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Application of multimedia in engineering design education

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Multimedia applications can provide enormous enrichment to the methodology of teaching, learning and learning by doing. When developing applications for the teaching of engineering design using these means of communication it is important to consider the special features of this field. This contribution gives a report on the experience gained by using multimedia applications in different ways of teaching in the education of engineering design students. In 12 years of using digital media to train students and six years of delivering compulsory lectures by tele-teaching, it has proved that the classic didactical forms such as lecture, tutorial, project work and private studies are still the mainstay of methodology. However, using information and communication technologies (ICT) in basic teaching forms has an impact on the impartment of knowledge itself as well as its perception by the students. This paper exemplifies the didactical forms successfully used in the education of engineering students. The following activities will be reported on: enhancement of conventional lectures and tutorials using multimedia; development of learning software for individual private study and its application; and delivery of tele-teaching lectures, and co-operative work during tele-tutorials.

1. Introduction

Multimedia as a mode of communication can serve as an enrichment to the methodology of teaching, learning and learning by doing. The teaching of engineering design, in particular, has specific features of relevance to the use of this means of communication.

There is currently a huge variety of activities in this field (Proceedings of the International Workshop Education for Engineering Design 2000, Proceedings of the Integrating Design Education Beyond 2000, 2000). The following is a selection of applications in use:

- Interactive software programs for modelling, calculation and selection of components (Beitz and Grote 1999, Zimmermann 2000, Homsy *et al.*, 2001) used to complement textbooks in engineering design.
- Tutors for such software packages as CAD and CAE (Mensch and Maschine Software AG 2000, Parametric Technology Corporation, 2001).
- The use of design rules, calculation programs and parametric solution variants as offered in electronic catalogues and on the Internet by component supplier industries (web2CAD AG 2002, INA Wälzlager Schaeffler oHG 2003), in order to provide support for special object-oriented design tasks.

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- Learning software (Computer Aided Learning, Computer and Web Based Training, etc.) applied to selected subjects, which are frequently used in specific areas of technical disciplines (Vetter and Wirth 1999, Feldmann and Schlögel 1999, Höhne, Lotter, Chilian and Henkel 2001).

When engineering design is being taught, these developments must be taken into account to match the requirements of industry and the rapid improvements of ICT for engineers. Industry requires engineers who have not only sound technical knowledge but also a sufficient understanding of CAE, CAD, CAM systems and their operation, uses and limitations. As teaching time is always so restricted, employing ICT in the learning and teaching process is a useful way of training students in their application. The student (later the engineer) should be accustomed to the computer work station as his or her learning environment.

2. Objectives and preconditions

One major concern of university teachers in the context described above ought to be the integration of sophisticated ICT into the teaching and learning process. The goal should be the improvement of advanced engineering skills, based on knowledge of the properties, composition and calculation of engineered products. These skills essentially consist of moving between abstraction and concretization in the description of the product, spatial imagining, and allow the student to recognize which resources will be involved in a product that has had no previous existence and to open up the range of solutions by using a combination of systematic and intuitive methods. Eventually the students have to learn how to criticize and evaluate their own and others' solutions (figure 1).

The teaching and learning materials currently available (including interactive software) offer, at best, unsatisfactory support for the training of these skills, which are important to the students' development of their problem-solving faculties.

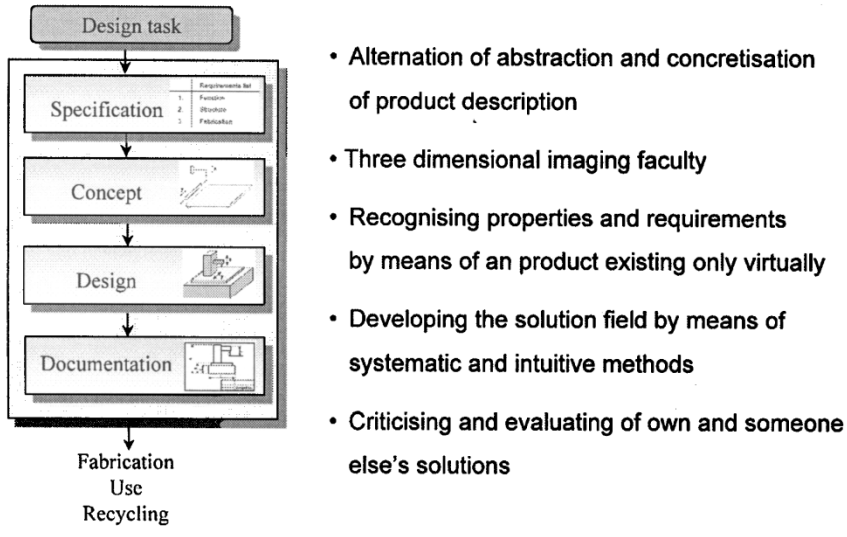

Figure 1. Main steps of the design process and skills to be trained in the education of designers.

