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EXPERIENCES WITH 'DIRECT PRODUCT FEEDBACK' IN COURSES ON ENGINEERING DESIGN

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ABSTRACT
The article reflects student learning experiences with open-ended problems in an Engineering Design project by presenting a questionnaire-based survey that was conducted in a course held during the spring of 2016. In this project, Mechanical Engineering students from two different campuses (Mannheim and Friedrichshafen) were teamed up in distributed teams of four to five members.
Each team received a mini-drone (quadcopter) and was asked to design a device that is able to carry a matchbox containing a number of five cent coins. Touching a defined landing zone, the mechanism should drop the matchbox without further external impact on the system. During the last stage of the project, i.e. the testing of the devices, the students had to shoot several uncut digital videos. Together with 'traditional' feedback given by the educators the project deliverables were graded by an indicator that was derived from these videos.
Contrary to standard exercise series that usually accompany lectures in Engineering Design, the project does not just ask students to execute ‘pure paperwork’ but to design, build and test real products within extremely tight time constraints (eight weeks). A specific educational concern of the design project was to integrate so-called ‘direct product feedback’ into the practice of assigning grades of these 'design-build-test-experiences'. In other words, the students should be able to learn directly from the operating behaviour of their products and not just indirectly from the teachers’ grading.

Keywords: Project-oriented and problem-based learning, grading, learning feedback, evaluation, Flipped Classroom.

1 INTRODUCTION

In higher education, students traditionally acquire factual and methodical knowledge in lessons and try to apply this know-how to posed problems in exercises. In the case of Mechanical Engineering programmes, the teaching of design methods is mostly split up between a basic course and an advanced course. The basic course mainly focuses on teaching factual knowledge (e.g. on Machine Elements) while the advanced course addresses methodical knowledge (e.g. Product Development methods). A commonly advocated justification for this two-step approach rests on the hypothesis that students can hardly design properly without knowledge, and therefore, a solid foundation of knowledge must be built before they work in design projects.
More recent research breaks with this traditional line of argumentation. As detailed in a guideline of seventeen cases for successful teaching of design methods at university, the German *Scientific Society of Product Design* [1] recommends the combination of both, factual knowledge of machine elements and basic knowledge of design methods in an early stage (i.e. already during the first year) of Bachelor’s studies [2].
The new paradigm goes well with the specific study concept at *DHBW Baden-Wuerttemberg Cooperative State University,* where the curriculum combines academic education and on-the-job training in industry. It empowers students to easily complement their academic skills with practical experience [3]. Over the complete study period of three years the students alternate between university and the working place at their company in three-month cycles.

2 COURSE DESCRIPTION

2.1 Engineering Design Education with 'Design-Build-Test Experiences'

Enabling students to explore the design process on their own plays an important role in teaching Engineering Design [4] [5]. Consequently, the main concern of the first-year course presented here is to let the students take over full control to manage the design process by confronting them with an open-ended problem. Engineering Design projects are thus considered to be ‘an engineering adaptation of problem-based learning approaches’ [6]. The main difference compared to other Engineering Design course assignments is, that students do not execute pure paperwork and just document their calculations and reflections. They additionally gain the opportunity to build and test the appliances they have planned (and make so called 'design-build-test experiences' [7] also [8] [9]).

2.2 Design Task

In the project of the academic year 2015/2016, the students worked on the following design problem. Students from two different campuses (Mannheim and Friedrichshafen) were teamed up in distributed teams of four to five members. Each team received a mini-drone (quadcopter) and was asked to design a device that is able to carry a matchbox containing a number of five cent coins. Touching a defined landing zone, the mechanism should drop the matchbox without further external impact on the system. Figure 1 shows such a student-made device mounted on the mini-drone.

