New Education Concepts for the Training of Creative Engineers

The Karlsruhe Education Model for Industrial Product Development- KaLeP -

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ABSTRACT

The **Karlsruhe Education Model for Industrial Product Development – KaLeP** (**Ka**rlsruher **Le**hrmodell für **P**roduktentwicklung) – is a general education concept orientated at the real industrial development process and designed to promote competence in product development.

Since 1996 the **Institute for Mechanical Design and Automotive Engineering –** University of Karlsruhe (TH) – was developed a new education concept, which was already being used during the training of design engineers in 1998. In particular, the changing working environment of industrial companies today is taken into consideration. The lecture '**Mechanical Design**' is the basic component of the KaLeP-Model, which covers the constructive basics. The summer semester of 1999 marked the beginning of this new concept. Right from the start, the lecture was supported by an accompanying workshop, the goal of this workshop is to build up important skills, such as the capacity for teamwork, the ability to comprehend and to organise as well as to develop the student's creativity, skills which are mostly neglected in today's academic education. However, with two additional components – **Basics in Product Development** and **Integrated Product Development** – based on the lecture mentioned above, high-level training as a design engineer in product development can be achieved. Those components are explained thoroughly in (2).

1 INTRODUCTION

Development and production processes have changed drastically over recent years. The industrial environment and the management systems which the students will be confronted with in their future working life, are hardly comparable with those a few years ago. Nowadays companies develop, manufacture and promote their products in projects almost entirely based on teamwork. The professional everyday life of future engineers is characterised by teamwork and, after a period of training, by team leading. Soft skills, like team and management skills, become more and more important for a successful position in the industrial and professional field. Engineers with an academic education are mostly employed by the industry as a 'solution finders' or 'creativity pools'. Right from an early stage, the engineer has to deal with open questions or unpredictable problems, since technology is subject to constant change. Knowledge grows with unbelievable speed. The fusion of different disciplines – e.g. mechanical design and information technology – in the field of mechatronical products demand a multidisciplinary approach and openness for new ideas. Only on rare occasions will the engineer find the complete solution for a specific problem in his own handbooks from university. This is impossible if one considers the broad variety of specialised branches, tasks and fields of work. A engineer should instead 'find' an adequate solution by using his methodological knowledge combined with profound basics and a goal-orientated working method. Those are the general demands on the academic education of engineers in the 21st century! A 'Problem Solving Manager' is desperately needed in the technical industry today.

2 DEMANDS ON THE ACADEMIC EDUCATION AT UNIVERSITIES

The typical curriculum for engineering students at universities is primarily aimed at teaching profound and extensive theoretical knowledge. Methodological competence and the so-called soft skills like the potential for creativity and social competence are paid little attention. (Figure 1)

