TEACHING VIRTUAL PRODUCT DESIGN AT UNIVERSITY LEVEL – A REVIEW OF 3 YEARS OF FRESHMAN STUDENT EDUCATION

Chantal WEIGEL, Georg JACOBS, Claudia DITTMANN, Tim KATZWINKEL, Christian KONRAD, Fatmir SULEJMANI and Daniel VAN ISSUM
Institute for Machine Elements and Systems Engineering (MSE), RWTH Aachen University, Aachen, Germany

ABSTRACT

This paper reviews the teaching of virtual product development during the past semesters for students of mechanical engineering at RWTH Aachen University. It outlines the specific structure of the course and the exam, and discusses possible impact factors on marks that students achieve. Furthermore, it illustrates challenges in teaching. The so-called digital natives have grown up with computers and digital media. Nevertheless, in education at university level still difficulties using CAD software can be identified.

Keywords: PLM, Computer Aided Design, Virtual product development

1   INTRODUCTION

Today's communication in the field of mechanical engineering requires digital models and drawings. The early phases of today's product development processes are carried out mostly with virtual design tools. Therefore, at RWTH Aachen University these skills are taught to freshman students in the bachelor programme of mechanical engineering studies. During the course "CAD-Introduction", theoretical basics for a qualitatively well-designed CAD-model (e. g. design according to machining processes) are instructed and practically applied within a specific CAD programme. A step-by-step wiki-based online instruction guides the students through the different course tasks and currently builds the basic frame of the teaching concept. Learning by doing is the credo. The course is carried out to 1600 students in block units of 300 students each. Every student has to work at a single workstation and can address upcoming questions to student assistants of higher semesters. The course is organised in 6 different rooms simultaneously and supported by a live instruction of one research assistant, who is video-streaming, his presentations into all classrooms.

2   STATE-OF-THE-ART

Since the development of CAD applications in the 1960's and the industrial usage of those systems for engineering design, CAD technologies and CAD design methodologies are basic part of the education of students at colleges and universities [1]. The international market of today's CAD/CAM-Systems shows various vendors and had a worth of over 7 billion US-Dollars in 2016 [2]. Within the range of CAD applications, in 2016 the market share of 3D design tools was approximately 73% [3], while 72% of the applications have been used by windows operating systems [4]. The leading market vendors of 3D-CAD-Systems in 2016 were Autodesk, Dassault, Siemens, Hexagon, and PTC [5]. As a consequence of the obvious presence of 3D-CAD-Systems in the industrial practice, the technological education of freshman students in contemporary tools is very important for study programmes of mechanical engineering. In addition, the trend for cloud-based CAD solutions and the increasing application of concurrent engineering worldwide demands for a strong educational fundament in methodological application of computer aided design [6]. Using the possibilities of modern digital teaching technologies in combination with orthodox personal tutorial has shown good results in the past years of students' education in the mentioned field [7].

3 COURSE DESCRIPTION

This chapter describes the structure of the CAD introduction course and the structure of the subsequent exam. It illuminates the tasks and difficulties in offering a computer-based exam for high numbers of students.

3.1 Course Content

The lessons follow the goal to generate one assembly of medium complexity. During the semester, all parts necessary for the assembly are created step by step, using specific tools and commands of the CAD-system. Motivation shall increase by seeing a sense in creating different parts with different steps, shapes, and details. Each session starts with an introductory presentation explaining features, difficulties and peculiarities to deal with in the following practice time. The first paragraph of the step-by-step wiki available for the students explains the part to create, its functions and characteristics.

In the first session, the students are introduced to the basic user interface of the CAD programme and learn how to create prismatic parts using the extrusion function. The start is made with very small steps, creating a new part, preparing the sketch environment and the generation of a simple base body. Subsequently, different tools (e. g. chamfers, holes, etc.) are introduced step by step, explaining every adjustment necessary. An additional exercise, providing a technical drawing but no detailed step-by-step instruction, is meant for homework. Hereby, the students shall deepen the skills taught in the small step instruction and internalise the essential steps in working with a CAD programme. Hints and suggestions for the solution shall help students out of possible stagnancy during practice.

The second session tackles generating bodies of revolution. First, general information on bodies of revolution is given. The actual start of the construction is once again made by creating a new part. In the following, the base body creation, via sketch and revolution, is explained. The lesson covers how to add a relief groove to an existing body, followed by the compilation of a thread and chamfers. Finally, the appendix of extrusions to the body of revolution follows.

The third session amplifies and amends the skills from the previous two sessions in a new turned part. The fourth session's concept is similar, yet aims at the additional illustration of characteristics and challenges of cast parts. The shell tool and integral keys are introduced in the fifth session.

