COMPUTER-SUPPORTED DESIGN EDUCATION FOR LIFELONG LEARNING FOR INNOVATIVE PRODUCT DEVELOPMENT

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Abstract

The contribution concentrates on the various characteristics of computer-supported teaching and learning focussing on methods and tools for innovative product development.

A concept was developed by several universities in an overlapping education network which stands out for high modularity and flexibility to adapt to technical changes and new methods and tools, especially regarding IT technologies. Web-based multimedia elements are being developed for all sections that can be used either individually or via the internet in work groups. Modules are being developed that simulate cooperation forms which are catching on in enterprises.

Six German universities which develop web-based courses of Basic and Main Study in product development work on the Pro-Teach-Net project. The contents of these courses can be modified for use in further educational courses. The concept and the realisation are presented.

1 Introduction

The time span of innovation cycles for technical products and technological processes is constantly getting shorter. In the field of mechanical engineering the rate of renewal has come down to 3 to 5 years. The development period of a car, for instance, is 3 years, for printers 2 years and electronic products 1 year and less. The share of new products in turnover has grown from 30% to 50% under the influence of mechatronics [EHR 2003].One consequence of this trend is the need for adequate methods in engineering design education and continuous, lifelong learning.

An efficient computer with graphical functions and an interactive surface with access to intranet and internet is the most important workplace environment for engineers in industry today. The use of this ICT-equipment (information and communication technology) in the learning environment can contribute to the training of students being educated in this technology. In industry the engineers can make use of their familiar workplace environment for continuous education.

For this reason the education requirements for developers and constructors must be determined and the contents of teaching applied in a computer compatible manner.

The results of two projects which were accomplished by a network of German universities with internet-based teaching material show how modulated computer-aided education and further training could be designed.

2 Objectives and contents of education

For the education of students as well as the continuous education of engineers in industry it is very important to mediate and train skills for effective problem solving (Fig. 1)

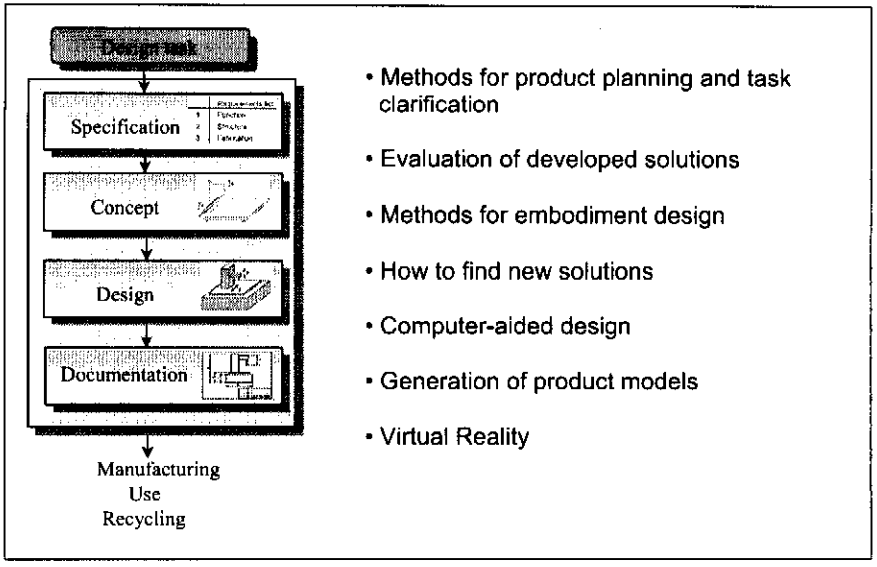

Fig. 1 Main steps of the design process and training skills for the education of design engineers

A computer-based learning environment offers the possibility to use multimedia presentations as combinations of hypertext, graphical demonstrations, video and audio sequences and animations etc. as a new means for the development of the mentioned skills and the mediation of know-how and methods.
Computer assistance can be developed based on the long-term experiences of the universities with regard to the essential contents of the curricula in the education of engineers with the structure in a mathematical, scientifically oriented basic-study period and a technical and method oriented main-study period.
This requires an adequate computer-technical and didactic preparation of the contents
The required contents of further education must be determined for engineers working in industry. The TU Ilmenau carried out a survey in 2002 and questioned approx. 50 German mechanical engineering companies (predominantly SME, small and medium sized enterprises and large enterprises, e.g., Siemens, Carl Zeiss, Leitz). The results are displayed in fig. 2.