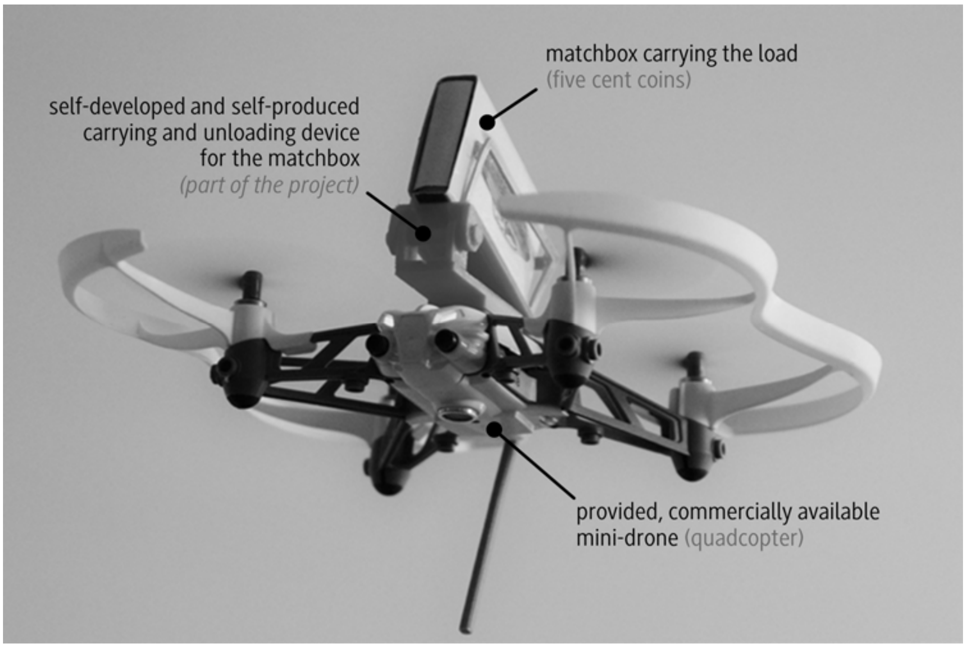

Figure 1. Assembled student-made device

A critical point in the project was the manufacturing of the parts. Therefore, the students were instructed to build their devices entirely with help of 3D printers (using Fused Deposition Modelling technology). In addition to the design-build-test experience this adds another important aspect to the course. Additive manufacturing has become increasingly necessary in product development over the past years, enabling direct prototyping and manufacturing of parts [10].
Another common problem of project-oriented courses is that they are highly demanding in terms of communication between students and teachers (the entire project should fit into a semester with a fixed deadline). As a measure to optimise that, a series of electronic lectures was prepared that delivered the basic content of the first-year course. This allowed to flip the classroom and to use the in-class lectures more efficiently for the design project [11].

2.3 Direct Product Feedback

Building products physically in student projects (instead of just planning them) opens new paths to integrate ‘direct product feedback’ into the practice of assigning grades. The fundamental difference is in the way how students receive feedback when testing their products. This allows them to observe the (real) behaviour of their product (and not just a simulation of it) on their own, see Figure 2. Briefly expressed, students learn from their product, not from their teacher. Therefore, we speak of direct product feedback. Experience shows that this direct feedback creates strong motivational effects and allows students to develop a deeper understanding (perhaps not only of the problem studied but also) of complex interactions in the design process. There is also an effect on the educator. Since this feedback loop is not centred on the educator, the educator can fully concentrate on his role as 'learning facilitator'.

The assessment of desired product features and the product performance (e.g. the number of coins that the drone can carry) delivers easily measurable criteria. But the challenge for educators is to find meaningful parameters which align the specific learning outcomes with a selection of criteria that cover the spectrum of expected competencies, knowledge, skills and abilities as broadly as possible [11].

