INTERNATIONAL CONFERENCE ON ENGINEERING AND PRODUCT DESIGN EDUCATION
2 & 3 SEPTEMBER 2010, NORWEGIAN UNIVERSITY OF SCIENCE AND TECHNOLOGY, TRONDHEIM, NORWAY

MULTI-SYSTEM CAD-TEACHING IN LARGE CLASSES

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ABSTRACT
This paper describes the approach chosen to teach 3D-CAD to large classes in a one credit course at RWTH Aachen University, where a maximum of 1400 engineering students are given an introduction to 3D CAD each year. The overall strategy is to create an introduction to autonomous and extracurricular CAD-learning, because the rather low credit-value prohibits a course extent that can cover the subject as broad and deep as necessary for design engineers.
The main features of that concept are:

- a standardized example project designed to give insight into as many modelling techniques and aspects as can be covered in a single-credit course
- blended learning with a choice of alternative media, which means that different media and teaching concepts can be compared with regards to their suitability for CAD training
- an option to choose from currently 3 different software products, which also means that the course can be used as a comparative study of different CAD-systems

This approach could only be realized as a result of a collaboration of three different chairs of two universities and the willingness to consider this project not only as a teaching obligation but a systematic study of different engineering software solutions and alternative teaching concepts.

Keywords: CAD-education, multi-classroom teaching, blended learning

1 INTRODUCTION

The effective use of state-of-the-art computer-based engineering tools such as CAD has been a prerequisite for competitiveness for any engineering-based enterprises since personal computers have become available. It should therefore seem logical to satisfy the industry’s demand for skilled design engineers by adding adequate courses to the curricula of engineering programs at universities. The existence of the PACE partnership, a sponsorship program initiated by an automotive producer to support the improvement of engineering education by supplying selected institutions with computer soft- and hardware, documents the existence of such demand and the failing of universities to fully satisfy it [1].

With regards to that shortcoming, the Bologna Process could have meant an opportunity for European Universities to include adequate CAD-education into the new study programs, which in most cases had to be redesigned from scratch. However, the general tendency - at least in Germany - seems to be that the new restrictions lead to further cuts in engineering core subjects which result in reduced scopes (credits and hours) for teaching CAD [2]. As a result of the switch of the study system in Germany, the new Bachelor program of Mechanical Engineering at RWTH Aachen University leaves one credit point for CAD education. While this might seem somewhat sparse at first impression, a study in 2009 by Hesser [2] revealed that there does not seem a mutual idea of how much CAD education is appropriate. While some universities assign several credits to that topic, others do not include CAD at all. The same disaccord seems to exist with regards to what kinds of systems should be considered: the study reveals that about the same shares of all Universities use what Hesser categorizes as “low performance systems” (2D systems), “medium” and “high-performance” systems, the latter being 3D systems categorized according to undisclosed performance ratings. This lack of a uniform academic standard encourages detailed considerations, studies and new concepts.

2 RESTRICTIONS, OBJECTIVES AND APPROACHES

2.1 Scope/extent

There are arguments against including extensive CAD-education into study programs, the most notable being that teaching CAD means a lot of effort in relation to seemingly little academic relevance. Compared to conventional classroom teaching, teaching CAD always is a logistical challenge. Computer hard- and software is expensive, computer labs make inefficient use of space and maintaining the network and server infrastructure as well as keeping up with the constantly updating software keeps staff busy before having even started to define course contents. The challenge becomes even bigger with large numbers of students because each teaching unit has to be offered multiple times as lab space only allows to teach a fraction of the student body at a time. This "inconvenience" can quickly lead to a neglect of CAD-education if paired with a common misinterpretation of CAD as "just another computer tool" by decision takers who do not recognize its relevance for teaching the fundamentals of machine design and design methodology. One can argue that not all engineering students will end up designing technical components, so advanced techniques do not have to be covered in a course compulsory to all. On the other hand, a decision to specialize in one field usually is taken at the later stages of studies, while basic CAD skills must be at hand for many courses and projects in the earlier stages.

Therefore, to avoid unnecessary workload for the students, a concept for CAD-education within a newly designed study program of mechanical engineering seems appropriate that is made up of two main components:

1. A compulsory course to ensure that all engineering students have the basic skills necessary to tackle the basic CAD techniques, but also for further independent studies. Giving credit and grading will ensure enough motivation even for the students with little interest in design engineering, but the workload should be minimal in order to allow for maximum flexibility of the study program
2. A complementary offer to satisfy the need for independent self-study.

This concept which is outlined in this paper has been implemented in the Bachelor program of Mechanical Engineering at RWTH Aachen University and has proven itself in the first two runs so far.