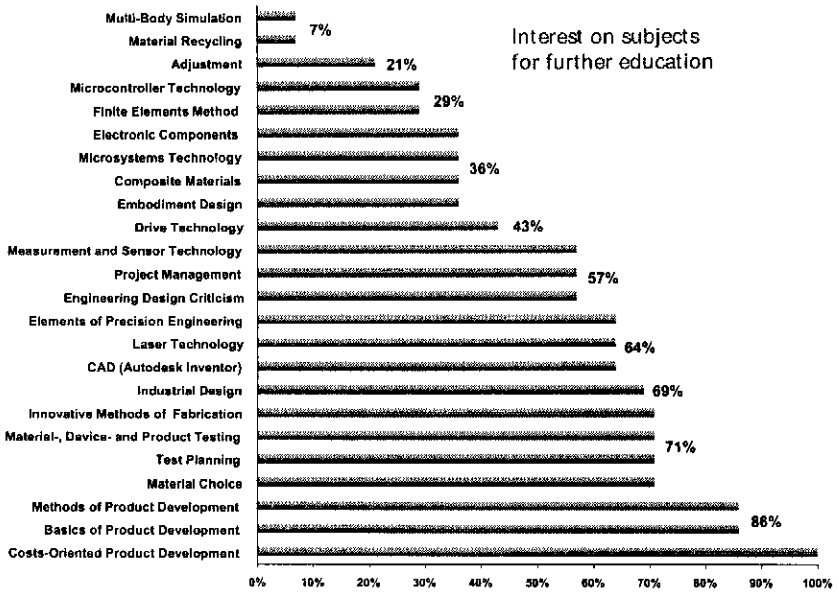

Fig. 2 Interest on subjects for further education

An appropriate combination of lessons requiring physical presence (at weekends) and computer-aided distance learning were required for the completion of the courses.
The survey also showed that the solving of current work problems of the engineers should also be a matter of interest during their education, e.g., in form of project work (training on the job). There are many different approaches and concepts for the realization of computer-aided education and further education.

3 Concepts for computer-supported education of Engineering Design and Life-long Learning

For the determination of an appropriate e-learning concept in the area of product development the didactic types of imparting knowledge need to be analyzed. The integration of Computer-Based Training (CBT) and Web-Based Training (WBT) is a step-by-step process. Previous experiences show that there will be an optimum between the extreme of a virtual, digital university and the conventional face-to-face lessons combined with self-determined education using technical literature.

Table 1 gives an idea on the didactical forms of education.

Table 1: Forms and stages of development of computer-aided education [Hö 2001]

Level of support	Lecture	Seminar	Project Work	Private Study
Conventional	Blackboards, overhead transparencies, videos, demonstration models	Blackboard, overhead transparencies, posters, flipcharts, hand-drawn sketches, individual work and teamwork	Hand-drawn sketches and hand-written texts, standardized technical drawings, calculators, lists of parts	Textbooks and other literature, scripts, teaching material for students
Computer supported, local	Presentation of texts in digital form and graphic animation, simulation of product models	Computer-lab, students' and tutor's computers integrated into a network, individual work and team work	PC, client-server-system, standard software (CAD, PPS, calculation, word processing)	PC-work station, educational software, learning on demand
WEB-based	Tele-teaching, video, audio and data transfer, fully digital presentation	Tele-seminar, bi-directional connection between different sites	Distributed work using intranet or Internet, e-mail, chat, application sharing	WEB-based private study, access to knowledge world-wide, news groups, interactive dialogue

Multimedia as a part of the method is applied in our projects as follows.

- Computer supported presentations in lectures,
  Tools: Microsoft Power Point, Macromedia Flash, URML, AVT-Movie;
- Computer based tutorials;
  Tools: CAD-systems (AutoCAD, Pro/E), Master Eye, MS Netmeeting
- Learning moduls for private Study;
  Tools: HTML, JavaScript, Macromedia Flash, VRML, AVI-Movies
- Individual and distributed project work,
  Tools: CAD-systems, MS Word, CAE-Programms, Maratech, One-Space
- Teleteaching between two Universities (transmission of lectures)
  Tools: Network with bi-directional audio-, video- and data channel

4 Exemplary realization

4.1 The e-learning platform Pro-Teach-Net

The contents of learning were compared and divided into modules for basic and main studies on the basis of curricula of 5 German universities and one university for applied science. This project was set up and structured on a mutual platform named Pro-Teach-Net.

