INTERNATIONAL CONFERENCE ON ENGINEERING AND PRODUCT DESIGN EDUCATION
6 & 7 SEPTEMBER 2012, ARTESIS UNIVERSITY COLLEGE, ANTWERP, BELGIUM

ESTABLISHING CAD AND PDM AS PART OF ENGINEERING EDUCATION IN LARGE CLASSES FOR UNDERGRADUATE STUDENTS

Martin GEIER[1], Steffen JÄGER[1], Thomas MAIER[3] and Albert ALBERS[2]
[1]Research Assistant, IPEK, Institute of Product Engineering, Karlsruhe Institute of Technology
[2]Head of IPEK, Institute of Product Engineering, Karlsruhe Institute of Technology
[3]Senior PLM Consultant, PTC, Parametric Technology GmbH

ABSTRACT
Computer Aided Design and Product Data Management software has become a standard in almost all sectors of mechanical engineering. Therefore companies expect experience with such environments from potential employees.
In order to meet that requirement, students of Mechanical Engineering learn using CAD systems, such as Pro/Engineer and PDM systems, e.g. PDMLink embedded in Problem Based Learning (PBL) at our Institute. An approach to teach over 600 students per semester in CAD/PDM classes is demonstrated in this paper.
The students participate in Mechanical Design courses over two years. Starting with hands-on workshops in the first semester, the students work on engineering problems with increasing complexity over the second, third and fourth semester. It is described how CAD/PDM tasks are embedded in this PBL approach.
This paper explains how student's private laptops and workstations are integrated in the institutes PDM-infrastructure. Furthermore the technical aspect of the infrastructure is described briefly.
As there are only a limited number of at most four CAD/PDM lectures per semester, numerous materials and support services are provided to assist autonomous learning. The setup of screencasts, manuscripts, task sheets, slides, office-hours, expert consulting, mail support, FAQs, newsletters and more is depicted in detail.
This paper illustrates the ongoing evolution of the CAD/PDM education over the past years, with increasing numbers of students and changing IT-environments. The effects of the recent developments were evaluated by student surveys shown in this paper.

Keywords: CAD, PDM, mechanical engineering, problem based learning, PBL

1 PDM/CAD IN DESIGN EDUCATION

The application of 3D parametric CAD-Software has become a standard and the utilization of Product-Data-Management Systems is growing. Therefore companies expect experience with working within such environments and with such software-solutions from job entrants. This demand has been addressed by universities in various ways. In most cases the necessary skills are taught in separated courses and the necessary practice is expected to be gained in following projects.
At some universities very large systems have already been established to supply a lot of users with modern CAD and PDM solutions. The RWTH Aachen with its initiative ProVerStand is supporting about 45000 users throughout the federal state of NRW (Germany) based on the PDM-system PDMLink supplied by Parametric Technologies (PTC) [2]. In various publications ideas and requirements for the integration of CAD and PDM into the education of product development engineers have been expressed. Bitzer et al. has proposed an education concept in which the necessary theoretical engineering background, soft skills and the usage of CAx-systems is taught accompanied by work on projects derived from industrial design tasks [3]. Ye et al. [4] emphasize that not only the mere use of CAD and PDM software should be thought, but more how to actually use it in the product development process.

This has been addressed by Feldhusen in the undergraduate course "Introduction to CAD". Next to a project task supplied by an industrial partner the students from Aachen were teamed up with students from the Korean Hongik University in Seoul [5]. Watty and Binz comment on the experiences with the introduction of project based work in second semester design courses and give an interesting insight on how to overcome heterogeneous team compositions and to ensure equal learning opportunities [6]. In previous publication of the authors it was shown how different kinds of IT-solutions like CAD, PDM and Wikis can be integrated in the education of large amounts of students. It was shown what kinds of challenges have to be faced, what measures are suitable to address them and that the combination with the problem-based learning approach KaLeP is very promising.

2 ENGINEERING EDUCATION AT OUR INSTITUTE

KaLeP is a Problem Based Learning approach and similar to known curricula, e.g. [8]. Besides having classical core engineering skills, design students should also be familiar with modern methods and technologies which they will most likely encounter in their future. Furthermore requirements on graduates in design are continuously increasing, not only for professional skills but also for social skills as well as proficiency with new technologies and methods as current study of the German Chamber of Industry and Commerce shows [9]. The overall goal of the work on KaLeP is to improve design education by addressing these issues with a combination of classic lectures and an accompanying project work within a realistic environment. The evolution and the key aspects of KaLeP are described by the authors in previous publications.
The presented work is part of the Mechanical Engineering curriculum at our Institute. During their first four semesters the students have to participate in a Mechanical Design course. The course consists of lectures, tutorials and project workshops.