The sophisticated techniques involved in multimedia presentation (combination of hypertext, graphics, animations, audio and video sequences, etc.) are powerful tools to develop a new generation of teaching and learning programs, as are interactive communication networks. For engineering design subjects, the main task when using these techniques is the adequate preparation of the content.

In the following some of the experiences and outcomes obtained in a project on this topic are reported.

3. Learning and teaching using multimedia

3.1. *Prerequisites*

The first requirement for the use of multimedia in teaching is the installation of computer hardware and software forming a learning environment (figure 2) consisting of equipment for private studies, tutorials, lectures and tele-teaching. It provides basic functions: access to the World Wide Web (browser); communication tools (e-mail, chat, application sharing); and engineering tools (CAE, CAD, CAM, FEM-Systems).

The production of teaching and learning programs demands a set of tools containing tools for editing (HTML, scripts, picture, video and audio), for creating graphics and animations, and for authoring and programming.

At university the students should have free access at all time to the CAD laboratories, with the addition of the learning environment as described above. To support learning at home, it will be necessary to establish a knowledge database, a set of homework tasks and a variety of learning programs, all in such a form as to permit the use of students' home PCs.

The other prerequisite is the selection and preparation of the learning content using multimedia. For this a tried and tested method is to divide the subject into teaching modules.

Table 1 shows the module concept with examples of selected subjects as a basis for elaboration of learning and teaching modules. These modules are used for teaching engineering design to students of mechanical engineering, mechatronics and materials science. The modules for machine elements courses as well as the fundamental

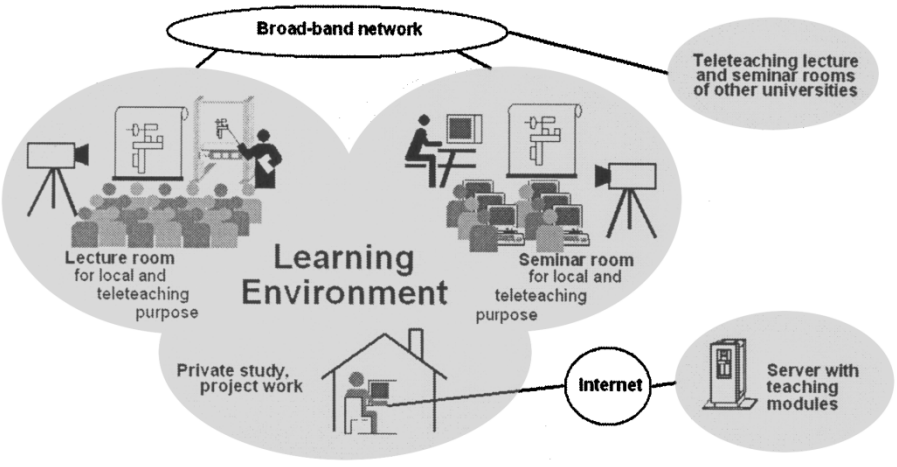

Figure 2. Components of ICT-based learning environment.

Subjects			
Design methods	Computer-based design	Design for manufacturing	Machine elements
	Modules		
Structure and description of technical products	Fundamentals	Fundamentals of embodiment design	Overview, classification
Process of engineering design	CAD hardware and software	Influences and general requirements	Joinings by form
Definition and specification of design tasks	Geometric modelling two-dimensional (2D), three-dimensional (3D)	Relationship between shape and manufacturing process	Joinings by force
Methods to establish function structures	Interactive designing	Design rules for individual pieces when drilling, milling or grinding	Joinings by material
Combination and variation of technical principles	Macro technique and design of variations	Design rules for individual pieces when bending or stamping	Shafts and axes
Methods to encourage creativity: brainstorming synectics Delphi method	Feature technology Parametric and constraint solving	Design rules for individual pieces when moulding Design rules for individual pieces made of ceramic material	Bearings Springs
Evaluation and decision methods	Computer-based dimensioning	Joinings	Gears
—	Databases for design	Design rules for assembly	Couplings and clutches

Table 1. Teaching modules for engineering design (selection).

modules of the other courses are used in the basic studies by about 250 students per annum. The modules for computer-based design courses are used in the main course by about 150 students per annum.

3.2. *Types and examples of teaching modules*

For each module it is necessary to figure out the didactic form in which it could be delivered and studied best. The basic didactic forms, the lecture, the tutorial, private study and project work can be improved by the use of multimedia as part of the methodology.

