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ALTERATIONS IN STUDENTS' ABILITY TO SOLVE PROBLEMS BY INTRODUCTION OF THE ELEMENT MODEL C&CM INTO THE KARLSRUHE EDUCATION MODEL FOR INDUSTRIAL PRODUCT DEVELOPMENT KALEP

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Abstract

In 1999 the Institute of Machine Design and Automotive Engineering of the University of Karlsruhe (TH), Germany, introduced a new education model, the so-called Karlsruhe Education Model for Industrial Product Development (Karlsruher Lehrmodell für Produktentwicklung KaLeP). This education model is based on the Humboldt approach to academic education as well as on the introduction of the element model „Working Surface Pairs & Channel and Support Structures", by means of which the connection of function and embodiment design of technical systems can be illustrated. In order to make the success of the KaLeP measurable a reference task was developed and carried out. Having completed the same period of studies students of three successive years were to analyze the functioning of an unfamiliar machine system. The first test was carried out with students, who had been taught according to the classical machine element education model. In the following years, however, lectures were gradually changed to the new education model. This paper is to demonstrate in which way the introduction of the new education model, and in particular the element model, has affected the student's way of thinking and how this result could be measured by means of a reference task.

Keywords: descriptive models of designing, human learning, design skills, design education, cognition and learning process

1 Introduction and Objectives

Since 1999 the Institute of Machine Design and Automotive Engineering at the University of Karlsruhe (TH), Germany (mkl) uses a new education model for the education of Mechanical Design. It is called Karlsruhe Education Model for Industrial Product Development (Karlsruher Lehrmodells für Produktentwicklung KaLeP).

The success of introducing this new education model was to be evaluated with a reference task. One of the objectives of the reference task presented in this paper was to find out if and how the student's way of thinking during the design process can be optimized by the introduction of the new education model.

Apart from that the reference task was to point out that the education model developed at mkl, provides an efficient tool which enables students to easily solve unfamiliar engineering problems.

A further goal was to examine whether students apply the taught methods intuitively without being explicitly asked to do so. This would be a hint that students accept the methods considering them as something sensible and useful.

2 Methods

2.1 KaLeP

The Karlsruhe Education Model for Industrial Product Development (Karlsruher Lehrmodell für Produktentwicklung KaLeP) [6;7;8] was introduced at the mkl in 1999. It is a new approach to academic education in the sense of Humboldt.

KaLeP is mainly based on the division of education into three sections. The first section contains the teaching of basic knowledge, which is expanded in the second section. In the third part, however, parts of this knowledge are intensively deepened. These three sections allow the students a better understanding of the taught subjects as there is not only a lot of knowledge to learn but also the simultaneaos application of the taught subjects.

Thus the lectures, which are the core of the education offered at the mkl, are divided into three lectures embracing the whole period of studies. The undergraduate studies contain the lecture “Machine Design”, which is completed by the compulsory lecture “Methods of Product Development A” in the first part of the graduate courses. The lecture “Integrated Product Development”, which intensively deepens the knowledge acquired before, is the third and concluding part of the educational program.

Further basics of KaLeP are the as realistic as possible environment at the education of product development and the taught knowledge of subjects, methods and knowledge.

For the three pillars of the KaLeP described here see Figure 1.

In the lectures this division into three sections is continued into the deepest layers. The lecture “Machine Design” is divided into three semesters. The students start this subject in the second semester and take it until the end of the fourth semester during which they usually have their intermediate exam.

The division is continued even in the individual lectures of a semester as they are all splitted into the lecture itself, tutorials and a workshop. The first part, the lecture itself, again contains the teaching of basic knowledge, which is intensified in the tutorials and is applied to practical design tasks in the workshop .

A further essential part of the KaLep is the element model C&CM, which is described in the following section.