3 CHALLENGES IN CAD/PDM EDUCATION

In the sense of Problem Based Learning taught content is to be supplemented by practical project work. We are also facing a growing amount to about 600 students of Mechanical Engineering in the second semester in 2010.
One aspect of our IT environment is the heterogeneity of the computer skills of the participating students. A survey from 2010 shows that 80% of students estimate their skills as good or very good and only about 10% have any previous knowledge of the used software-solutions. So the task is to enable a large amount of students to do their project work efficiently by using the CAD-software Pro/Engineer (Pro/E) and the PDM-system PDMLink.
The second source of heterogeneity is the computers used by the students. While the workstations available at our Institute are maintained according to predefined standards, these standards do not apply on students computers. Nevertheless the usage of those student owned computers is necessary. The amount of 140 workstations located at our Institute is not enough for two parallel semesters with CAD-usage which consist of about 1200 students. Besides that, this offers the students to work anytime and anywhere they want. The range of student's computers is between high-end gaming pcs and ultra-portable netbooks, all more or less suitable for Pro/E.

4 SOLUTIONS AND THEIR IMPLEMENTATION

The complete CAD curriculum is today tailored to the Mechanical Design project tasks. Among others the most important measure to cope with large numbers of students was to switch from a two week block course to a two year regular tutorial.
A PDM system was introduced as an important pillar for the CAD education. Additionally to teaching PDM-skills the PDM system at our Institute actually enables to tie a network between computer rooms, private computers, education material, project tasks and project results. Students are required to contribute their CAD models in the team related product space on the PDM server.

4.1 Curriculum

Today each tutorial is held as an ex-cathedra teaching session of 1.5 hours length between two and four times per semester. The goal of the lecture is to make students aware of certain functionalities in Pro/E and PDMLink and to actually see typical workflows and possible snares with their own eyes. In opposite to teach pure CAD theory the tutorial is always dominated by live CAD operations.

Students must prove their CAD/PDM skills continuously during the regular project meetings during the last three of four Mechanical Design semesters.
The curriculum at our Institute traditionally includes a broad range of CAD techniques explained in the following and shown in figure 1.

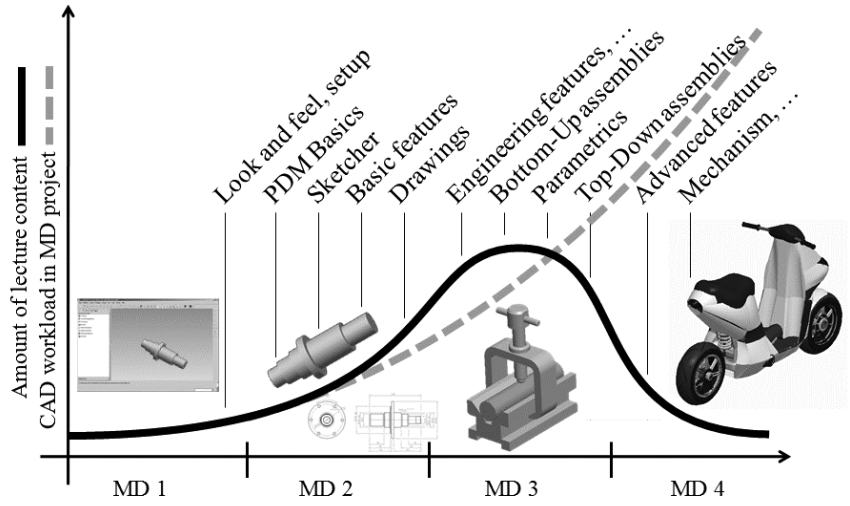

Figure 1. Curriculum of CAD tutorial during Mechanical Design lecture and CAD workload

For most students the handling of engineering software is quite new. In order to overcome inhibitions the very first lesson is a "hands on session". Students get explained how to obtain a student edition of Pro/E, how to install the software and how to get a feeling of the new system. Figure 1 also shows the amount of CAD lecture content over four semesters. Clearly the 3rd semester is quite packed with CAD topics. Even though the number of tutorial sessions is reduced from four to two in 4th semester, the amount of CAD activities in project work still increases.

