

IMPROVING THE MECHANICAL DESIGN EDUCATION BY HANDS-ON EXPERIENCE WITH MACHINE PARTS

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ABSTRACT

Mechanical engineering design education usually provides theoretical knowledge about machine parts and the required skills to develop products using methodical design approaches. Beside this, practical experience is of high importance to successfully design products. Unfortunately, the education not seldom lacks adequate courses to gain practical experience. In addition, students often had no contact with machine parts prior to their studies. The concept described in this contribution closes this gap using hands-on experience with engineering artifacts. An interactive machine part exhibition will be used to create an association with machine parts, to enhance drawing and design skills, to improve the comprehension of the function and working principals of sophisticated machinery and to motivate the students for their studies. The description of this approach addresses universities that would like to add a strong practical element to their design education.

Keywords: Machine parts, engineering artifacts, interactive exhibition, hands-on education, practical experience

1 INTRODUCTION

The automotive as well as the machine building industry are of high importance for the economy of industrial nations like Germany. The success of companies in this innovation-driven industrial sector relies on the skills and qualifications of their employees, as the VDMA (German Engineering Federation) points out [1]. To ensure a sustainable economic growth, the demand for highly qualified engineers has to be matched. Unfortunately, the VDMA observed that universities were not able to qualify enough students in time. In Germany's machine building industry 8,000 to 9,000 positions could not be staffed [1]. Although the number of students, who start mechanical engineering programs has increased, the number of graduated engineers remains low. In order to enlarge the output of graduates, universities have to find ways to improve their educational concept to reduce the dropout rates.

The reasons for high dropout rates were studied by the Impuls-foundation [2] and Derboven and Winker [3]. The Impuls-foundation interviewed students of mechanical engineering programs, who had abandoned their studies, about dropout reasons. They found that insufficient performance capabilities of the students, failing of examinations, financial problems and lack of motivation are the most mentioned reasons. Derboven and Winker have taken a similar approach, but did not only focus on the mechanical but on different engineering programs. They found that the pressure to perform, the domination of theoretical aspects and lack of professional relevance, insufficient support by the lecturers and the absence of success are the most critical factors. Both works observe that not a single reason causes students to abandon their studies, but a combination of different motives. Moreover, it is not only the insufficient abilities and qualifications of the students as well as external factors which causes dropouts, but also the educational situation at the universities itself. This can be seen as a chance to provide more and better-qualified engineers by improving their education.

Design education is an important part of mechanical engineering studies and a possible field of activity to improve the studies. This leads to the question of, how the design education can be improved and if this improvement enhances the whole mechanical engineering study. To answer this question this contribution will investigate design education at Hamburg University of Technology

(TUHH) that sets the constraints for improvements. Afterwards possible work areas will be identified. To find solutions in the selected work area literature research is performed and the found concepts are used to create an approach suited to TUHH. This approach will be discussed in detail.

2 DESIGN EDUCATION AT TUHH

The replacement of the former “Diploma”-programs by bachelor and master programs (Bologna process) offers the possibility to review the existing lectures. Lately, additional funds have been made available at TUHH from tuition, which are designated for educational improvement.

The design education, visualised in Figure 1, starts with the theoretical fundamentals of design and machine parts in the lectures “Mechanical Engineering Design I – IV” with classrooms sizes between 150 to 500 students. In auditorium exercises, the students are taught the dimensioning calculation of machine parts. Using this theoretical background, the mechanical design students participate in the practical courses “Design Project I – IV”. The students build up practical design abilities by designing a spindle driven apparatus as well as a complex gearbox. They also gain the skills for methodical design during a teamwork activity. In these practical courses, it became obvious that some students are not able to connect the design elements which they draw with the real physical objects.