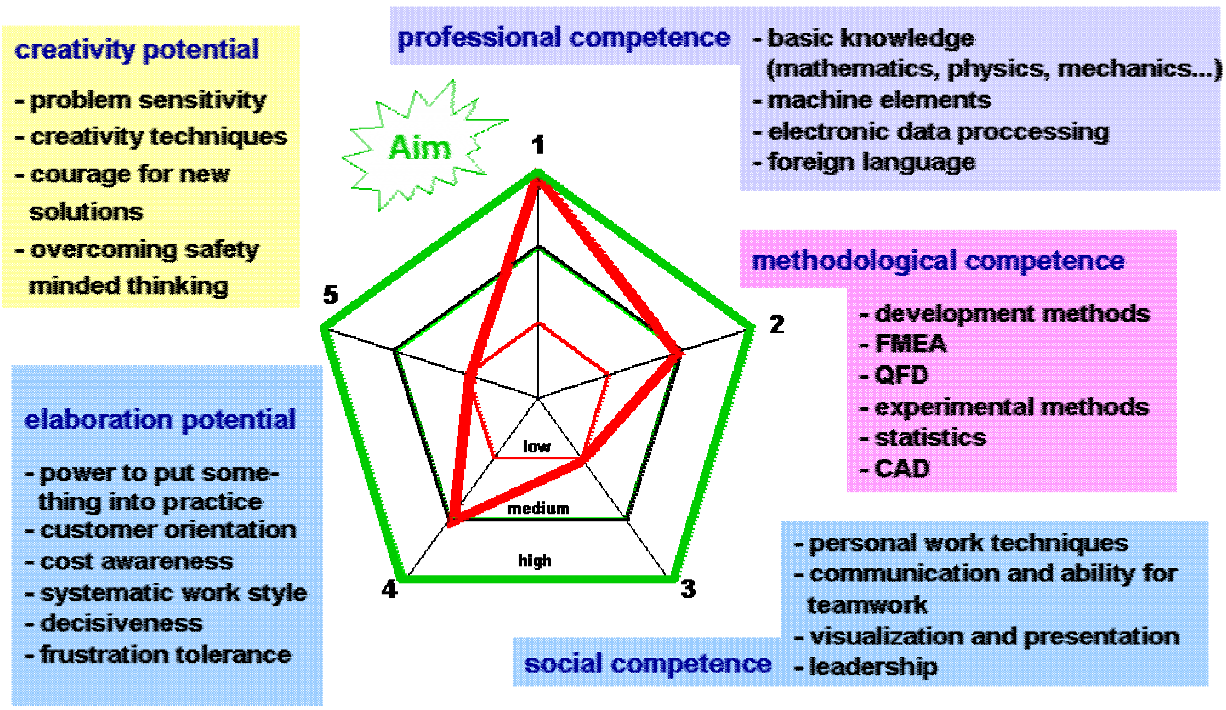

Figure 1: The changed profile of skills of an design engineer (10)

The goal of every academic education concept for engineering students has to be the special training of professional skills for a job in the industry, along with the training of fundamental theoretical knowledge and the ability to deal with problems academically. Academic education prepares professionals for leading positions in companies. Most of them will find positions in research and development as well as in strategic production management. (1) Some universities have already acknowledged 'that engineers of this millennium can't be educated by using the methods of the past one' (A.Albers). Existing education concepts must be revised and, together with new elements and ideas, adapted to the changing demands.

3 THE IMPLEMENTATION AT THE INSTITUTE FOR MECHANICAL DESIGN AND AUTOMOTIVE ENGINEERING

– The Karlsruhe Education Model for Product Development – KaLeP –

The Institute for Mechanical Design and Automotive Engineering contributes considerably to the training of students in general engineering and specially to those in product development, by using the newly developed 'Karlsruhe Education Model for Product Development – KaLeP' (Figure 2).

Figure 2: The Karlsruhe Education Model for Product Development

The general education concept **KaLeP** consists of a maximum of three different, successive lectures:

Mechanical Design I – III	a three-semester, compulsory subject in the basic training of the student
Basics in Product Development	a one-semester, compulsory subject in the main study of the student
Integrated Product Development	a lecture, which can be chosen as consolatory lecture in the main study by the students.

The individual subjects are self-contained, although based on each other and deal with a variety of elements of the product development, but with a different level of reinforcement.

The lecture '**Mechanical Design I – III**' (**MKL I – III**) teaches fundamental knowledge in the field of machine components. The review of these components only makes sense, if the students are simultaneously trained in the process-orientated and methodological knowledge of machine development. This would enable them to use the theoretical knowledge and to classify it as a part of the whole construction process. Therefore, even the lectures in the basic training are aimed to promote profound knowledge about construction and development processes, and their close relation to different structures within the company.

Right from the beginning the individual machine elements are seen from a construction-methodological point of view on a higher level of abstraction and in the whole system of the surrounding machine. The review of an individual machine's component stands on this level of abstraction as an example for similar machine elements. Since 1998 the Institute has been developing, and already using, a new method of abstraction for the description of machines and their correlation in function. It is referred to as the '**WSP&CSS–Method**' ('**Working**

Surface Pair and **Channel and Support Structure – Method**’ in (3). With the WFP&LST–Method the important skill of the future engineer to generalize is trained from the very beginning. (5)

The lecture **Mechanical Design** integrates theoretical and methodological knowledge of the basic lectures for the outline and dimensioning of machine components or whole machines, according to specific demands, into the complete ‘thinking and working’ of a professional engineer. With this we have the chance to make a decisive contribution to the promotion of theoretical and methodological competence. Importantly the chance exists to promote the development of creativity and the potential to elaborate by combining the lecture with independent development work of the students. (Figure 1).