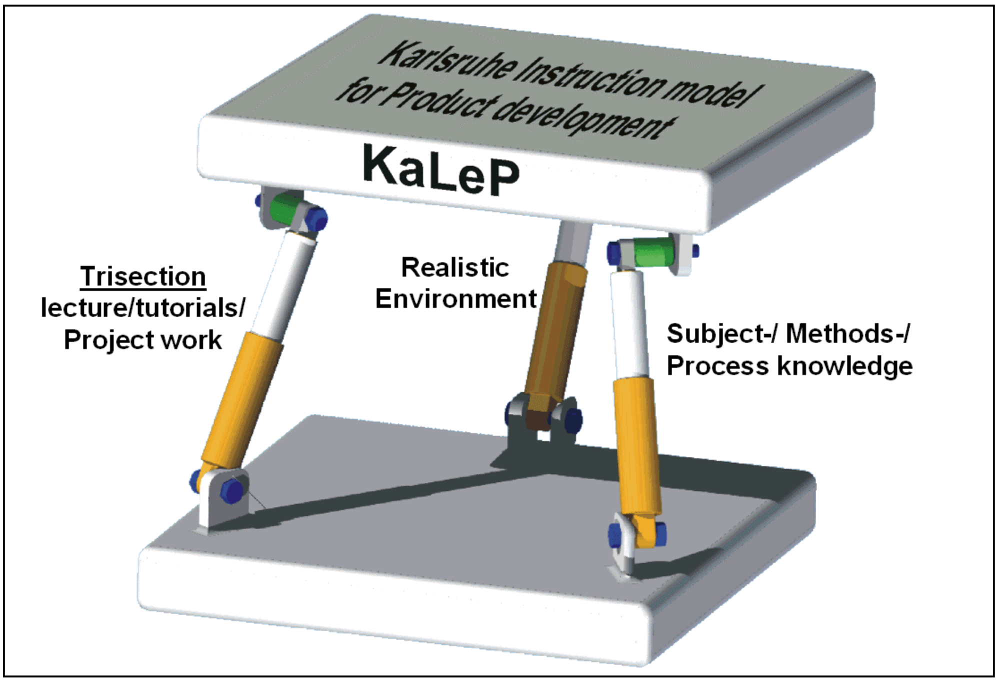

Figure 1: The three pillars of the KaLeP

2.2 The Element Model C&CM

The Element Model C&CM "Contact & Channel Model" presented in [1] and [2] is a new scientific approach to the description of the correlation between embodiment design and function of technical systems. It is integrated into the mkl in the scope of KaLeP within the individual lectures. C&CM is taught as a basic methodical way of proceeding with the examination of machine systems as early as in the first semester of the Machine Design studies.

In its basis the element model is a new methodical and didactic approach to the abstraction of machine elements and systems to a superior abstract level, in which the embodiment design and the properties of the working surface pairs as well as the channel and support structures are of crucial importance for the system context of the machine elements.

According to this idea machine systems are reduced to the smallest common features relevant to their function. Those are the surfaces determining the function of a machine element in the system context: the Working Surface Pairs (Wirkflächenpaare WFP) and the Channel and Support Structures (Leistützstrukturen LSS), which are the structures responsible for coupling them. However, this approach is not restricted to mechanical systems made of solids. All technical systems and effects occurring in mechanical engineering can be described, even those based on fields [2].

A big advantage of the Element Model C&CM is its variability of examination. Due to the changeable resolution a complete technical system can be examined in its system context. By means of increasing the resolution the function of individual system parts, individual machine elements as well as of microscopically small areas of a WFP can be examined in an abstract or detailed way depending on ones preferences.

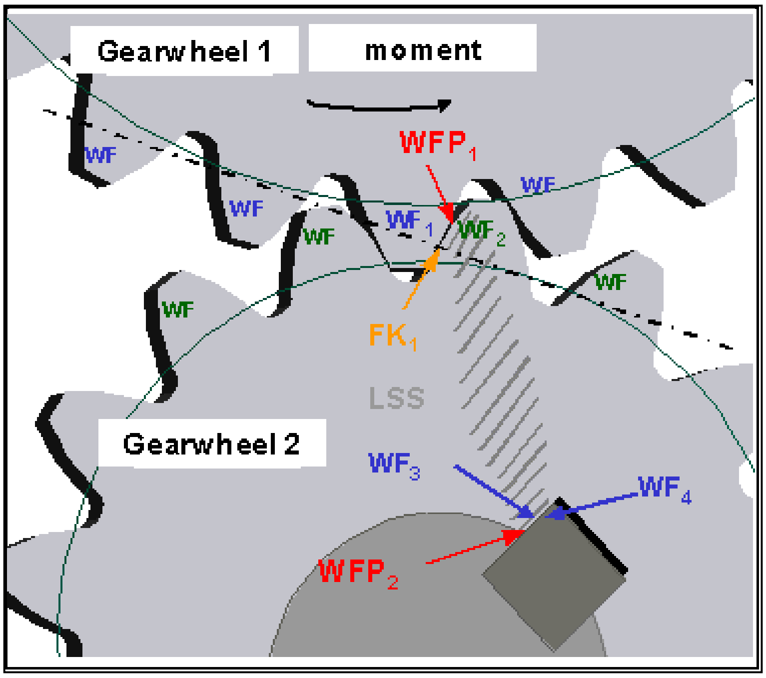

Figure 2: WFP and LSS at the example of a gearing

There is no restriction to a certain abstraction level in any phase of the product development process and it is rather easy to move from a very abstract level of functions and partial functions to the detailed shape of individual WFP or LSS or vice versa. Thus, one never loses touch with the general function of a technical system.