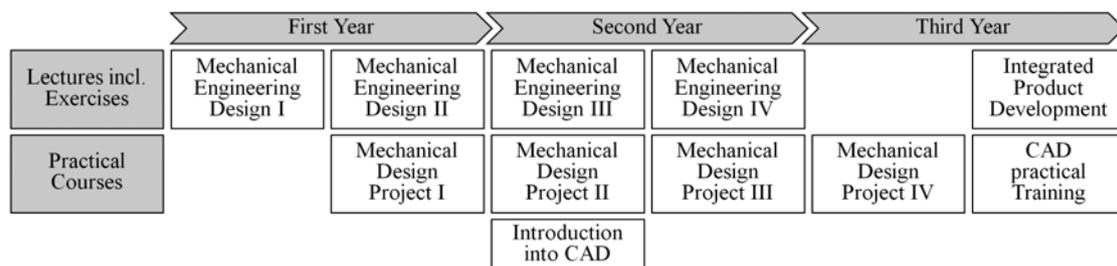


Figure 1. Design Education at TUHH [4]

In order to improve design education at TUHH, measures should be used that can be integrated into the current educational concept. The staff- and cost-efficiency of the measures is of importance.

3 POSSIBLE WORK AREAS TO IMPROVE THE DESIGN EDUCATION

The studies of the Impuls-foundation [2] and of Derboven and Winker [3] describe different shortcomings in the engineering studies. Their results, as well as observations made in educational practice at TUHH, lead to possible work areas to improve design education. Some examples will be given.

Over 40 percent of the students who abandoned their studies had shortcomings in time-management and in scientific work techniques when they started their studies [2]. In addition, more students drop out in the beginning of their studies since the change from the Diploma to Bachelor and Master systems [2]. Therefore measures that assist students in the first year might be beneficial. In the study of Derboven and Winker [3] the students criticised that isolated facts are presented without the bigger view and the connection between these facts. Educational concepts that connect different disciplines could be a measure to improve this. Beside these examples, another possible work area was observed that will be described in the following. This work area will be investigated by this contribution in detail.

A lack of motivation to study is a major issue according to [2] and [3] that drives students out of their studies. On the other hand, students often miss the industrial and practical relevance of the studies. In addition it was observed in the described practical design exercises that some students have a lack of comprehension of the function of machine parts and are not able to read or understand technical drawings. This may be a result of the matter that students have not had any contact with these elements prior to the university. The skill of connecting representations of machine parts with the physical objects is vital to understand the working principle of the parts and qualifies students to use machine parts in their designs.

Therefore, an educational concept that improves the students’ comprehension of machine parts, enhances the industrial and practical relevance of the design education, and motivates the students for the mechanical engineering study should be found (Figure 2). Because of this, a literature research will be performed in the next chapter, to locate and adapt pre-existing concepts.

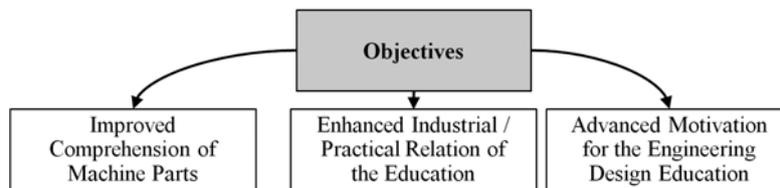


Figure 2. Objectives of the Interactive Exhibition

4 RELATED WORK

4.1 3D-Models in design education

Field, Burvill and Weir [5] studied the influence of the visualisation abilities of design students on their ability to read and analyse technical drawings. Therefore, they used tests, like the mental cutting test, to quantify the visualisation skills of second year students. They compared the results with the outcome of a second test that checks the students' ability to read and understand technical drawings. The authors observed that students with strong visualisation skills performed better in the examinations as well as in the drawing test and were better in identifying kinematic failures in drawings.

Field, Burvill and Alirezaee [6] continued the research and used three dimensional wooden models to train casting mould designers. The half of a group of participants of this study was trained with conventional 2D materials, the other half was educated with wooden models. Prior to this, the visualisation skills of the attendees were monitored. Afterwards a comprehension test about mould design was performed. It was observed that students with high visualisation skills reached comparable results no matter if they trained with 2D or 3D materials. However, students with weaker visualisation skills performed significantly better after being trained with 3D models.