The next field of attention is assemblies. The sixth and seventh session tackle the steps that are necessary to assemble several parts with a 3D-CAD-System. General rules build the base, explained at the very beginning. The placement of the first part of an assembly is described in detail and reasons for fixing its position are clarified. A subassembly is the first task, beginning with the creation of an assembly file in CAD, and then explaining the positioning of the other parts, one by one and step by step. Another subassembly, without step by step instructions, shall enable the students to deepen their understanding. In the next session, the completion of the overall assembly follows.

Finally, the last two sessions deal with the generation of technical drawings. The explanation of fundamentals once again builds the foundation for the following explanation of drawing views and preparations for the drawing creation. The steps start with the generation of a new drawing sheet and placing a base view, followed by a projection view. Sectional views and necessary preparation steps as well as placing a 3D view are explained afterwards, followed by the insertion of centre lines and the explication of the labelling field. Another drawing addresses the creation of a blowout and editing of hachures. The following session on drawings deals with annotations, manual dimensioning and dimensioning properties. Furthermore, the creation of detailed views and geometric tolerances according to the GPS (Geometric Product Specification) norm are embraced. The last steps cover the insertion of tables, preparations for BOM (bill of materials) balloons as well as the bill of materials itself.

The course is held with approximately 300 students simultaneously in six separate computer classrooms. The 3D-CAD-System NX 10.0 from Siemens PLM is used on a Microsoft Windows operating system, which represents a typical use-case in real-life scenarios for future design engineers [3] [4] [5]. The course is instructed by one supervisor (assistant researcher), whose lecturing is video-streamed into all classrooms at the same time. Graduate students assist in every room, to answer problems of the undergraduate students. In addition, the course material is provided through a wiki website, which can be accessed through a web browser within the classroom or from home (for later revision and exam preparation). This combination of media utilisation has been proven feasible and efficient for freshman students' education in the field of computer aided design [7].

3.2 Exam Tasks

The exam consists of four different tasks. The first and second task is to build a part based on a technical drawing. The first task is the construction of a prismatic part while the second task is a body of revolution. The third task is to build an assembly, for which the parts are given. The fourth and last task is to create a drawing equivalent to the given sample. The tasks contain a selection of the functions introduced during the course sessions.

Due to high numbers of students participating in the exam, which is usually over 1000 in the summer and between 50 and 100 in the winter, it is not possible to conduct the exam for all students at a time. The size of the computer pools call for nine to twelve sessions in all available rooms, to serve the demand. Therefore, it would be inappropriate to give out the exact same tasks in all sessions, since students who take the exam later, might have the chance to get a glimpse on the tasks beforehand. In order to approach equivalent opportunities, the tasks are released 14 days before the exams start, using parameters instead of numbers for the dimensioning. This way, all students have the equal opportunity to practice the original tasks. In the exam, the different sessions are assigned specific parameter groups and therefore have individual results. The parameters are only used for one session, so that no student can profit in that way from a later personal exam date.

4   EXAM RESULTS

Prior to the concrete discussion of exam results, the explanation of the German grading system shall take place briefly. The British/American grade A+ equals the German grade 1.0 and is the best possible grade. The grades are subdivided into …,3 and …,7 grades (e. g. 2.3 and 2.7) until the 4.0 is reached, which equals the UK grade D/ US grade C. Looking at the exam results since summer 2015 shows some peculiarities. Figure 1 shows the overall results (regarding 1.0 to 4.0) between summer 2015 and summer 2017. The results in summer 2016 stand out negatively, the marks are inferior to the other semesters.
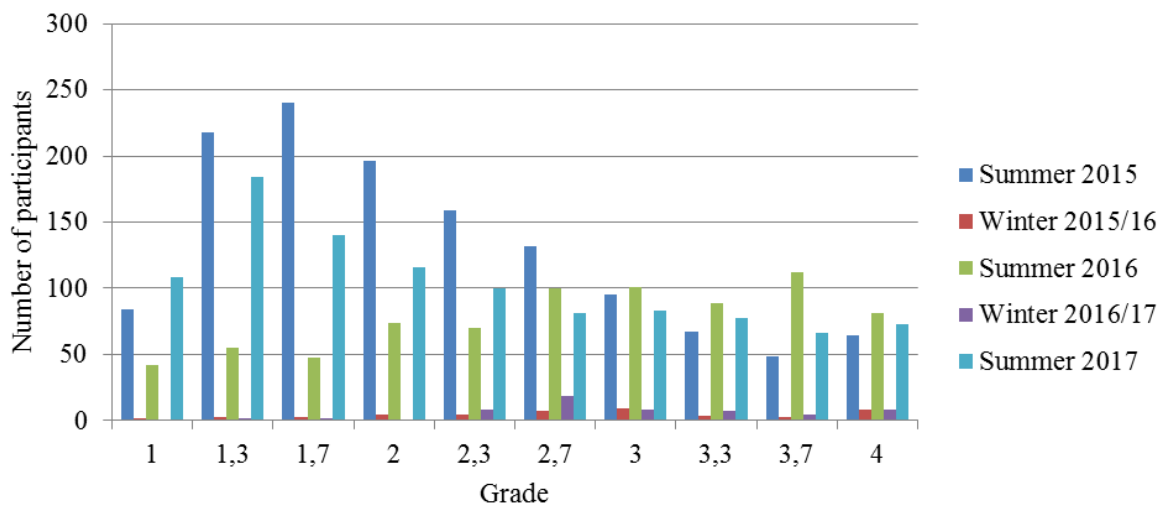