4.2 Education material

Two *textbooks* have been written for the course, one covering CAD topics and the other dealing with PDM functions. For quick access to typical CAD/PDM operations such as "sketching" or "check in", *screencasts* about these topics are provided online. A screencast is a click by click display capture with additional on-screen comments and interactive navigation elements rendered as Flash clip. To allow repetitions of live tutorial sessions at home, the display content together with the lecturer's voice and the interaction with the audience is captured and also provided online as *tutorial movies*.

4.3 PDM and CAD infrastructure

The external access to the web-based PDM-System enables the students to also work from within the campus wireless-LAN or their homes and is therefore virtually extending the amount of available workstations at our Institute.
The underlying servers are based on a virtualization infrastructure. The servers are clustered and a load balancer is distributing the user request to the currently three slave nodes plus a master server. The environment can be scaled relatively easy by increasing the amount of slaves. This system is comparable to the infrastructure of medium sized enterprises.

4.4 CAD start tool

To facilitate a standardized, easy accessible CAD working environment throughout computer rooms and students computers a *CAD start tool* is provided, shown in Figure 2. The tool is installable and executable on a broad range of platforms, such as for example any Windows from XP to 7 on IBM compatible hardware, VirtualBox, Boot Camp, 64 bit systems or netbooks.
The tool automatically detects any properly installed version of Pro/E on a computer. Once all presets concerning graphics, language and version are made the tool supports the dial-up to the VPN and eventually the startup of Pro/E with the given configuration.
In addition the tool also offers easy access to all our support resources, such as the textbooks, screencasts, lecture movies but also information about office hours and access to the local Pro/E help

pages. In order to really reach all students with important news about technical and organizational topics related to the CAD tutorial the tool features a RSS feed reader.

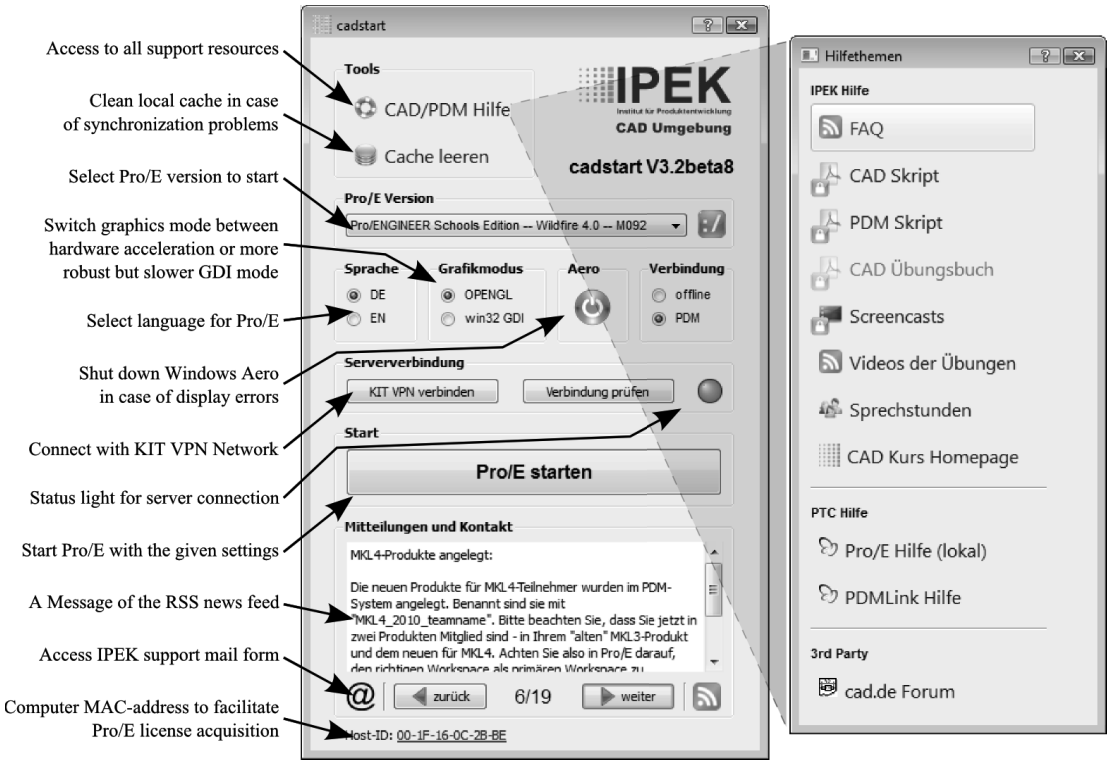

Figure 2. The graphical user Interface of the CAD start environment

4.5 Support

An average answering time for the approximately 30 support request mails per week is between a couple of hours up to a week according to the problem severeness. Many questions are asked multiple times. Thus a Frequently Asked Question list is provided which is also provided as RSS feed.
Some problems can only be solved face to face with the concerning model opened in Pro/E. So two levels of help-desks are offered, the *office hour* and the *expert consulting*. The latter is once a week and is held by very experienced Institute staff. The office hour is four evenings a week and is conducted by student assistants.