The authors' findings show that three-dimensional models are a possibility to educate students with low visual skills more effectively, so that they gain a deeper understanding of complex 3D-machinery. On the other hand, better students have no disadvantage from the 3D teaching. It seems reasonable to use such models, but there could be an additional benefit if one would use real objects, that are not made of wood but from their normal material e.g. steel. In that case students would be able to experience material specific characteristics of the models like the weight or the surface structure.

4.2 Artifacts as engineering design education tool

Lilly, Fentiman and Merrill [7] use single-use cameras as education tools to improve their students understanding of design. The goal of the educational concept is to train students to look at products through "engineers' eyes" and to understand why the product was built and designed that way. Thus, students get the opportunity to learn from experienced engineers by inspecting their products. The cameras are used in beginner as well as in upper-division courses. Multiple tasks and exercises are performed, for example, disassembling the product and analyzing the overall function; reviewing the design of components to understand its restrictions and constraints that had caused this specific shape, and to learn the basics of functional decomposition and product platform planning. The courses offer the opportunity of an early contact with engineering design and artifacts. This can be seen as a countertype to the usual lectures like math that are mostly theoretical. The authors point out that a single-use camera is a good artifact to be observed, because it is complex enough to catch the students' interest but is still easy enough to be handled in a design course. On the other hand single-use cameras are no classical mechanical engineering part and there might be a benefit by using mechanical parts like gearboxes that have a higher relevance for German industry. Nevertheless, it was reported that the students cited this specific course as one of the most effective and interesting ones.

4.3 Improving drawing abilities with artifacts

Robb, Childs and Flora [8] address the issue of decreasing hand-sketching skills of the students. As they identified this capability as important for engineers to present concepts and ideas, they implemented it in an educational concept. This concept contains different measures, for example sketching and design training, but also museum and site visits. The concept uses hands-on involvement and observation of existing products to develop design skills. In the course the students observe engineering artifacts and create drawings to describe the function of the part. In this way the

students improve their design abilities as well as their hand sketching skills and learn how specific machine parts are used and how the artifacts work.

The different approaches show how engineering artifacts can be used to improve the design education. Each work focuses on a specific aspect:

- Field, Burvill and Weir: 3D-models as teaching tool to increase the students comprehension for complex spatial machinery
- Lilly et al: Artifacts, especially single-use cameras, to learn design from highly engineered products and understand their function
- Robb, Childs and Flora: Artifacts to improve hand sketching and design skills by observation of real products.

The combination of these aspects may add additional benefits to design education. Moreover, the concept for improvement should fit the defined constraints like big classroom sizes, as discussed before. Furthermore, engineering artifacts that are typical for mechanical engineering industry might be better examples to motivate the students, because they will work with and develop these parts in their future career. Moreover, artifacts that are presented in the lectures can be used to create a direct connection between theory and practice. In consequence, it seems more reasonable to create a new approach based on these related works that suits the specific needs of the design education described in chapter two. This new approach combines the existing concepts and provides additional ideas, which will be presented in the next chapter.

5 THE CONCEPT OF THE INTERACTIVE MACHINE PART EXHIBITION

The cornerstone of the exhibition is the idea that the students should have the opportunity to handle, touch and interact with all exposed objects to create a better comprehension of machine parts, complex mechanical system and the process of designing. The exhibition facilitates the “open door” principle, in order to provide access for the students whenever it is needed. The interactive machine part exhibition integrates different educational concepts, as visualised in Figure 3.

The concept will be tested in everyday teaching in order to evaluate the success of specific elements of the concept, the overall improvement of the design education and its effect on the quality of the mechanical engineering study.