Figure 1. Results between 1.0 and 4.0 during summer 2015 until summer 2017

One reason for the bad outcome in summer 2016 can be found in the aforementioned cut down of programme diversity. Before summer 2016, the students were able to choose which programme to use for the exam. The options were Siemens NX, PTC Creo and Autodesk Inventor. During the exam, students have had huge problems with file management in their chosen CAD programme and were often not able to save their files properly. Since different programmes require different saving and preparation steps, three different explanation presentations were necessary. Siting the working directory etc. in PTC Creo and Autodesk Inventor caused the most time consuming problems during the introductory presentation of the exam. In contrast, Siemens NX caused the smallest problems in comparison, which was one of the reasons for its selection as the only taught programme. Due to the organisational time effort allowing three different programmes, the options were cut down to the usage of only one programme in teaching and exam in summer 2016.

Figure 2 shows the average mark achieved by the students during the considered time period. The best result was 2.36 in summer 2015, while the worst result of 3.41 was achieved in summer 2016.
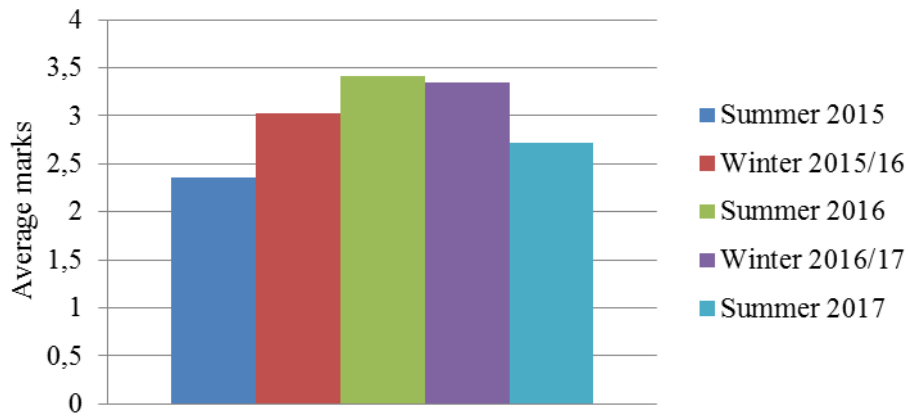
Figure 2. Average marks summer 2015 until summer 2017

The contemplation of the number of withdrawals from the exam in relation to the overall registrations in figure 3 shows quite plainly, that in the winter semesters the rate of withdrawals is much higher. In the winter semesters, no course is held and usually students register, who do not take the exam in the regular semester, either prior or posterior to its curricular anchorage.
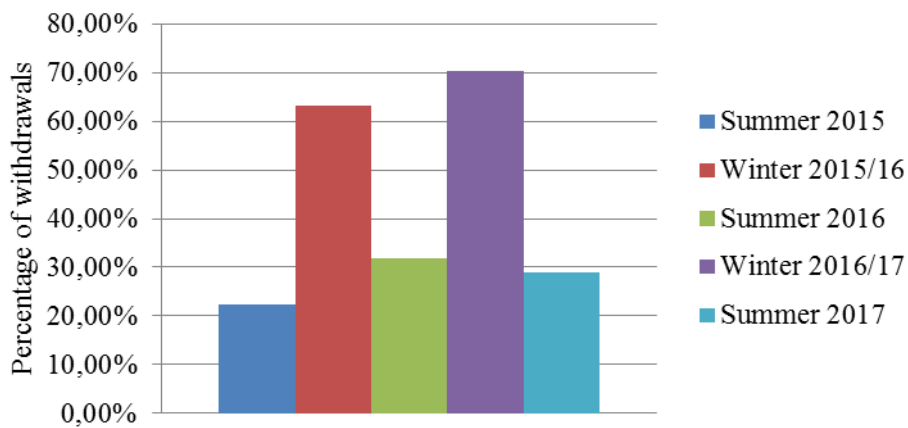