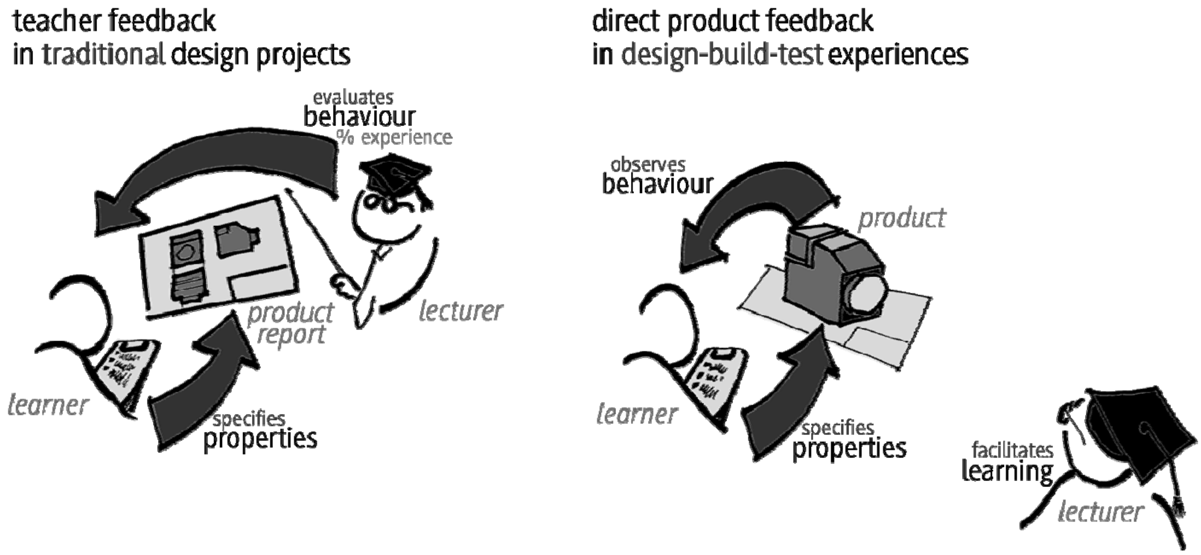

Figure 2. Feedback in the learning process

For testing their devices, the students had to shoot several uncut digital videos (one for each defined criteria) which they had to upload on the Virtual Learning Environment *Moodle.* Together with 'traditional' feedback given by the educators (e.g. quality of the technical drawings of the device) the project deliverables were graded by an indicator that was derived from these videos (e.g. by the number of coins the drone can carry, or by the precision of landing manoeuvres in a defined landing zone).

3 RESEARCH METHOD

The study group consisted of 83 first year BEng students in a Mechanical Engineering programme divided into three classes. Six months after finishing the course, the students' feedback was collected through an online-questionnaire. The sampling instant was judged sufficiently distant from the course grading which may have influenced the responses. The survey produced a return of 37 questionnaires (which corresponds to a response rate of 45%). The online-survey was designed to be fully anonymised and voluntary.

Three main aspects were investigated in the survey. The first aspect was the overall perception of the course, especially the content on 3D printing and the use of the e-learning platform (Virtual Learning Environment) *Moodle.* The second aspect was the evaluation of the 'design-build-test-experience'. The students were asked to assess their degree of agreement to six statements to gain deeper insights on how the students evaluate the design project. The third aspect was the evaluation of the grading system. Three statements were given to find out how the students think about 'direct product feedback' compared to 'traditional' feedback given by a teacher.

4 RESULTS

4.1 Overall evaluation of the course

A significant majority of 83% of the course responded positively (outstanding, very good, good) on the question *'How do you evaluate the course overall?'* Figure 3. Slightly more (89%) responded positively on the question *'How do you evaluate the introduction to 3D-printing?'* This outcome is particularly important since the course was held during the first year of studies, where the students did not have any lessons in Computer Aided Design (CAD) or 3D printing yet. But the positive response shows that the students were willing to obtain these skills on their own or had already first (self-learning) skills in the subject.

The questions on the use of the e-learning platform *Moodle* and on the electronic lectures provided less clear results. While the acceptance is still high (68% respectively 65% positive responds), some students (3% respectively 8%) responded negatively. This may reflect that some students are used (or nearly 'conditioned') to learn the skills that are necessary to pass examinations by attending lectures. Consequently, using an e-learning platform with additional course content leads (from a student's point of view) to extra work. The additional workload is finally acceptable for the students, but they have high expectations concerning the e-learning content. This experience shows that an e-learning platform (like Moodle) must support and enhance the lecture in a reasonable way.