5 VALIDATION OF THE MEASURES

To evaluate the effectiveness of the implemented measures a survey was conducted in summer 2010. It is compared to the results of another survey that was done in summer 2009, before some of the described measures were implemented. The answers are specified in percentage of casted votes or with a point range of 1 to 5 (1: very good, 5: very poor, according to German high-school grades).
In 2009 111 out of 190 students participated at the survey while in 2010 190 out of 500 students participated at the survey, resulting in a 55% ratio in 2009 and 35% ratio in 2010. The results are shown by their arithmetic mean. The standard deviation is between 0.9 and 1.3, while the point range was usually fully utilized. The standard deviation is not mentioned for all results. Figure 3 shows the students estimation of their CAD/PDM skills and shows how the previously discussed measures influenced the teaching efficiency.

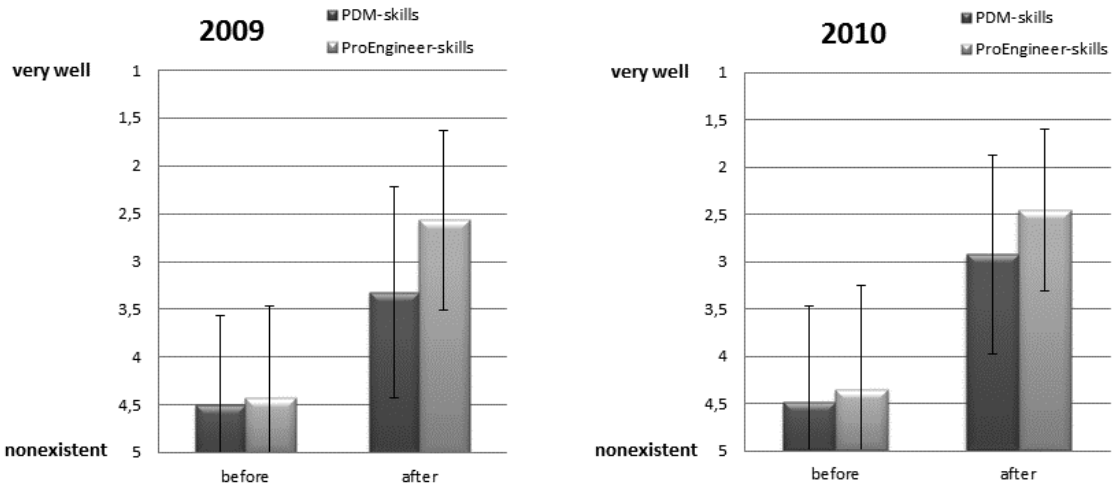

Figure 3. Students Estimation of CAD/PDM Skills

About 60% of the students declare to have started the course without previous knowledge of Pro/Engineer. Nevertheless more than 50% declare to have coped well with Pro/E within the course. Only 9% of the students had difficulties. The self-rated increase of skills during both years is significant, but the numbers remain similar for both years. At this point it is important to take the number of students into account which is more than twice in 2010 compared to 2009.
Problems can be observed with the handling of the PDM-system. The students had almost no previous knowledge of PDM-Systems, only 36% declare to successfully work with it and even 28% declare to have made rather negative experiences. Nevertheless there is improvement compared to 2009 (2009: 3.32 points; 2010: 2.93 points).
Considering the rating of the whole approach for CAD/PDM education there can be observed a positive development from a rating of 3.21 in 2009 to a rating of 2.9 in 2010. While only 21% answered with good or very good in 2009, in the current course about 35% did so.

5.1 Support

Despite higher participation the rating of the quality of support remains almost the same with 2.34 compared to 2.4 points in 2009. But it can be stated, that less participants use the *mail support* actively in 2010 (2009: 3.55 points, 2010: 3.7 points).
The quality of the *help-desk* sessions gains an overall positive rating. The expert-consulting gains a rating of 2.24 points, the evening office-hours gain a rating of 2.38. The help-desk sessions are used quite frequently by the students, 65.9% of the students visited the expert-consulting at least once and 55.8% visited the evening office-hours at least once. Some of the students used them very intensively (6.0% and 4.3%).

