasks of the workshop are part of a design project as described in chapter 3.1 “Overview over KaLeP”. Students have to think about the whole project when they generate a solution for a small part, they have to think about system correlations and interfaces and the problems that they have to solve are mostly evolved from the project itself and not given in the task itself. So they get a very high self-reliance of their learning process and the motivation for understanding and learning is quite high. This requires a bigger autonomy of the students than a "classical" way of education as it is practiced in most fields of academic studies, but it gives the students the best chance to understand the things they are learning.

3.2.2 Group work

The tasks of the workshop are conceived as group work. Students have to learn team work and they have to inform and help each other both solving the task and learning the basics of the lectures, tutorials and other relevant sources if necessary. This teamwork is evaluated during the presentations of the project. Teamwork stimulates not only the professional competence of students but also the other competence fields described above (competence in methods, potential of creativity, social competence and potential of elaboration). The changing situation of engineers in industry require these competence fields more and more.

3.2.3 Open tasks

The tasks of the workshop are formulated very open. This openness increases quickly with the students' duration of study. Undergraduate students who attend the lecture "Mechanical Design" firstly get a technical system which they have to complete. Soon the systems become more and more complex and the task changes to the design of a new system under certain boundary conditions. Students who have almost finished their studies attend the lecture "Integrated Product Development". Here a typical task of a age-class ago was "*Develop an innovative micro-product basing on the technologies of the collaborative research center SFB 499* [13] *which has potential for a formation of a new company*". This open task forces the students to occupy intensively with the task and it gives them the chance to learn everything about their task completely in their own way.

3.2.4 Evaluation of students' work

One of the main functions of the presentations of students' results is giving them a feedback about their strengths and weaknesses. As this feedback is specified into five fields of competence as describes above, students can improve their competences very purposeful. An example for this evaluation is shown in Figure 1.
Knowing the own weaknesses is the only chance to improve them consciously. So this evaluation is made very carefully and it is discussed with the students at the end of the presentation so that every student has understood it.

3.3 C&CM embedded in KaLeP

A further essential part of the KaLeP is the embedding of a theory to abstract technical systems into every theme of the courses. It is called "Contact & Channel Model" (C&CM) [3] and describes elementary correlations between the function and the embodiment design of technical systems. In its basis it is a new methodical and didactic approach to the abstraction of machine elements and systems to a superior abstract level.
Once students have understood this theory, they are able to derivate the function of an unknown machine part or system from its design or vice versa to synthesise the design of a technical system basing on the description of its function.

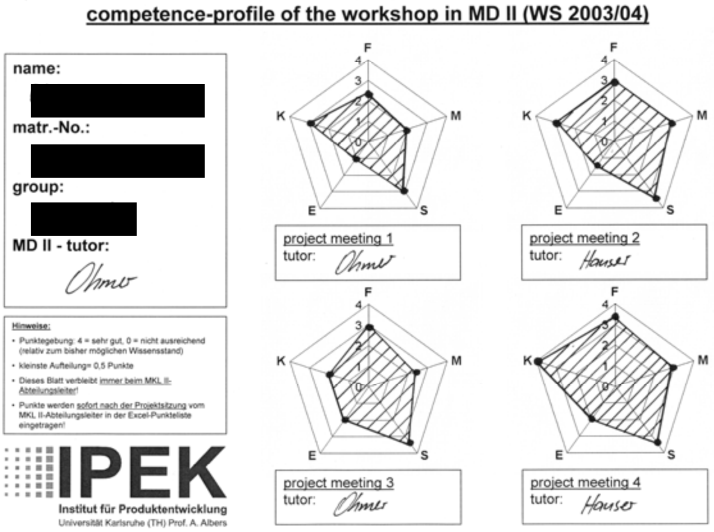

Figure 1. Evaluation of a student in the workshop (made anonymous)

3.3.1 Overview over C&CM

C&CM is a method to analyse and to synthesise technical systems in a abstracted way so that commonnesses of many different systems can be deduced and the transfer of them to other systems is simplified.

One of the basic hypotheses of C&CM is that every technical function is fulfilled in the contact between two elements – the *Working Surface Pairs (WSP)* and the structures linking them, the *Channel and Support Structures (CSS).* Some further basic definitions about the number and arrangement of these elements are the basic of the thinking model. Further rules for the application of this model help the designer to use these theoretical definitions solving a technical problem.

One of these rules is that the only possibilities to change the function of a technical system are a) *adding* WSP and CSS, b) *removing* WSP and CSS or *changing the properties* of c) WSP or d) CSS.