To accomplish this, we have divided the course **Mechanical Design** into three different components:

- The Lecture
- The Exercise
- The Workshop

These components cover different educational goals. The lecture, always the major component of the education concept, provides the theoretical fundamentals for both the other components. Here, the processes of product development are discussed and demonstrated by using examples from the industrial development work (3).

Since the summer semester 1999 the lecture **Mechanical design** is supported by an accompanying workshop.

This helps to gain knowledge and skills that can’t be trained during the ‘traditional’ lecture; above all the very important soft skills mentioned at the beginning. Right from start, the students are consequently asked to work within a team.

In the workshop **MKL I** the students are confronted with a simple machione. The students have the opportunity to dismantle gear-engines and to analyse the different system components. The teams have to handle tasks in the fields of technical free-hand drawing, analysis of components in form and function, analysis of surface composition and measurement considering all forms of manufacturing techniques and first synthesis considerations.

The tasks, which are carried out by the exercise guiding assistant, are presented and prepared in a weekly organized seminar in the lecture theatre.

Figure 3: Student teams at the work in the workshop MKL I

In the workshop **MKL II** the teams will keep their line-ups, to in order to save time, as the winter semester is very condensed, in comparison to the contents. This workshop, which is actually divided into 5 smaller ones, is mostly designed to train the design and construction of machine components with an increasing level of complexity.

In the construction project **MKL III** – during the third semester of **Mechanical Design** - an industrial orientated development project has to be processed through teamwork. The students are divided into new teams of five members. The project work is so extensive, that it can only be solved by division of labour within the team. The margins to each part are determined by the teams themselves. Individual constructions have to be prepared, put together and are then rated by the assistant as a complete work. The course of this one-semester workshop resembles a normal project work found in the industry today. In the summer semester 2000 the project work contained the development of a fully automatic assembly machine for ball-bearings.

4 ADJUSTMENT OF THE DEVELOPMENT TASKS AND THE EDUCATIONAL DEMANDS

The problem with the concept of such an open task is the integration of the specific training contents in reference to the interpretation and dimensioning of the machine components, which will have to be taught in the lecture, but necessarily utilized and trained in the accompanying exercises. However, this very open task should not lead to a trivial task, it could easily be caused by the creative solutions and by that trivialize the work. Such ‘simple tasks’ – as it occasionally has been proposed or already been used – produce an incorrect picture of the engineers field work. At the same time, clear deficits are to be expected in the specialized basic competence of engineer educated in this way. To solve this didactic dilemma the Institute has developed the ‘**Di-Pole-Approach**’ to realize the adjustment of the contents of the workshops and also of the examination tasks. What is meant by a ‘Di-Pole-Task’? One pole of the task is the creative part of the work – **Creative-Pole** – which is characterized by the most possible open task. The second pole is the conceptually determined part of the task **– Concept-Pole**. Its aim is the integration of indispensable training, such as the structuring and interpretation of complex bearings or gear structures, in the workshops. Here the time needed for correcting the work should be as little as possible. This didactic attempt was used consistently and has proven itself to be workable and generally applicable.

In a large lecture exercise, the student is first confronted with the task in a more open, practical form. The type of bearings and to what amount they are assembled, with a limit on the amount of available room in the assembly shop are the only constrains. For a better clarification this room is set up in the **Product Development Center** (**PDC**) of the Institute, including the interfaces of the environment.

All additional exercises are covered by the conceptually determined part. Among other things these are calculations of interpretation and dimensioning, e.g. tooth-foot - and tooth-flank-load capacity-proof (DIN 3990*), screw-calculation (VDI 2230*), solidity-proof of shafts, interpretation of shaft-hub-connections, etc. Through the establishment of these additional tasks in the conceptually prescribed part, the solutions – presented by the student teams in the project meetings – become predictable and with that rectifiable in due course.