5.2 Education materials

The improved situation on the *education material* – particularly on the *screencasts* – could be a decisive criterion for the decreasing demand for *mail support*. See figure 4.
The *lecture movies* are rated positive by 42.31 % but they are watched rather seldom (4.02 points). This might be traced to the intense participation in the tutorial.
With 1.93 points in 2010 compared to 2.79 points in 2009 the *screencasts* are rated significantly better than in the year before. This can be explained by the increase of available clips per topic and the resulting gain of usage. (2.24 points vs. 3.48 points). The comparison of both surveys obviously shows an interrelation between the usage of *textbook* and *screencast*. See figure 4.

5.3 CAD start tool

A good supporting service is rendered by the *CAD start tool* which is reflected positively with 1.84 points (2009: 2.82 points). The ongoing improvement of the program warrants a high level of acceptance.

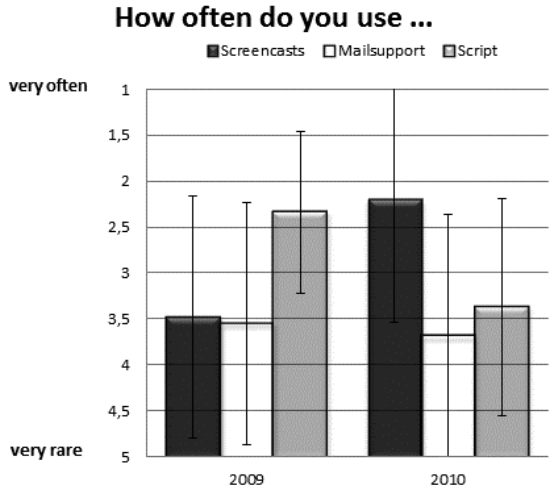

Figure 4. Usage of Education Material

6 CONCLUSION AND OUTLOOK

We outlined our solution to cope with massively increasing student numbers. Most important we have set up a PDM system to connect student laptops to the education infrastructure. To support an easy connection of most laptops we have developed a special piece of software. Furthermore we offer a wide diversity of conventional, electronic and personal learning measures.

Survey results and personal student feedback show, that the extension of CAD education to all students of a Mechanical Design year and the new measures to improve quality, impact and sustainability of CAD training are successful. Based on the surveys the efforts put in the educational materials the students preferred are currently increased and will be further developed.

Technically the implemented PDM functionalities in the CAD education only represent a fraction of all the available functionalities like workflows, process-models and release/change process. There are plans to further ease the evaluation of the students work by using workflows and lifecycle states.

ACKNOWLEDGEMENT

Partial support for this project was provided through Parametric Technology Corporation. A lot of the infrastructure established at IPEK to support this kind of education was financed directly by tuition fees.

REFERENCES

[2] Feldhusen J., Löwer M., Nurcahya E., Macke N., "Advances in Collaborative Engineering Education", *Int'l Conf. on Engineering Design*, Paris, 2007.

[3] Bitzer M., Burr H., Eigner M., Vielhaber M., "Integrated Concepts of Design Education", *Int'l Conf. on Engineering and Product Design Education*, Barcelona, 2008.

[4] Ye X., Peng W., Chen Z., Cai Y., "Today's students, tomorrow's engineers: an industrial perspective on CAD education", *Computer-Aided Design*, **36**, 2004, pp. 1451-1460.

[5] Feldhusen J., Brezing A., Bungert F., Löwer M., Yim H., Lee K., "An Interuniversitary Education Concept for Collaborative Product Development", *Int'l Conf. on Engineering and Product Design Education*, Barcelona, 2008.

[6] Watty R., Binz H., "Project-Based Learning in Under-Graduate Courses at the University of Stuttgat – Experiences and Challenges", *Int'l Conf. on Engineering and Product Design Education*, Barcelona, 2008.

[8] Simcock A., Thorn R., "Engaging Engineering Students with PBL (Problem Based Learning) Problems from Industry and Community", *Int'L Network for Engineering Education and Research*, Arlington, 2009.

[9] DIHK, Fachliches Können und Persönlichkeit sind gefragt – Ergebnisse einer Umfrage bei IHK-Betrieben zu Erwartungen der Wirtschaft an Hochschulabsolventen, 2004.