Figure 2 demonstrates the described approach at the example of a gearing. The force between the tooth flanks of the both gearwheels is transmitted by the Working Surface Pair WFP1. This force is channelled to the Working Surface Pair between gearwheel and the fitting key by the Channel and Support Structure of the gearwheel.

By this scientific approach all main levels of the learning target hierarchy in each stages of complexity [3] are supported, from knowledge, understanding and the capability of application of this knowledge to the ability of analysis and synthesis. Complex system correlation can be understood much easier with the aid of this element model. Apart from that acquired knowledge concerning the function of the total system can be easily transferred from a known machine element or system to another unfamiliar one.

According to Humboldts basic understanding of academic education at the mkl actual results of research are applied directly in the individual lectures. In the period of time it was studied the element model was still subject to research- a task which has not been completed yet. Therefore, the mkl will continue using an education model, which permanently undergoes changes and improvements.

2.3 The reference task

The profit in learning the element model “Working Surface Pairs & Channel and Support Structures” in connection with the new education model KaLeP has been examined and analyzed since its introduction by means of a three-year investigation, which has been completed recently. This investigation refers to the development of the application capability of the knowledge taught and above all to the capability of system analysis, which apart from the ability of synthesis is one of the central goals of teaching.

The students of three successive years were to carry out an exemplary examination test in the form of a reference task . By means of this it has been stated that the newly introduced education concept, especially the new approach to education using the Element Model C&CM, has resulted in the fact that students can learn and recognize the function of an unfamiliar machine system from a technical drawing better than those students that were educated with a classical way of mechanical design education.

In order to examine the aforementioned abilities, which the students had acquired within some regular examinations in the undergraduate examination, a 20 minute examination not announced in advance was carried out. Words explicitly pointing out the Element Model C&CM, such as “Working Surface Pairs” or “Channel and Support Structures”, had not been used deliberately. The intention was to examine if the Element Model C&CM had been applied autonomously, or ideally even unconsciously, within the thinking process.

The first of these examinations took place even before the introduction of the Element Model C&CM in 1999. So it was possible to compare the students to those who had been taught according to the classical machine element education model. The other examinations were held in the following two years during which the increasingly perfected element model had been taught as an overall basic methodology.

The examination task demands the ability to draw conclusions from a technical drawing in order to understand a machine system and its function. Thus, the capability of analyzing the presented machine system and the process of solving problems, and especially the application of the element model, are examined.

The task is structured into four parts:

The first part is a technical drawing of a special machine system that was not yet mentioned in the lessons. So most of the students do not yet know its function. They have to analyse it working on the task.

The second part is the question for the function. This can be answered spontaneously or after solving the following questions.

The third part – the main part of the task – consists of several questions about the behaviour of the technical system during and after a long period of operation. One question is e.g. where will be appearances of wear after a long time. So the students have to think about details of the function. Those who do not yet know the whole function of the system now have the chance to find out some subfunctions. So some of them are able to combine these to the whole function of the system.

The fourth part consists of some questions about the way and the order of the answers the students have given. These answers help to find out more about the thinking process during the solution of the task. The combinations of these answers and the answers of the first three parts of the task are the basis for the analysis of the thinking process of the students.

Due to didactic reasons the formulation of the question did not obviously aim at finding out if and to which extent the students are able to apply the Element Model C&CM for solving the task. However, this was in fact the actual aim of the reference task. Therefore, it had to be drafted in such a way that combining several of the student's answers would provide the desired information.

Firstly, it was necessary to find out if the students already knew the machine system. Students, who were familiar with it because of a former project, did not have to analyze its function anymore as they already knew it. As a result, the further answers of these students could not be used for finding out whether and by means of which method they were able to derive the function of this machine system. Students, who did not know the machine system presented by an engineering drawing, however, had to find a way to derive its function in the further context of the system.

Combining the answers of the latter was necessary to establish if and by which way the students were able to derive the solution. Although this was not explicitly asked it was also possible to determine how the students tackled the task in the course of the test. E.g. the question about which parts of the machine system would show signs of wear after a long period of operation was used to find out if the students were actually able to divide the machine system into the WFP, the junctions relevant to their function. This answer combined with some other answers gave hints for the thinking process of finding the solution.