The multimedia education content for the basic study period:

The modules of the WBT-unit for the basic studies are shown in fig. 3. In some of the modules the students have the chance to expand their knowledge with the help of exercises in the areas of design or dimensioning.

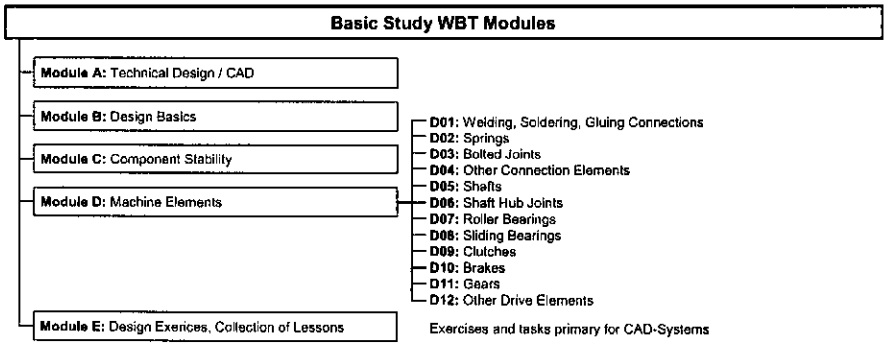

Figure 3. Elements of the learning environment for the basic study period

The multimedia education content for the main study period

The content, see fig. 4, is offered in a WBT-unit. Some of the modules concentrate on methods, some on structure and possibilities to work with information technology tools. A very important module deals with concurrent engineering which is the basis for the support of realization of virtual product development and simulation. With these contents the work in a distributed environment at different locations is trained. The students are given a training situation where they combine their solutions and complete their task during a synchronous meeting on the internet. For this reason a software solution was developed for synchronous and asynchronous communication and for the co-ordination of the course participants.

A module named "industrial product development process" is for practicing the theoretically gained know-how on the basis of case studies from industrial practice. The examples therein are composed so that reference to the contents of the learning environment is enabled by the means of corresponding links. Emphasis will be placed on displaying and explaining the typical work steps during product development and the practical handling of methods and IT tools used. In time the case studies will be amended and expanded by updated tendencies from industry. Thereby, not only a learning environment is created, but in the long run, a wide knowledge base for product development and engineering design which can be made available to wide circle of users.