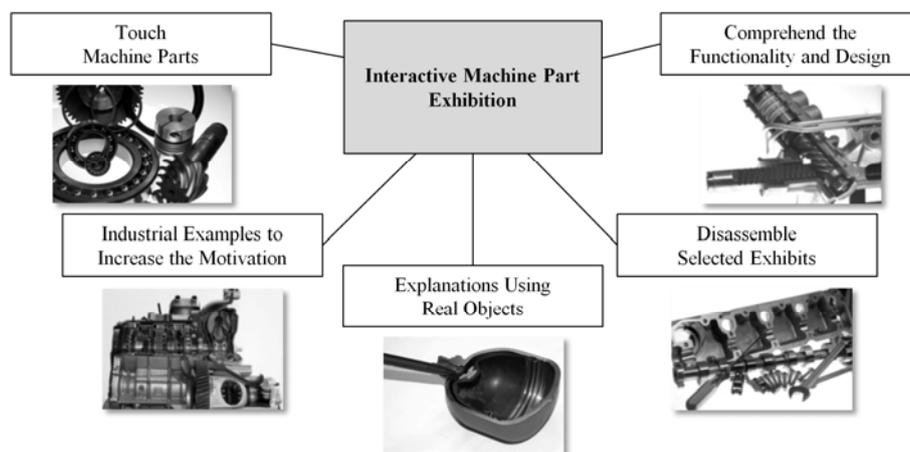


Figure 3. Concept of the Interactive Exhibition

The first pillar of the exhibition is the concept of “Touch Machine Parts”. The machine part exhibit will contain a selection of fundamental machine parts, such as bearings, fasteners and shafts that covers the objects that are presented in the lectures. This offers the opportunity to create a deeper understanding by hands-on experience. Real artifacts are not only adding the third dimension to the usual technical drawings like 3D CAD models would do, but also add the possibility to experience the part tangibly. The students can experience the feeling of different materials such as metals, ceramics, plastics or composites, especially its surface and weight, which cannot be offered by wooden representations of the objects. This interaction with these fundamental parts can increase the motivation as well as the comprehension of these parts. In addition students, which often have not

touched or sometimes even seen these basic components of mechanical engineering, get in touch with them.

Furthermore, this collection offers the possibility to enhance the students' skills in creating technical drawings and modelling in 3D CAD, because it creates a spatial picture of the real part in the students' mind, which will help them to abstract from the real object to a virtual reduced 3D model and to standards conforming drawings. In summary, the collection could create a deeper comprehension of the machine parts. It can be seen as a link between the real object and the virtual drawings and 3D CAD models that students have to handle in the lectures. This link is visualised in Figure 4 using a roller ball bearing. Therefore the design education could contain the theoretical knowledge acquirement in the lectures and complementary experience with real objects using the exhibition.