Figure 3. Withdrawals from exam in relation to overall registrations summer 2015 until summer 2017

The following figure 4 shows the number of participants between summer 2015 and summer 2017 and illustrates the big difference in numbers of examinees between summer and winter exams. While the summer exams serve over one thousand students, the exams in the winter only have around one hundred participants.
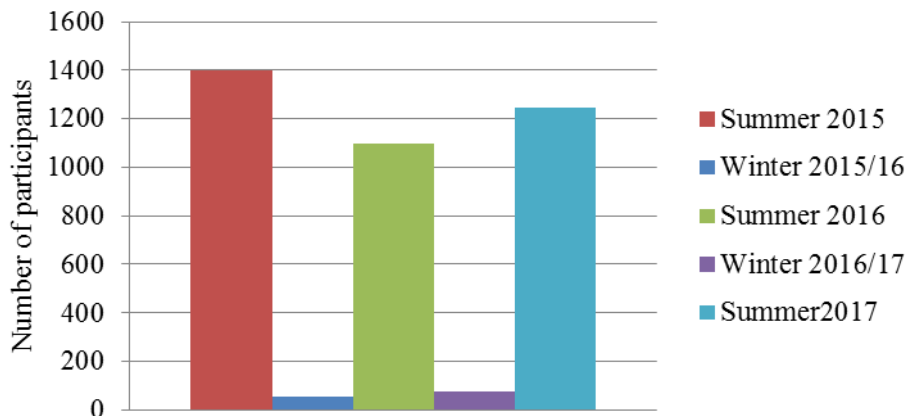

Figure 4. Number of participants in summer 2015 until summer 2017

5   STUDENTS EVALUATION AND STATISTICS

The course is well accepted by the students. The evaluation of the programme shows, that students like the structure of the wiki and enjoy working on 3D models. The most often filed complaint is the lack of time during the hands-on sessions. This can lead to a delay in the students' working progress on the tasks. The following diagram in figure 5 shows a selection of the evaluation results from the student evaluation that is mandatory to execute in every course at RWTH Aachen University. The diagrams work with numbers for evaluation, where one is the most wanted and five the least wanted result. Since all results are below 4, the legend has been shortened by the authors.
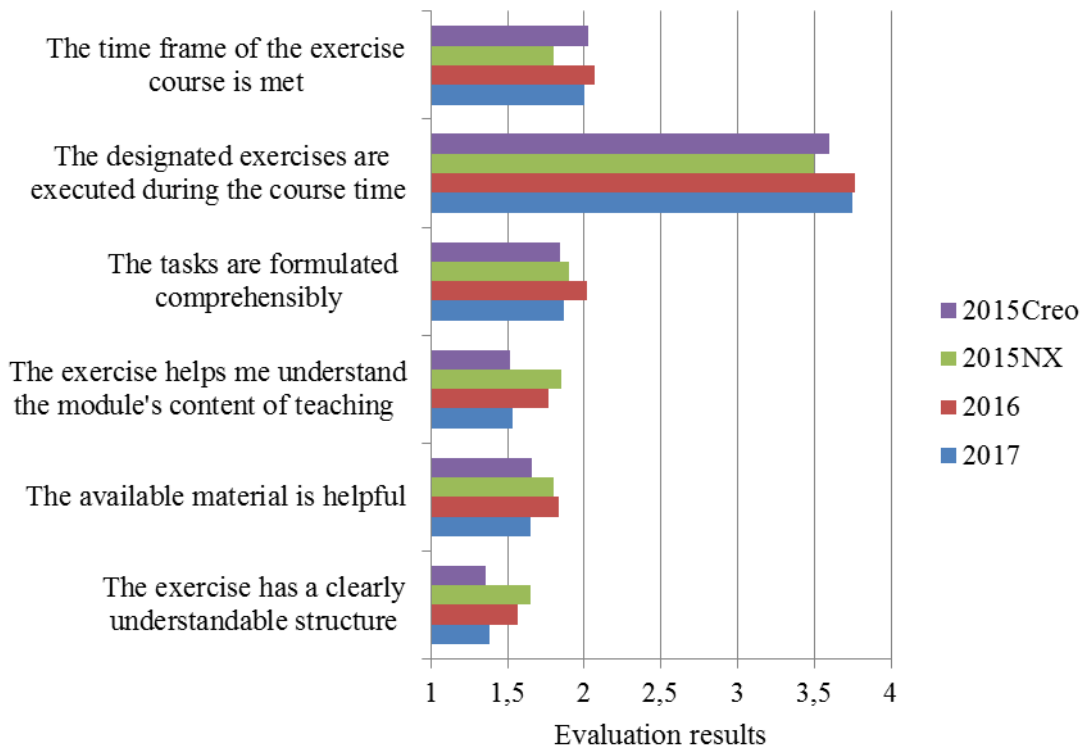