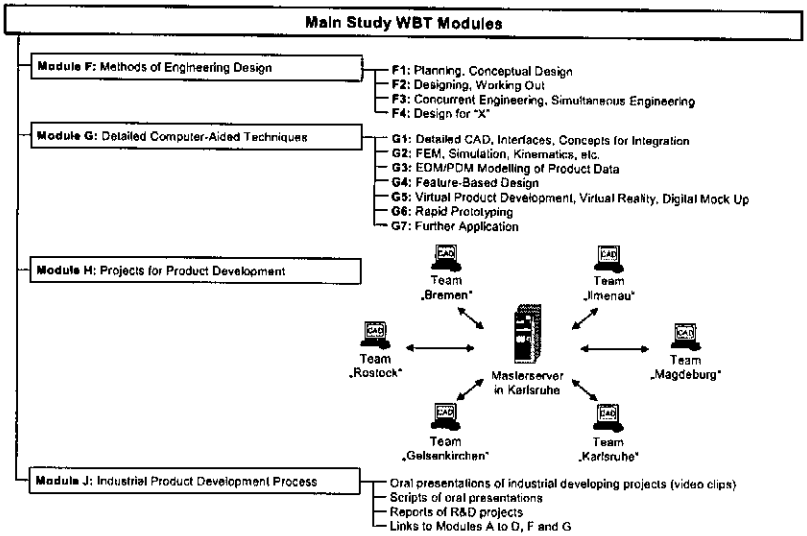

Figure 4. Elements of the learning environment for the main study period

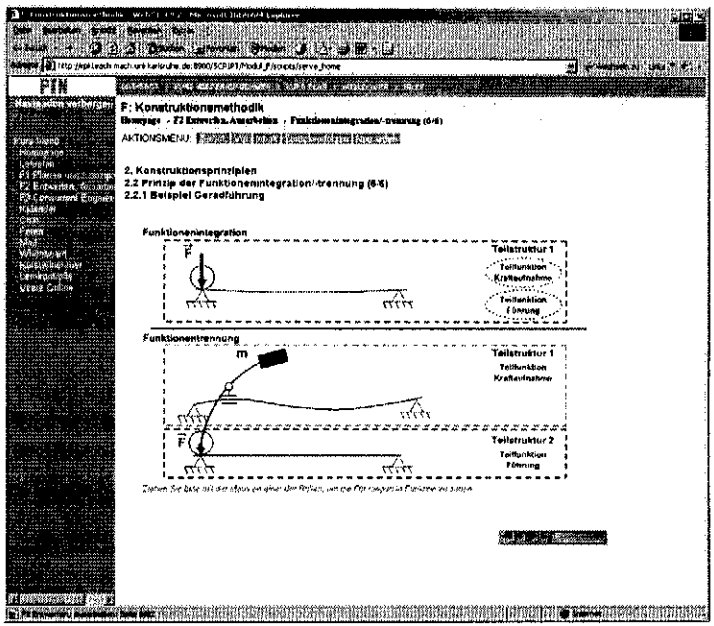

Figure 5. Example of HTML sheet, explaning the function of weight compensation of a guide by animation (the mass is moving)

Implementation of the platform Pro-Teach-Net

The learning management system "WebCT" is the basis of Pro-Teach-Net. After the test and evaluation phase, the WebCT Version 3.8 proved to be the best learning management system to achieve the project goals. The above named modules were realized in WebCT courses. Access to the WebCT-server is platform independent via the internet, so that access from a home computer, laptop or using wireless LAN is possible. During transfer of the entire teaching material as an e-learning content into WebCT, special emphasis was placed on the preparation of multimedia components (videos and interactive training). This and the navigation in terms of learning progress and the speed of learning enable individual learning. All modules are permanently updated and comply to the current state of the art. The modules also can be used by engineers coming from industry for further education so that their knowledge and competencies can be reconditioned permanently. They can either collect modules of their own interest or gain modules by following a special education plan developed by an instructor. Access to the platform is directly possible from the workplace via Internet.

Apart from the tools to create WBT-Units, WebCT also includes tools for the tutor to control training modules for self-determined learning sessions and for the communication between student and instructor, resp. between the students themselves. For the virtual product development projects Pro-Teach-Net use, in addition to WebCT, special software solutions for videoconferencing (Maratech) and for CAD-collaboration (One-Space).

4.2 Modular course of study for continuous education

Designers, engineers and technicians working in co-operation with the product development division require permanent qualification. They are addressees for this course.

Therefore, the course has to offer the adequate contents and must be flexible to follow the ongoing trends and new knowledge.

Based on the analysis of demand in the industry the following emphases are placed on the contents of the course:

- basic knowledge of methods and tools for product development,
- selection and renewal of contents,
- advanced manufacturing technologies,
- testing of contents, modules and the entire product.

During further education, the mechanical engineers working in product development have to predominantly concentrate on the following tasks instead of the basics:

- how to work in a complex environment in Concurrent Engineering,
- information on new principals and new components and systems such as mechatronics,
- how to use design techniques based on INT-technologies,
- evaluation and reduction of product costs, target costing, vario analysis.

The content to be studied is structured in training modules which are selected according to the previous knowledge of students or to the professional qualification of engineers, their field of activity and the new qualification required.

The second step is to determine and organize the teaching and learning process in a well balanced compromise between computer-based and conventional face-to-face lectures as well as group-oriented work.