2.2 Objectives

The initial target definition that led to the development of the concept included

- learning efficiency: maximum scope of impaired skills within a workload of 30 hours (1 ECTS credit);
- teaching efficiency: up to 1400 students per year necessitate a most effective use of resources, especially lab time and instructor workload;
- teaching flexibility: teaching should be possible on any of the major CAD-systems on the market, allowing efficient customizing to new programs and updated versions.

2.3 Specific restrictions and resources

The teaching concept described here has become possible due to existing resources at RWTH Aachen University, especially at the department of mechanical engineering and the Institute for Engineering Design (ikt), which has already been responsible for CAD-education before the switch to the bachelor study program. These resources include

- a computer lab with a capacity of about 200 in 5 rooms;
- sufficient licensed installations of the SIEMENS CAD-software NX (current version) due to the institution's status as a PACE institution [1, 3];
- sufficient licensed installations of the PTC CAD-software Pro/E Wildfire (current version) due to an ikt project sponsored by the federal government of North Rhine-Westphalia [4];
- an e-learning and e-teaching portal of RWTH Aachen University that allows lecturers to offer protected domains that can be used to upload materials and publish Wiki-pages [5].

These resources are used to realize the compulsory course with a choice between two CAD systems within the curriculum of Mechanical Engineering. The concept developed at ikt already features the open architecture needed for teaching flexibility and teaching efficiency.

The added value of a didactic concept that provides alternative teaching media and evaluation tools was made possible by a collaboration with the Institute for Geometry and Applied Mathematics (igpm) at RWTH Aachen University and the FH Aachen University of Applied Sciences. In the following, the synergetic effects that result from the decision to fuse the individual teaching approaches will be outlined.

3 CAD-TEACHING CONCEPT AND IMPLEMENTATION

3.1 Philosophy

All major CAD-systems on the market today feature a similar approach at least to the basic modelling functions but differ with regards to layout, terminology and other operation details. Experience shows that while learning how to design a technical system on a 3D CAD system for the first time is complex and time consuming because it includes understanding a new workflow, the acquisition of any second system can be managed with comparably little effort. From an academic viewpoint, it hardly makes a difference which 3D system is taught as long as it follows the general structure common in today's system. On the other hand, it does make a difference for the student's portfolio when leaving the institution and trying to find a job, because employers seem to attribute more importance to the question if the applicant is experienced in their system of choice. Also, any personal experience with any software product will result in a preference for that product, and that preference will influence the purchase decision, so the question, which system is taught at Universities should mean a lot to the software suppliers.

These considerations have resulted in the decision to try to teach all available relevant systems if possible, because it efficiently allows to increase the graduates' "market value" while helping the institution to remain as unbiased against the system providers as possible.

While this philosophy undoubtedly means more effort for the teaching institutions, it will offer a chance to systematically study the systems' differences. This is an advantage for institutions like ikt that do research in the field of design methodology and offer consulting services to industry.

3.2 Collaboration

This collaboration on CAD-education between the institutes ikt and igpm of RWTH Aachen and the University of Applied Sciences Aachen has been started by the decision to use a mutual case study - a beer dispenser - to interconnect the existing individual teaching concepts, Figure 1. It was also agreed that ikt would work out the example for the two CAD systems used in the curricular course while the two other partners concentrated on transferring the given case study and their existing didactic concept [6, 7] onto further 3D CAD systems. Besides the shared workload on realizing the multi-system teaching philosophy, the collaboration has the benefit of enabling the partners to carry out comparative studies of different CAD-systems as well as different teaching approaches and media.