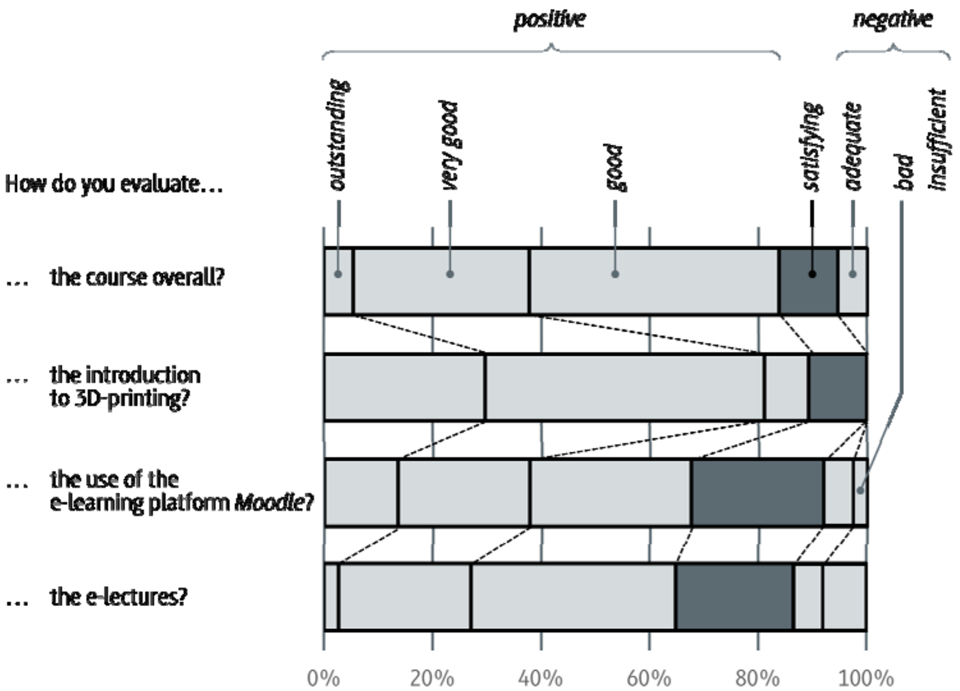

Figure 3. Evaluation of the course

4.2 Evaluation of the Design Project

An important aspect of the design project is the 'design-build-test approach'. The educational aim is that students should be able to undergo the 'ups and downs' of a real design project and learn from their own mistakes. The evaluation shows, that this goal could be attained, Figure 4. The major result is that a majority of 95% of the students agree (completely, mainly or moderately) with the statement that they learned how to work on a design task in a structured way. The students also agree (90% or above) with the statements that the assignment was close to practice, that they learned how real-life projects work and that they learned from their own mistakes. The statements on collaboration provide less clear results with a tendency for polarisation. While most of the students (89%) agree with the statement that they collaborated intensively with their fellow students, 27% agreed only poorly or not at all with the statement that they learned how to work in a distributed team.