By means of these and further answers as well as by their combination it was possible to establish how many of the students, who did not yet know the machine system and had to derive its function, were actually able to carry out this analysis successfully. The next step was to detect which percentage of the students in the respective groups obviously used the element model intuitively as a guideline for analyzing and how many students would not have thought of applying this model to the problem in question without an explicit hint.

Due to the combined answers it was possible to conclude if the students independently use the element model for the analysis and whether it provides any help in the course of the process.

The results of the tests, which were carried out from 1999 until 2001, were to lead to the conclusion if it was easier for the students of the later years, who had been taught according to the more sophisticated element model, than for the students of the first group, who had been taught according to the classical machine element education model, to come up with a good solution for the problem.

3 Results

The evaluation of the examinations in the first three years confirms the success of the application of the element model C&CM (Contact & Channel Model) "Working Surface Pairs & Channel and Support Structures" in the education model KaLeP. The attitude towards solving problems in the different classes of students has changed essentially over the considered period of time.

The new approach, which involves abstracting the function of technical components and systems to the explained higher level of the element model, also means a great aid as far as teaching is concerned as the systems' inner context and thus unknown components and machine systems can be understood in their functional context.

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 the mkl. (Figure 3). This is a clear hint for the success of the new way of thinking. Students that were educated with the Element Model C&CM within the scope of KaLeP have shown a much clearer understanding for the connections in a technical system. The new way of regarding technical systems on the abstract level of the functional surfaces and the structures linking them has enabled the double quantity of students to draw a conclusion from a drawing to the function of the technical system.

Even more astonishing is the result shown in Figure 4: Although there was no hint for the usage of the element model the number of students who were additional to the achievement shown in Figure 3 able to realise the Working Surfaces of the system elements increased rapidly. In 2001 almost five times more students were able to do this step. They were able to explain the position and the mode of wear in the technical system after a long period of time. This is a hint for the students no longer regarded only the single machine elements but also the contact surfaces – the WFP – that are the decisive areas of the technical system for the fulfilment of its function.

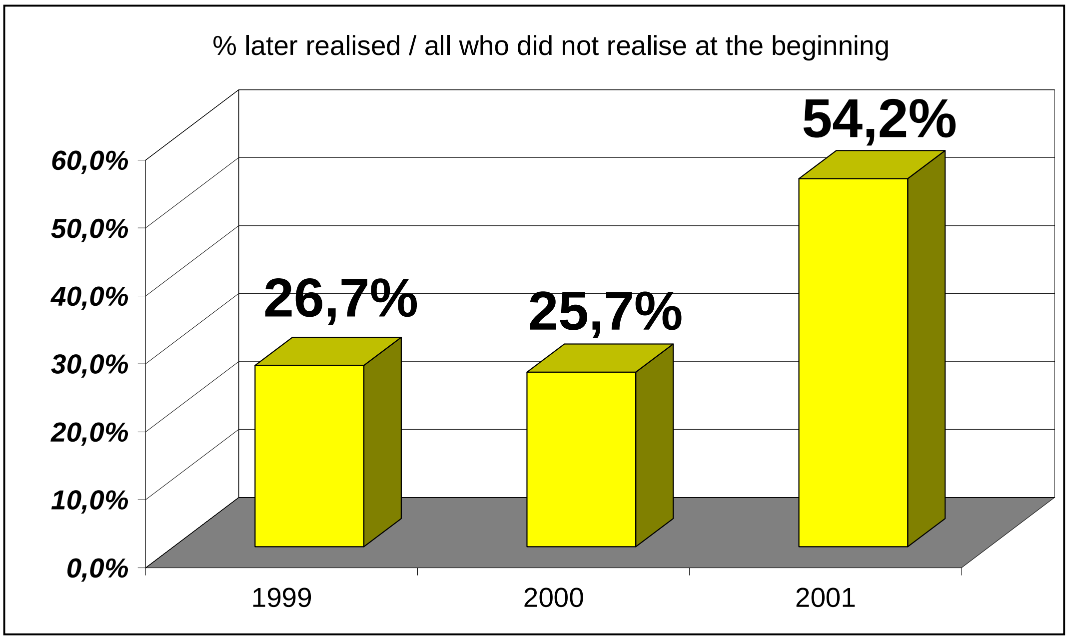

Figure 3: number of students who realized the function during the attention of the test