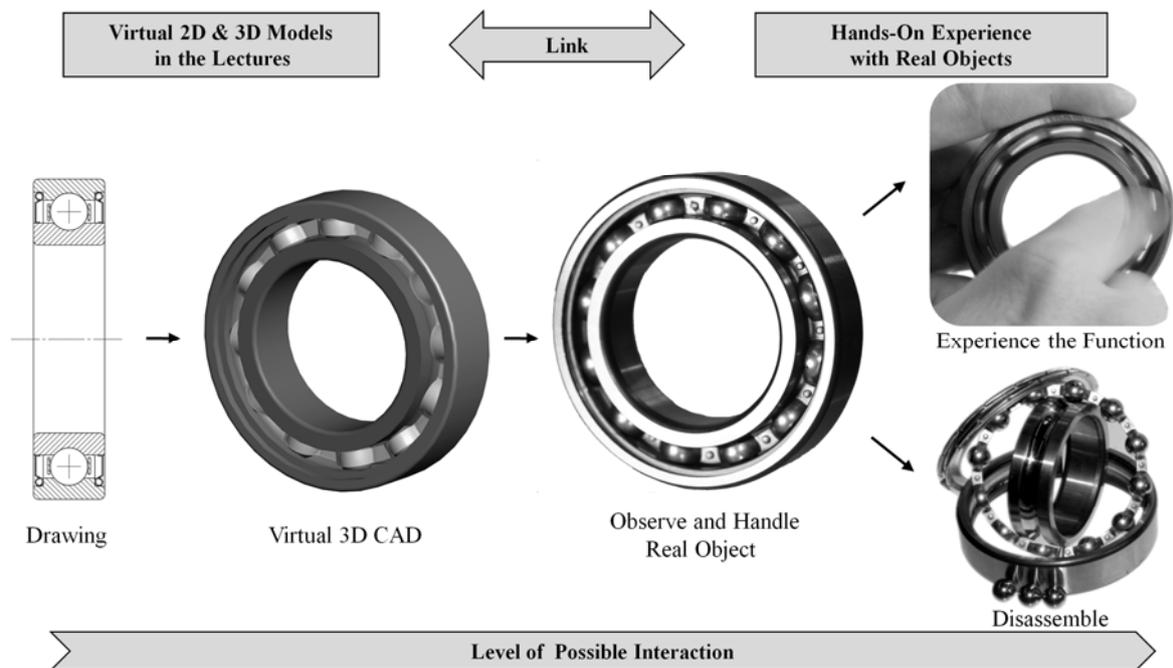


Figure 4. Abstraction from Real Object to a Technical Drawing

The second pillar is the aspect “Comprehend the Functionality and Design” (Figure 4). It utilises the fact that three dimensional models are a good tool to teach the functionality of complex machinery, as discussed above according to Field, Burvill and Weir. Cross-sectional models offer the possibility to look into the main functional core of sophisticated systems in order to understand the working principles. Operable models could make the kinematics and flow of torsion and force obvious. In addition, special demonstrators will be build that represent typical uses of machine parts or clarify their function. Some examples are different bearing setups or a centrifugal clutch, which can be turned by a crank handle in order to connect two shafts. Examples of parts manufactured by specific operations, such as turning, or parts designed for high loads and special constraints are provided. By observation of these parts students get a feeling how parts have to be designed in order to be built by a specific production operation or withstand defined loads or constraints [7].

“Disassemble selected exhibits” is another pillar of the exhibition and a possible practical way for students to understand the function of machinery. By dis- and reassembling systems students gain practical experience about how to design products suitable for assembly (design for assembly).

Summing up, the first three pillars shall build a pool of practical knowledge, which the students can rely on, when setting up their future design projects. The standard machine part collection offers the set of standard parts that the students can use in their design. The design models show how parts should be designed under different restrictions and the functional models show possible setups of systems. Besides the creation of partial knowledge, the exhibition can be used to answer students questions about machine parts using the real artifacts (pillar of the exhibition / Figure 3). For that reason, question sessions will be held in the exhibition room to enhance the students' preparation for the examination by giving more sophisticated and easy to understand explanations.

Finally, the exhibition will also contain “Industrial Examples to Increase the Motivation” to combat the lack of practical motivating content in the studies of mechanical engineering. Exhibits like the gearbox of a car could be used to motivate the students in the early phase of the studies, because they get in touch with real life, highly engineered products that are produced by the local industry. These objects shall answer the question of why challenging lectures like mechanics and the design lectures are necessary for future engineers. They visualise the reward of the challenging engineering studies – the opportunity to work in the fascinating area of mechanical engineering design.

In open door hours, the students get the chance to use the exhibits on their own. In this case, the exhibition can be seen as a library of physical teaching objects to answer students’ questions. Additionally, the exhibition will be integrated into the Mechanical Design Project I. Older Students will guide all first year students through the exhibition. They will present a variety of different fundamental machine parts and explain the working principle of selected models. After this the students create technical drawings of these models. In this way the students will have physical contact to basic machine parts prior to the lectures. This offers the opportunity to create an educational framework where mechanical design is taught by complementary practical hands-on experience, design projects and lectures.

6 CONCLUSION

The mechanical design education is of high relevance in the studies of mechanical engineering. Besides the acquisition of theoretical knowledge in lectures, practical experience with machine parts is needed. Hands-on experience with engineering artifacts, which will be provided by the interactive machine part exhibition, could be a possible concept to create this required experience. Furthermore, it could increase the comprehension of machine parts, engineering systems and the design process itself. Practical work with sophisticated products might be a possibility to enlarge the students’ motivation of their mechanical engineering studies. However assumptions have been made in the description of the educational concept that have to be validated in future research work. The concept is still in the implementation phase and an evaluation is required to estimate the success of the concept and its impact on the mechanical engineering program. Nevertheless, the educational staff as well as students, who decided to finance this improvement with tuition fees, are looking forward to the possible advance in design education, which has yet to be proven.

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