Figure 5. Evaluation results summer 2015 until summer 2017

Most of the students attend the course during their bachelor studies. The exercises help their understanding of the module's content of teaching and find the material helpful. The clearly understandable structure supports and facilitates the knowledge acquisition. The evaluation history throughout the past semesters does not show significant saltation.

Figure 6 visualises the distribution of male and female participants in the courses. Before summer 2016, the students could choose between a CAD course for PTC Creo and Siemens NX. It stands out, that there were significantly less female participants in the NX course when there still was the choice.
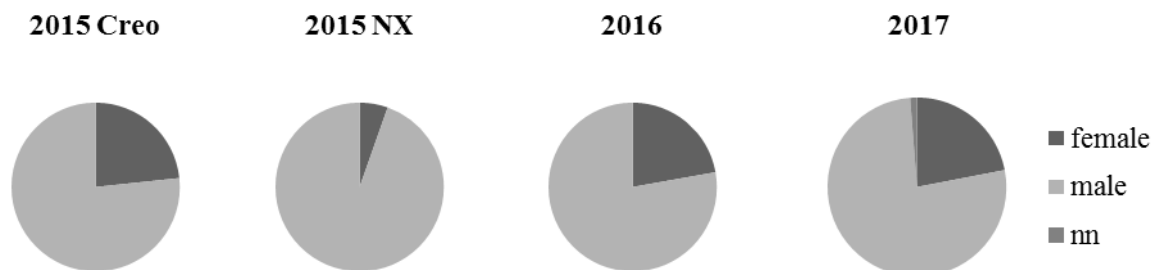

Figure 6. Distribution of male/female participants summer 2015 until summer 2017

Students from different countries study at RWTH Aachen University. The following figure 7 shows the distribution of German, EU, and Non-EU students throughout the past years. The majority of the students are German. It stands out, that the percentage of international students sinks after 2015.
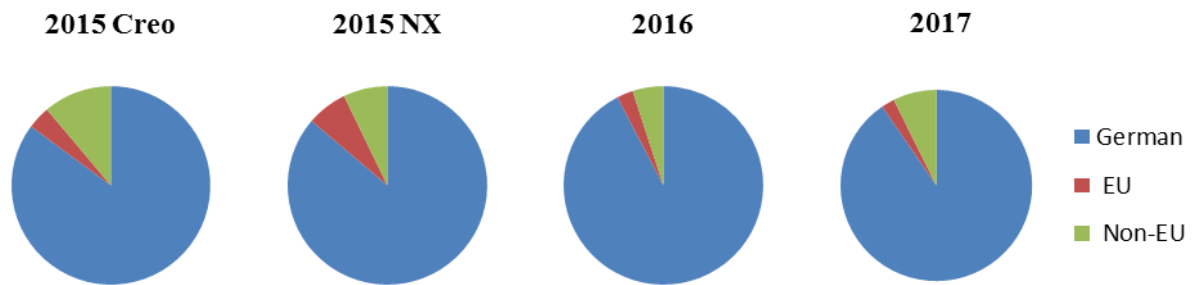
Figure 7. Distribution of German/EU/Non-EU participants summer 2015 until summer 2017

Overall, there seem to have been difficulties in the cut down to one programme, which are now decreasing. Since the lack of time is a remark constant through the semesters, additional time for the course would be helpful.

6   OUTLOOK AND CONCLUSION

The students like the introductory CAD course and find it helpful for their understanding. The biggest problem is the lack of time during the course sessions, leading to delay in working on the tasks during the sessions. A step-by-step wiki definitely makes sense in educating high numbers of students on computer programmes. The availability of a competent and experienced advisor to consult with difficulties eliminates stagnancy in the students' advance during the course sessions.

Since virtual product development becomes more and more important and needs more weight in studies on mechanical engineering, the future goal is to extend the CAD course and integrate Model Based Systems Engineering (MBSE), as well as a Product Data Management (PDM) System. A lecture, additional to the hands-on course, could deepen the students' understanding of the complex topic. The extension of the course could also conclude the time issue, which students mock. Furthermore, the introduction of several online assessments during the semester might enhance the students' participation and could hence decrease the number of withdrawals.

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