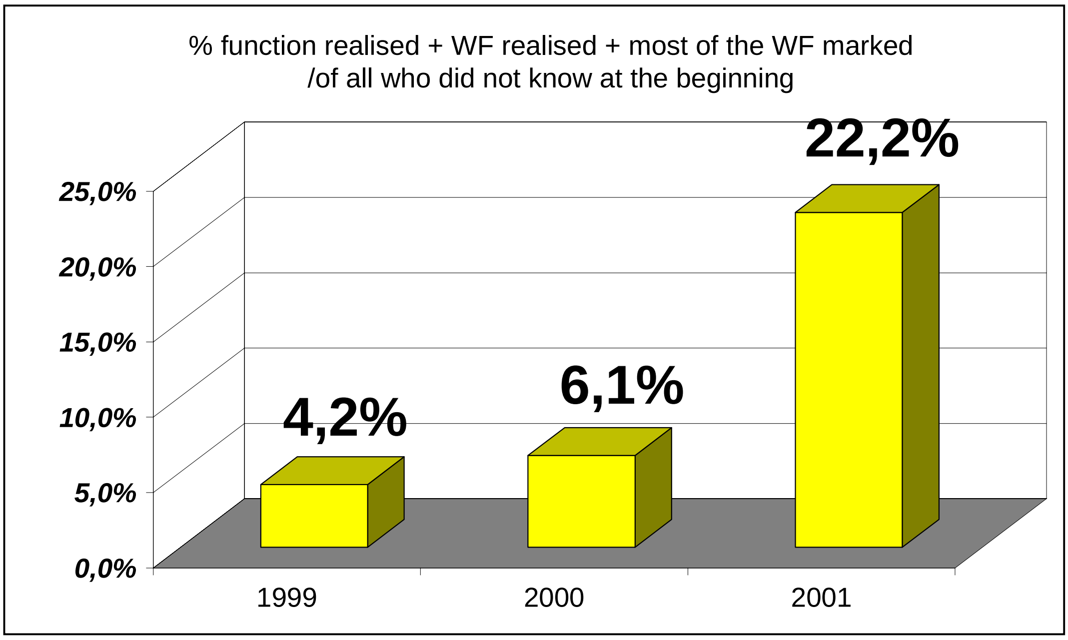

Figure 4: number of students who realised the function and the WF and marked the WF

4 Key conclusions

The results of the exemplary examinations show the very clear tendency that the Element Model C&CM provides a tool of great efficiency for the understanding and application of contexts regarding machine design in education.

Students, who had been taught according to the Element Model C&CM had less difficulties in finding the solution for an unknown problem. Especially the students who had obviously already internalized the new way of thinking and were able to analyze the unfamiliar machine system concerning its WFP and LSS without an explicit hint, had less problems during the analysis than those, who solved the problem in the “classical” way, i.e. by looking at the machine elements shown in the drawing without the aid of the element model.

The element model C&CM and also the Karlsruhe Education Model for Industrial Product Development are constantly developed as well as optimized. It is expected that the abilities of future students to carry out analyses, syntheses and to apply acquired knowledge will become increasingly better. Moreover, it is concluded that the continued preliminary examination tests will indicate a further positive tendency.

The extended tests, which are planned for the future years of students, will make it possible to examine not only the students’ ability to analyze, but also their ability to carry out a synthesis and create a new machine system or subsystem by a given (sub-)function.

The reference task is influenced by many external factors, such as the different levels of students of the three years in question, different background knowledge due to the changed education models in other lectures etc. Therefore, it is rather difficult to derive a statistic statement from the results of the reference task. However, the presented results make evident that the introduction of the KaLeP and above all the introduction of the element model into the academic education of the mkl have influenced the student’s basic understanding of complex system contexts very positively and will continue to do so in the future.

For these reasons the KaLeP will be permanently developed and improved by current research programs carried out at the institute according to the Humboldt approach to academic education. Apart from that practical experience from current projects in cooperation with industry are provided. Thus, the model can be continuously checked concerning its applicability and be updated if necessary. This will prevent it from becoming too academically.

With the described examination and its evaluation the continuous success of an education which increasingly refers to the new Element Model C&CM has been made measurable. By means of evaluating the results of this reference task the education model and the element model are constantly optimized.

The examinations will be continued in the following years. A further examination task is planned with that the capacity of the students for synthesis will be regarded. The Element Model C&CM supports the synthesis of technical systems as well as the analysis. The new reference task will be structured similar to the described one, but the direction of thinking will be the opposite one: the students will have to find out the embodiment design of a technical system starting from a functional description. Using C&CM it will be possible to arrange the WFP and LSS in a way to fulfil the given function.

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