5 DIDACTIC ATTEMPT FOR THE PREPARATION OF THE STUDENTS FOR THEIR PROJECT WORK WITHIN A TEAM

In the first lecture, in which the task is presented, the students must be prepared for the unknown project work. Photos of the preparation are very useful. With that an example of the practical procedure in the project work can be shown to the students. The extent to which that teams will follow that sample mode of operation is left to them. This classical and very old form of lecture, which is based on imitating the teacher, has proven itself to be very productive and moreover very time-efficient.

The individual assembly-steps, which are necessary for the complete assembly of the bearings, have to be compiled by the students at the beginning of the project work. A video was presented in which the installation is simulated manually.

With the help of the distributed work papers the individual steps can be discussed and documented by the team. Each student team receives the bearing which has to be assembled. It can be used for the clarification of the assembly phases and for the simulation of the assembly movements. The "manually" conceivably working steps have to be imitated by the machine.

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* German Industrial Norm

* Norm by a Society of German Engineers

The student teams now have to independently compile the solution of the development task. Every step in the development – decisions, sketches, drawings and calculations – are documented by the team and filed. The teams attend 4 project meetings (each of them three-hours long and led by the exercise guiding assistant), in which they have to present their progress. At the same time they are able to discuss problems and ask additional questions (Coaching).

The examinations continuously control the progress. Performances are judged with a performance-assessment. Striking deficits are transmitted to the exercise guiding assistant, in order to cover them in the exercises and the lecture once more (Feedback-component). From a didactic point of view, the examination is absolutely necessary, it gives less-successful students the possibility to understand individual problems and to avoid the "unhitching" from the team and from the necessary and expected individual progress through early counter-measures. Additional office hours were arranged to support this.

In the second part of the project meeting, the assistants have to support the students at their work. With the demand for creative solutions in the **Workshop MKL III** care-taking can only be understood as coaching. The independence of the student – promoted in the preceding semesters – is increasingly demanded.

The student teams are able to use the **Product Development Center** (**PDC**) of the Institute ‘around the clock’ (Figure 5). The center is designed to resemble a typical development office.

Figure 4: Students, working on a development project

The available 3D-CAD-Stations (35 workstations) and the 3D-CAD-Training by the Institute for Mechanical Design and Automotive Engineering have to be reserved for selected students. The selection is made by using the performance-assessment from the preceding semester. This restriction is very motivating, as only talented and simultaneously dedicated students receive a training offer. With that we are able to justify the very large expense of an accompanying 3D-CAD-Training and additional care-taking. The CAD-Training is voluntarily and in addition to the work done in the workshop **MKL III**. It was not considered in the curriculum. Thus we, from our view, don’t have to make inadmissible restrictions in the depth and quality of the constructive contents and activities in the lecture **Mechanical design** in favour of the CAD-Training. With the participation in the CAD-Training however, the teams commit themselves to provide their constructive project work with CAD.

It is planned to expand the workstations with an adequate provision of funds on part of the university or by industrial donations to 150 places. An accomplished survey shows, that 98% of the students wish for a CAD-Training as part of the construction project, despite the about 2-3times higher amount of work due to the necessary training in the CAD-System and the processing of the semester work with CAD.

7 RESULTS OF THE ACADEMIC DEVELOPMENT

Some examples of the workshop results shall give an impression of the – from our point of view predominantly surprising and motivating – performances of the students. (Figure 6 - Figure 9)