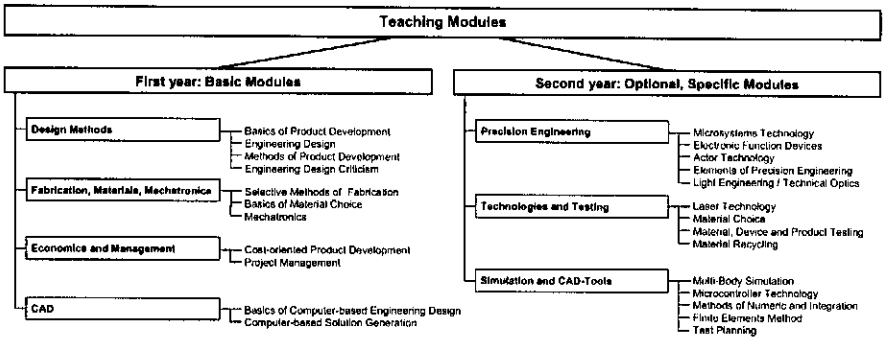

Figure 6. Modules of the education course "Innovative Product Development in Mechanical Engineering"

The modular set of subjects (fig.6) allows the compilation of a tailor-made course to the students' needs. The study periods of two years have 12 to 14 weekend presence courses (lectures, seminars, labs). This time schedule is doubled for participants doing private studies.

The following types of teaching and learning methods and teaching material are applied:

> Lectures with the professor present, print media and teaching software for private-studying, tele teaching-lectures, seminars using intra- and internet, on-site labs at the university and web-based tutorials. The teaching material is accessible for the enrolled students by download from an online information portal. A learning environment is made possible via a computer at home or at work.

Additionally, a platform is provided which enables the students to communicate with each other as well as with their tutors by use of chat, newsgroups, e-mail and file sharing.

Teaching examples:

- basics of product design (function, structure and characterization of technical products, product lifecycle, workflow in engineering design, design methods),
- computer-aided methods of product design (computer-aided searching for solutions, computer-aided variation and combination of solution principles, searching for solution principles using physical effects, engineering databases, constraint based design),
- costs in product design (formation of costs, designer's responsibility for the costs, calculation of costs in early phases of development),
- project management (defining objectives, task division, time commitment, project documentation, identification and use of resources, simultaneous / concurrent engineering).

During the phases of private study the students have to solve problems or work on projects. For this purpose design problems provided by the engineers' employers as teaching examples and as subject of the final project work can be included

4.3 Blended Learning

Computer-based multimedia simulations have been developed as a game to introduce the basic approach of Concurrent Engineering to students and engineers. Experiences are to be made to encourage parallel and cooperative working in a distributed environment.

Concurrent Engineering (CE) is an efficient method to increase the work efficiency of an enterprise and thereby its competitive ability. It is already being practiced by many enterprises, especially in the car industry and its supplying industries. It is to be ascertained that there is still a large demand in university education to clarify the possibilities of this method of working.

A multimedia simulation game was developed using the internet and with the aid of new techniques it was necessary to create a surface that can virtually reflect events very realistically.

Applications for the creation of a multifaceted communication platform, such as the use of telephone, e-mails, video conferencing and chat rooms were used.

The simulation game can be played alone against the computer or in a distributed environment, the latter being closer to Concurrent Engineering.
Different games can be played in the generated environment, e.g., simulated product development where the partners are given special tasks such as development, sourcing, production planning etc. The players learn the methods of practicability, which tools to use and also receive feedback from their activities.

The requirements from (Colb84) fig. 6 were realized here. The observations made of the participants during the simulation training were analysed and then used to develop a new concept which then lead to a new simulation game with revised praxis.

The conclusions made in the project are as follows:

- Engineers and engineer students can learn the methods and the organisation of Concurrent Engineering with the help of a simulation game.
- The developed modules have a variety of learning targets and allow effective communication and inter-cultural cooperation.
- Concurrent Engineering is mainly realized via the intranet or the internet. For the learning of methods social competency is however required for teamwork so that the approach of blended learning was of greatest importance.

5 Conclusions

This paper presents experiences in computer-supported education and lifelong learning in Engineering Design.

On the basis of requirements for the education and further education of constructers, suitable forms of e-learning in this area are chosen and the realization of these presented.
The developed Pro-Teach-Net platform offers students a web-based learning environment. The multimedia-based WBT-units support the basic and main study period in Mechanical Engineering. The network of 6 involved universities enabled the virtually entire digital production of the teaching contents in product development. In two construction projects the distributed work with the coordinated subtasks was successfully tested on student groups from associated universities with the use of specific software.