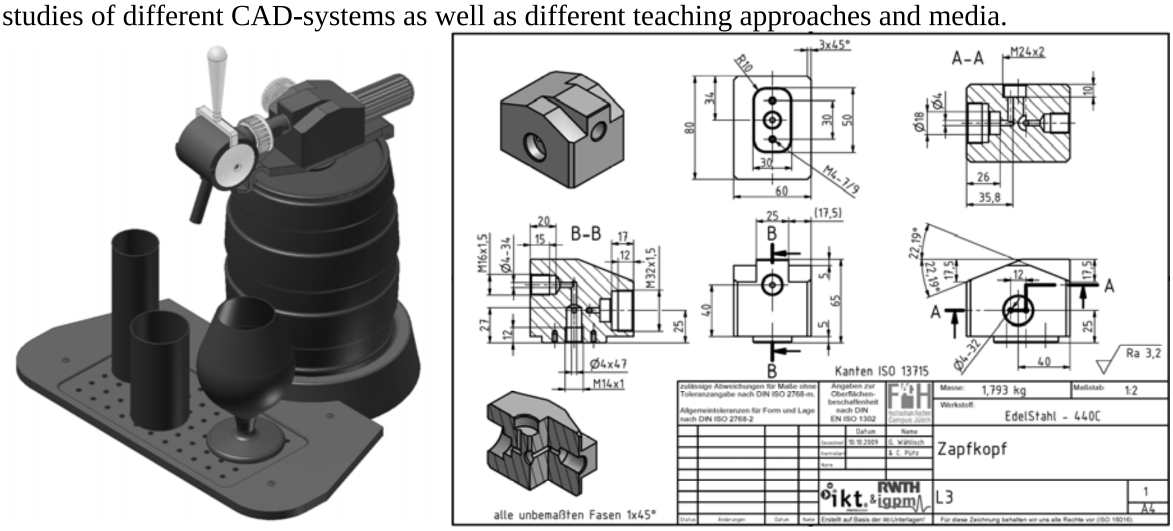

Figure 1. Case study "Beer dispenser", drawing of one component

3.3 Curricular and organizational framework

The new Bachelor program at RWTH Aachen University has assigned 1 credit and 45 minutes of lecture time per week to a second semester CAD course. In order to minimize downtime, the overall lecture time for this compulsory course is used for 7 90-minute sessions, so the course is completed in half a semester. This on the other hand leaves time and lab space for a second run of the course on a different CAD system. As each student only has to enrol in one of the two options, the number of participants of each of the course runs is reduced accordingly. The number of multiple runs for each session (which become necessary if there are more students than seats in the lab) again is reduced which means that offering the choice of two systems in this layout does not result in a higher workload for the instructor, if the initial effort is not taken into account.

These courses take place during the semester; an examination for grading purposes is carried out after the end of the semester at the beginning of the “free period”.

As the computer labs are available during that free period, additional CAD-courses on alternative CAD-systems are offered by igpm before the next semester starts. The FH Aachen courses take place on a different campus and do therefore not interfere with education at RWTH Aachen University.

3.4 Teaching concept and employed media

There seems to be a general agreement that CAD teaching of larger groups of students can only be effective with a mix of media. A classroom lecture type of presentation will quickly leave a share of the students behind if used as the only teaching resource but the presence of a real instructor is vital for the teaching success, not only for answering questions and reacting to unexpected technical problems but also to establish a personal contact between teacher and students. Detailed text-based instructions (“click-instructions”) are considered to be more helpful at the beginner level as they allow students to choose their own pace while less-detailed guidelines ideally support intermediate learners. Instructional videos seem to be regarded as very helpful when complementing written instructions [8], especially for faster learners or intermediate users who can follow the pace of the video.

These findings have determined the mix of media chosen for the curricular course: Short presentation-type lectures to start each session and detailed instructions published on the aforementioned e-learning portal as Wiki-pages are combined, Figure 2. The lecture is transmitted into the different rooms of the computer lab as an audio-video stream, so only one lecturer needs to be present. There are teaching assistants in each room to assist in case of questions or problems. The Wiki-pages can also be accessed over the internet, so the students can go through the materials again or even chose to stay away from the labs and learn at home. Finally, instructional videos with audio commentaries complement the self-teaching offer for fast learners or students who are learning to use their second or third system.