For example a hydrodynamic plain bearing is derivated in the lectures as adding new WSP and CSS (lubrication) with defined properties to a simple machine system consisting of a shaft and a bore hole.

3.3.2 C&CM supporting the self-construction of Machine Design

C&CM describes technical coherences with a very basically point of view. This makes it easy to draw conclusions from knowledge about one machine part or system to another. This works for the process of system analysis as well as for the process of system synthesis: Once students have understood e.g. the principle of connections with a transmission of force that is perpendicular to the Working Surface Pair they will be able to understand the function and the dimensioning of most similar connections and to design new ones for problems with no standardised solution.

So this theory helps students to organize their knowledge and to transfer it to new problems. This is a very important step for the construction of new knowledge in their minds.

3.4 Evaluation of KaLeP

Introducing a new education model that needs such a big capacity for looking after the Students as KaLeP is a step that makes only sense if it helps students learning the topics much better than a "classical" education model that requires only one lecturer two or three times a week. So IPEK developed an evaluation of student's ability to solve an engineering problem. Several generations of students were evaluated and the results were compared [1]. The results of this comparison helps developing KaLeP and its components.

3.4.1 Reference Task

A reference task was developed that indicated the ability of students to analyse a unknown technical system and to find out its function. The task was formulated in a way that allowed to draw conclusions about the students' way of thinking while they analysed the function of the given system.

The results of this reference task were amazing: The attitude towards solving problems in the different classes of students has changed essentially over the considered period of time. The share of students who had been able to fulfil the step of the function's analysis of the given unknown machine system was even more than double compared to the beginning of the testing, when the "classical" machine elements education model had been taught at IPEK. This indicates clearly that the new way of teaching that was introduced with KaLeP is a big help for the students to understand Mechanical Engineering. Figure 2 shows the growth of students' ability to analyse the function of the unknown technical system. Students who made the test in 1999 were educated with the former, conventional education model, in the following years KaLeP was developed and introduced in the education of IPEK.

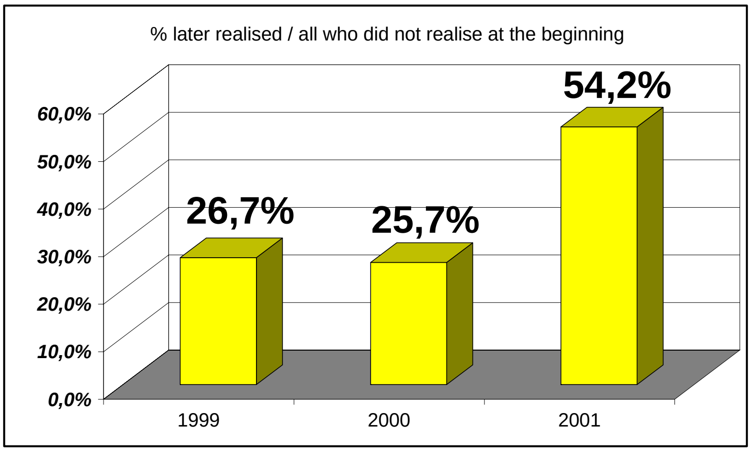

Figure 2 Evaluation of the reference task

3.4.2 Industrial feedback

Many of the workshop-projects are combined with a task from industry. All of the companies who were involved into such projects showed surprised about the engagement of the students and the quality of their solutions, even those companies who were very critical at the beginning of the projects. Industry clearly encourages us to carry on with this education model.

3.5 Further Development of KaLeP

The education model KaLeP is constantly extended and improved on the basis of the experience gained during the semester in order to achieve an increasing quality in the field of teaching at IPEK. The employees of the Institute are regularly trained by professional educationalists and a core-group of those scientific assistants who are involved deeply into education meets regularly to discuss necessary and potential changes in the concept.

A new reference task is developed to learn even more about the students' process of synthesis and their problems with designing a technical system. These insights will help to increase the quality of KaLeP even more.

A further project in the scope of KaLeP is the improvement of the infrastructure that IPEK puts at students' disposal (rooms, computers and software, further material for self-study etc.). This Year 80 new computers could be bought, so the students have much better conditions working on their projects.

4 CONCLUSIONS

The success with the new education model KaLeP and the very positive feedback from students and industry indicates that KaLeP has improved the education in Mechanical Design intensively. Among other circumstances this is surely a success of the effort of IPEK to support students' needs in their learning process, especially by regarding their cognitive needs. So the development and use of this education model will be continued increasingly.

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