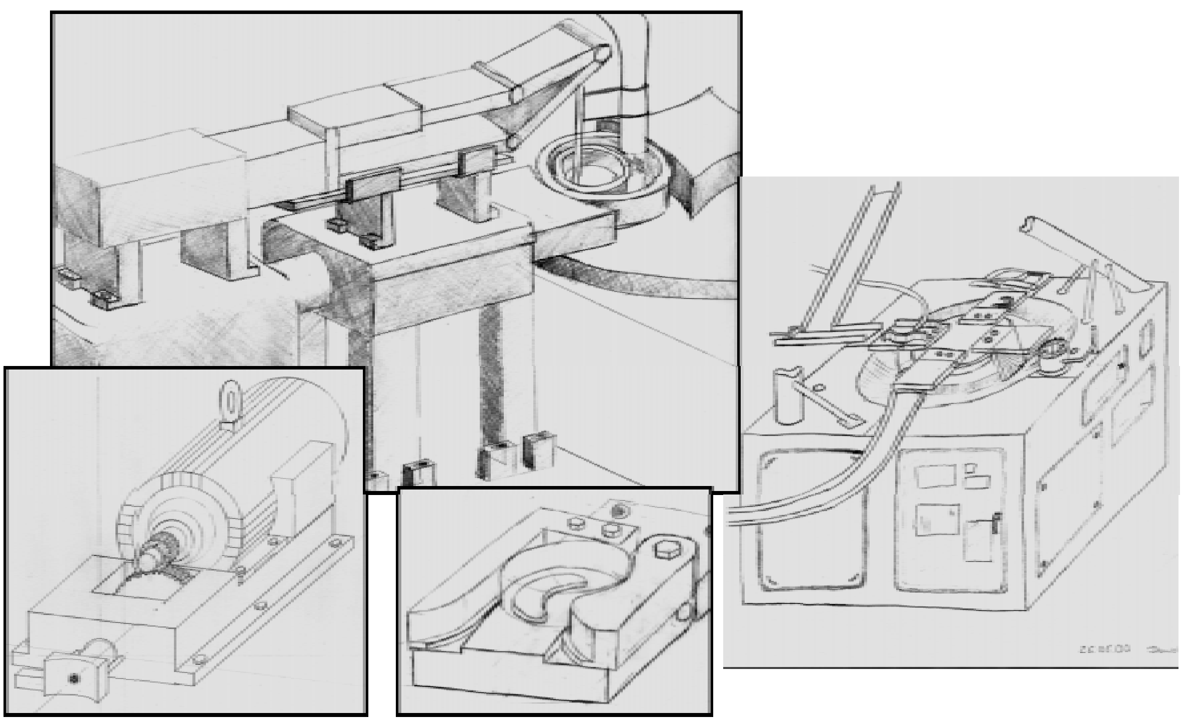

Figure 5: Results of the students’ work: concept

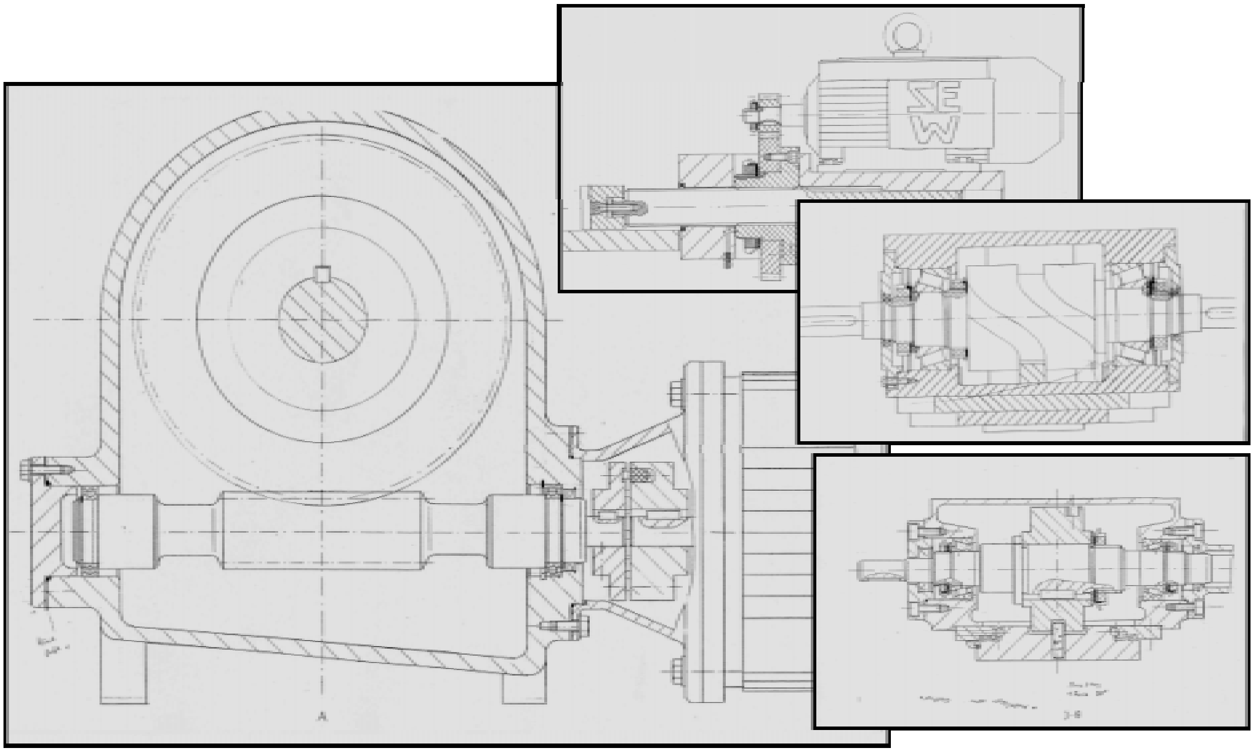

Figure 6: Results of the students' work: planning

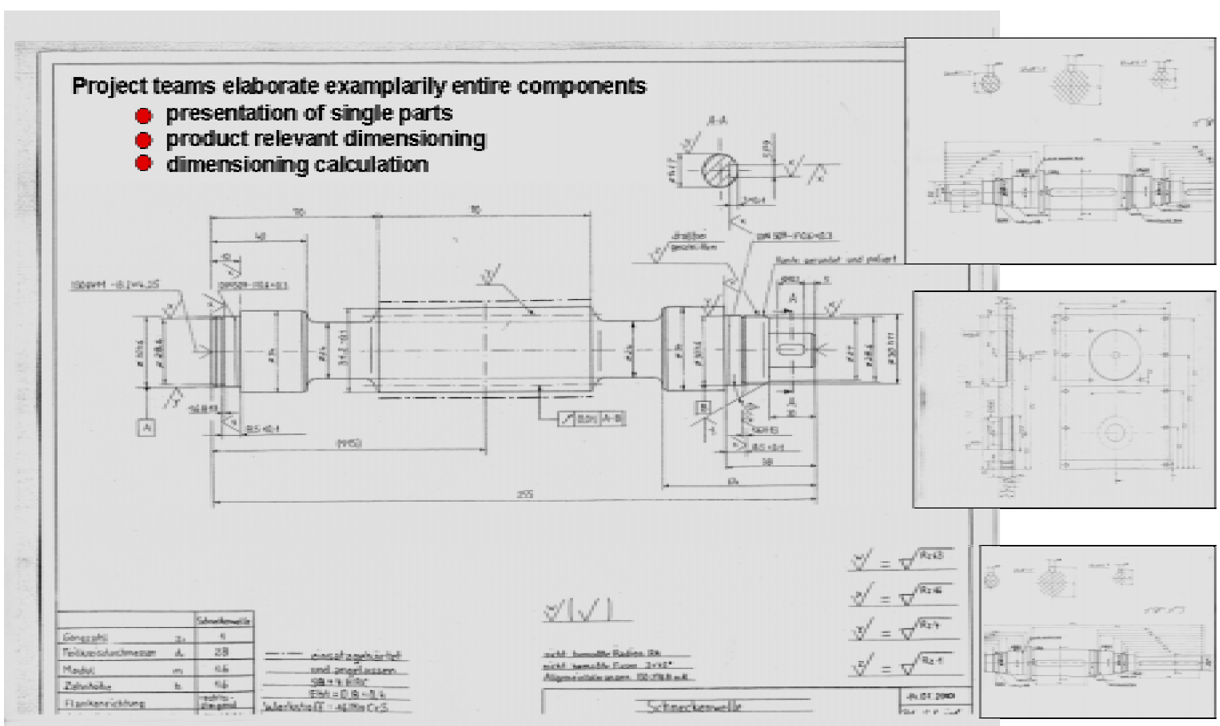

Figure 7: Results of the students' work: elaboration

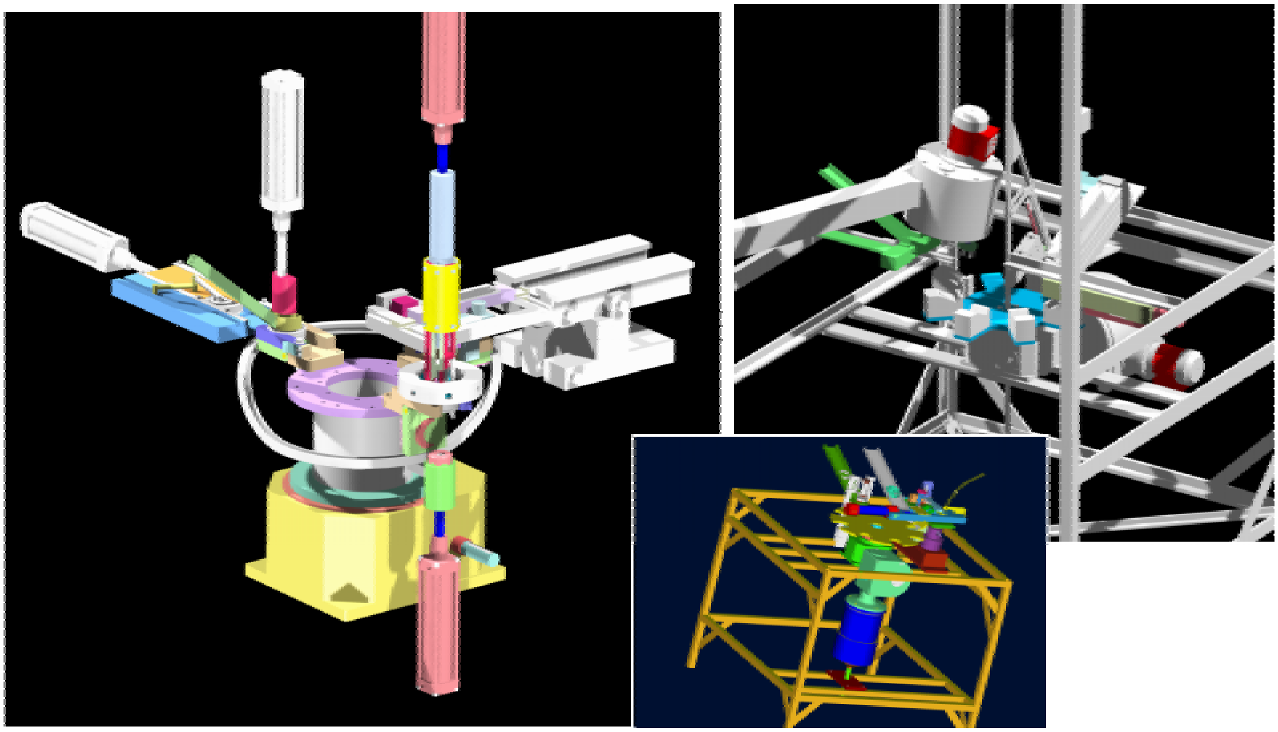

Figure 8: Results the students' work: CAD work

8 SUMMARY AND OUTLOOK

The experiences of in three semesters of the conceptually new Mechanical Design – KaLeP-Model – are characterised by a exceptional willingness to perform and motivation of the students. The reported missing motivation of today's students was not present. Also additional work – e.g. the making of product models with the CAD-System – was taken care of in a motivated manner.

The demands laid on the project assistants have clearly increased with the new education concept. As more is demanded of the students, the higher are the demands on the 'assistants'.

The expense for the implementation of the **KaLeP-Model** in the basic courses is explicitly higher than that of classical education concepts. But this expense is very profitable, when the results are so convincing, but this implementation is with a possibly increasing number of students – that we of course naturally wish for – and the current equipment not enough.

The constructive written final examination, for the first time using the **Di-Pole-Approach** – containing, similar to the project work in **MKL III**, a creative and a conceptually determined part – will give information about the training of skills and abilities of the students.

The very positive results of an evaluation of the lecture **Mechanical Design** by the students motivates us, despite some problems, to develop the new education concept and to employ it consistently in the training of our students.

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