The following experiences result from the use of the described e-learning forms:

- Abstract, multi-media based descriptions of technical products are effective for education and practice when they can be used as virtual prototypes.
- The alternation of modalities between graphic and notional descriptions supports the learning and application of methods.
- The linked embodiments of an issue on different levels of abstraction stimulates the understanding of the phase transitions, from the function via concept, to embodiment.
- Complex graphical embodiments and animations are easier to understand when the explanations are not only offered in written form but also spoken form.

For the students:

- The use of multimedia improves clearness and tangibility of the teaching material.
- The learning software supports individual learning as well as group learning and is available on demand.
- The students practice the use of modern communication technologies.
- The students practice the use of engineer tools (CAD, simulation, calculation).

For the tutors:

- The computer-based learning environment is only a tool.
- The teaching activities are to concentrate on technical understanding and problem solving.
- The development of learning software is complex:
  - approx. 200 hrs preparation/programming time for a 1 hour lesson
  - approx 100 hrs preparation/programming time for 1 hour of tele-teaching
- A modularisation for study courses, areas of education and subjects taught are an important precedent for e-Learning.

References

Ehrlenspiel, K.; "Integrierte Produktentwicklung", Hanser Verlag, München 2003.
Höhne, G., Henkel, V., "Application of multimedia in engineering design education", European Journal of Engineering Education, Vol. 29, No. 1, 2004, pp 87-96.
Höhne, G., Lotter, E., Chilian, G., Henkel, V., "Using multimedia to transfer knowledge in the teaching of engineering design", Proceedings ICED'01, Vol. 4, Glasgow, 2001, pp 411-418.
Homepage of Pro-Teach-Net, http://www.pro-teach-net.de
Homepage of the further education course "Innovative Product Development in Mechanical and Precision Engineering", http://fip.tu-ilmenau.de
Kolb, D A, "Experiential learning: Experience as a source of learning and development", Prentice-Hall, Englewood Cliffs, 1984.

Malmqvist, J, Young, P. W., Östlund, S., Berggren, K.-F., Crawley, E. F., „Setting goals for design education – an approach based on the CDIO syllabus", Proceedings of NordDesign 2002, Trondheim, 2002, pp 253-260.

Müller, D.H., Klöcker, S, Kastens, J., "Netzbasiertes Management von Konstruktionswissen und multimediale Vermittlung innerhalb einer internetgestützten Lernumgebung Kurztitel: Pro-Teach-Net, Online Bildung (www.onlinebildung.de), Zentrum für Multimedia in der Lehre, Bremen, Mai 2003

Müller, D.H., Klöcker, S., Stoklasek, P., "Net-supported co-operative learning of engineering design in a virtual working space", proceedings of the ICED 03, 14th International Conference of Engineering Design Stockholm, August 2003

Müller, D.H., Scholz-Reiter, B., Gsell, H., Höhns, H., König, F, "Kollaboratives Änderungsmanagement - Bedeutung des technischen Änderungsmanagements im Rahmen des Collaborative Engineering", Journal Industrie Management, Vol 5, pp 45, October 2003

Müller, D.H., Weber, F., Thoben, K.-D., Wunram, M., "Practicising KM in a RTD Organisation - Lessons from a Pragmatic and Succesful Case", series of lectures UNICOM London, published only on the internet, May 2002

Pawar, K.S., Thoben K.-D., Oehlmann, R. "Developing Concurrent Engineering Conceptual Model and Knowledge Platform", Proceedings of the second conference on Concurrent Engineering, Research and Application (CERA), Washington DC, USA, 23-25 August 1994, pp 487-497.

Ruohomäki, V, "Viewpoints on Learning and Education with Simulation Games", In: (Riis, 1995), 1995.

Thouvenin, E., Millet, D., Aoussant, A., "Learning process for innovation in small and medium sized enterprise (SME)- a constructivist meta-tool", Proceedings ICED'01, Vol. 4, Glasgow, 2001, pp 441-447.

Tietjen, T., Müller, D. H., "FMEA-Praxis, Das Komplettpaket für Training und Anwendung", 2nd revised edition, ISBN 3-446-22322-3, Carl Hanser Verlag, 2003

Trygg, L, "Simultaneous Engineering: A Movement or an Activity of the Few?", Proceedings of the International Product Development Management Conference on New Approaches to Development and Engineering, Brussels, May 18-19, 1992.