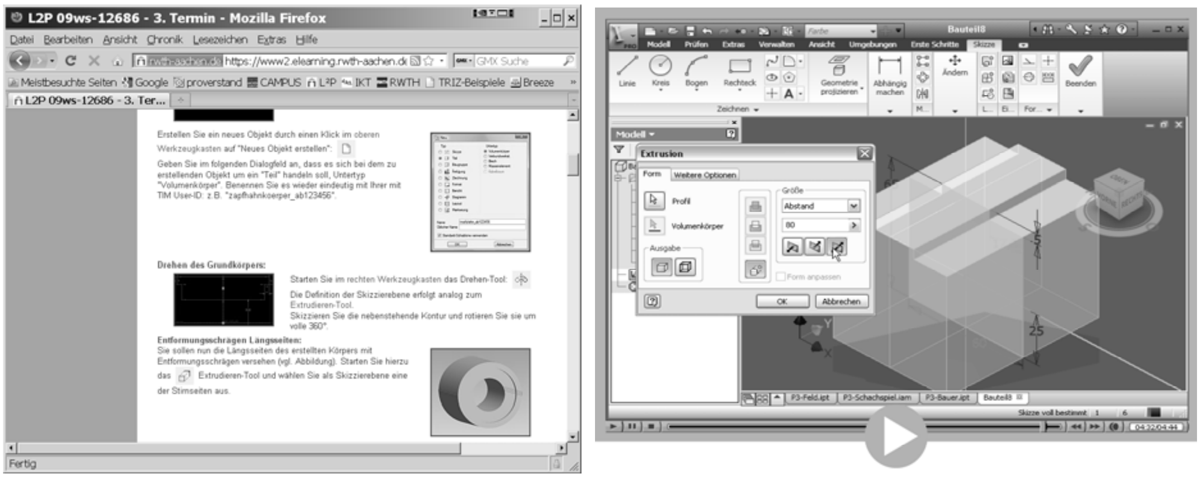

Figure 2. Screenshots of Wiki page and instructional video

3.5 Covered CAD functionality

As the course is directed at mechanical engineering students at the beginning of their studies, all modelling techniques are covered that correspond to conventional production technologies as well as modelling assemblies and drafting. It may be noted that these techniques correspond to the “basic functions” of most CAD systems relevant in today’s industrial practice. Such “basic functions” can typically be accessed directly by graphical buttons in the main window, while advanced functions are generally “hiding” in menus.

After a brief introduction to a Product Data Management System [4] which can be used for data storage by the students, accessible both from the labs and from home, the aforementioned product example is modelled in 6 sessions:

- modelling milled parts
- modelling lathed parts
- modelling cast parts
- modelling assemblies
- drawings, introduction
- production drawings

3.6 CAD-systems

SIEMENS NX and PTC Pro/Engineer Wildfire are currently being taught in the curricular courses during the lecture period and Autodesk Inventor in a course during the free period. These courses have been fully completed and run with a complete set of media including lecture-type presentations, detailed instructions and instructional videos, so they are suited both for novice and intermediate users or slow and fast learners. It is planned to realize self introductory courses at least for Catia and SolidWorks, mostly as instructional videos, aimed at users who are already familiar with other systems.

3.7 Examination/Student assessment

A practical test is used for assessing the students’ proficiency: within 90 minutes, 2 specified parts and 1 assembly have to be modelled and one production drawing has to be produced under supervision. Again, the large number of examinees calls for an unusual approach to ensure equal chances for all students. The organizational problem is that the test can only be carried out in consecutive runs, and students joining the later runs would inevitably benefit from the earlier examinees’ experience. In order to neutralize this effect, the task assignment is published a few days before the examination, but a set of parameters that is customized individually for each examinee is left open until the actual examination. For grading, each set of CAD files that is produced during the examination has to be looked at by the teaching assistants.

This approach has been validated in the last two years with satisfying results. In the fall of 2009 at RWTH Aachen, more than 94% passed the first attempt of the curricular examination, 32% with very good and excellent exams. At FH Aachen, the results are similar, but the layout of the examination is different so the results cannot be directly compared.

4 CONCLUSION AND OUTLOOK

CAD education at Universities generally causes a lot of work and can also cost a lot of money, so it is understandable that some institutions do not include any state-of-the-art CAD training in their already crammed curricula but rely on the students’ self motivation to make themselves familiar with a system of their choice. On the other hand, it is the Universities’ duty to prepare future engineers as well as possible for the needs of the industry, and CAD skills rank high on employers’ wish-lists. As a compromise trying to satisfy all restrictions - especially large classes with up to 1400 students each year - as well as possible, an educational concept has been realized at RWTH Aachen University and FH Aachen University of Applied Sciences that uses a minimum credit course as an entry to effective CAD-self training and a free choice between the CAD systems that are most important in today’s industry. While a share of the students will get through the rest of their study programs with the scope of the single-credit course alone, students focusing on design engineering can either deepen their skills on one system by turning to additional training materials offered for each system or familiarize themselves with other systems using a standardized introductory course offered for each system. The

blend of different media and discussed here has proven itself to work for different kinds of learners (fast/slow, intermediate/novice). The use of internet based media such as Wiki-pages and instructional videos also leaves it up the students, where and when to learn and how often to repeat a lesson.
Finally, as a benefit to the institutions, this approach has given a methodic insight into the subtle differences in usability of the different systems. It was decided not to share this insight with the students to allow for an unbiased choice, or rather, a choice based on what opinions and facts are available on the internet or elsewhere. It was interesting to find out that this type of information does not help to reach a clear decision between, for example, Siemens' NX and PTC's Wildfire, which have been the choices for the graded course in the last two years. While only about 10% of the students took both courses, 55% of the students preferred the option that would be offered in the first half of the semester, regardless of which of the systems would be offered first.
Overall, the authors conclude that the teaching concept described here is successful, which can be substantiated by good results both of the students' examination and their feedback given on the course evaluation questionnaires. There is no data available yet to prove if the concept goals of "motivating further studies" and "improving applicants' market value" are reached, but one anecdote indicates that this could be the case: only a few weeks after having joined the course, one student posted an animated video of a complete model of a motor-coach, referencing the course, on Youtube.com. This student was consequently contacted and hired as teaching assistant by ikt.

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