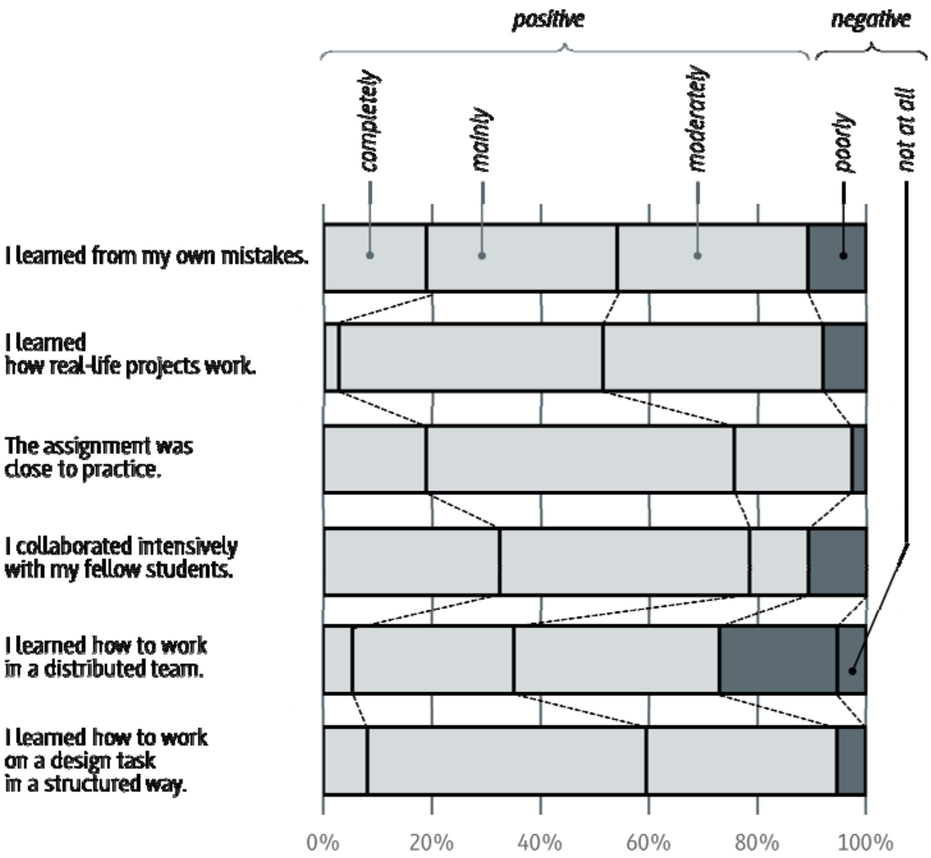

Figure 4. Evaluation of the design project

4.3 Evaluation of the grading system

A majority of 86% of the responding participants accepted the statement that the grading reflects their performance (completely, mainly or moderately), Figure 5. Comparing the perception of 'direct product feedback' and 'traditional' feedback given by an educator, the results show that both ways of feedback are accepted. Nevertheless, the acceptance of the 'direct-product-feedback' was slightly higher. On the negative end of the scale only 14% of the students accepted the statement that the direct product feedback grading was comprehensible poorly or not at all while 19% responded negatively on the statement that the traditional grading was comprehensible.

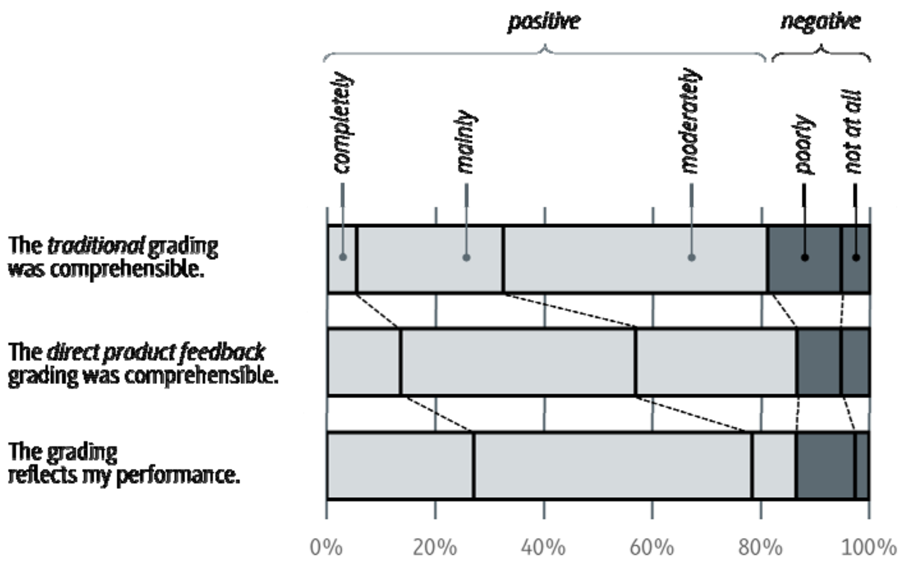

Figure 5. Evaluation of the grading system

5 CONCLUSION

The evaluation gives valuable insights in learning outcomes that students perceive in an Engineering Design project. The answers of students that worked with the 'design-build-test approach' significantly differ from their peers in traditional classes, [4]. It could be shown that the direct product feedback made assessments more transparent and comprehensible. Students also stated to have gained more insights in 'real-life' design projects and gained higher skills in structured approaches during their design-build-test project.

6 OUTLOOK

In order to broaden the digital design skills of Mechanical Engineering students and to amplify research on collaboration and performance of distributed teams, a so-called 'collaborate 3D laboratory' (Pilot CoLab) shall be established at DHBW Baden-Wuerttemberg Cooperative State University. The laboratory will be equipped with a user-interactive virtual reality environment for the visualisation of digital products, 3D printers for prototyping and manufacturing and a 3D scanning system for the digitalisation of objects (Reverse Engineering). The aim is to cover the entire process chain from Engineering Design and Development right to the manufacturing of the product. The laboratory shall facilitate collaboration between distributed, interdisciplinary teams, especially in the early stages of product development and shall demonstrate the student's important levers to reduce iterations and shorten time to manufacturing [12].

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