3.2.1. Computer-supported presentations in lectures

The use of multimedia is valuable when computer simulation, animation, video and audio during lectures help to explain difficult subjects and their properties, such as, for example: objects' behaviour under changing environmental conditions; dynamic behaviour of products and processes; complicated geometrical arrangements; and sequences of potential steps have to be investigated in working on a problem.

Two modes are in use:

(a) Support in respect of relevant problems using multimedia from time to time with features as indicated above. This change of medium from conventional to computer-aided presentation is a methodological enrichment. The example in figure 3 explains the term 'degrees of freedom' as a part of the module 'Fundamentals of embodiment design'.

(b) A lecture that is entirely supported by the computer. This involves preparing each didactic step from beginning to end in order of presentation (e.g. as a PowerPoint presentation). However, the teacher still has some scope for a response to the students' reactions, and can bring in a personal point of view on the material. This also applies to tele-teaching. Using this method, it is important to keep the students in an actively receptive state. A well-tried way for this is having the students complete accompanying teaching materials during the lecture (figure 4).

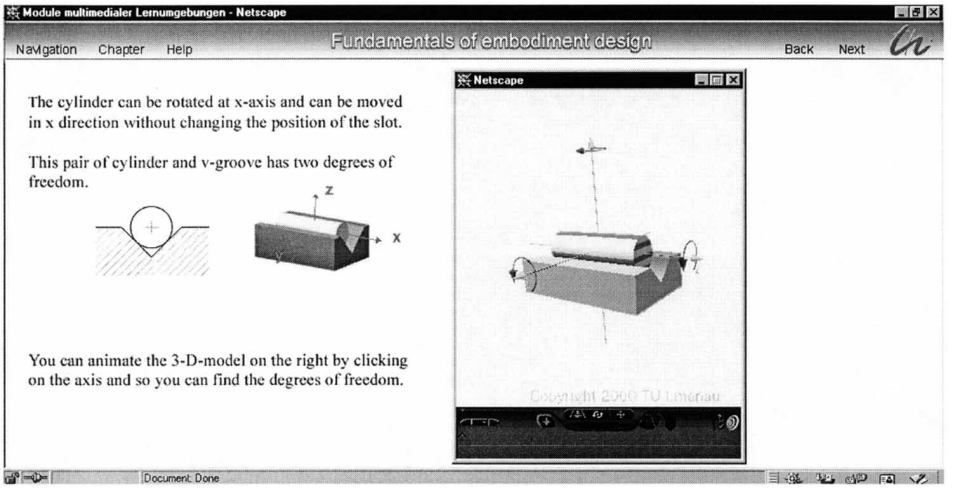

Figure 3. Interactive 3-D animation explaining degrees of freedom for students in the second semester.

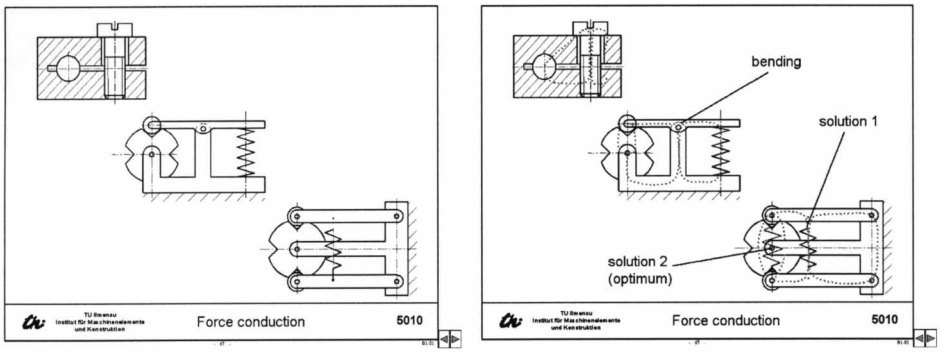

Figure 4. Teaching material for students to complete during the lecture.

3.2.2. Computer-based tutorials

Tutorials based entirely on computers require a considerable amount of technical equipment: a PC for each student, a control module for the tutor and projection equipment to enable the content to be presented visually to the whole group at once. Academic learning, the acquisition of skills with hardware and software and work on set exercises are enabled by means of an interaction between student and computer, communication between student and tutor, and problem-solving on an individual or collective basis.

In tutorials on 3D-modelling, the students become familiar with the relevant software and can exercise the order of steps for modelling. To enable students to develop new solutions and to communicate ideas rapidly, hand-drawn sketches are most effective. When the tutorial is about design for manufacturing, each student can work through a number of possible variants individually (figure 5).

The tutor can keep a check on all the student workstations from his monitor and help where necessary or can present interesting solutions for discussion to all students.

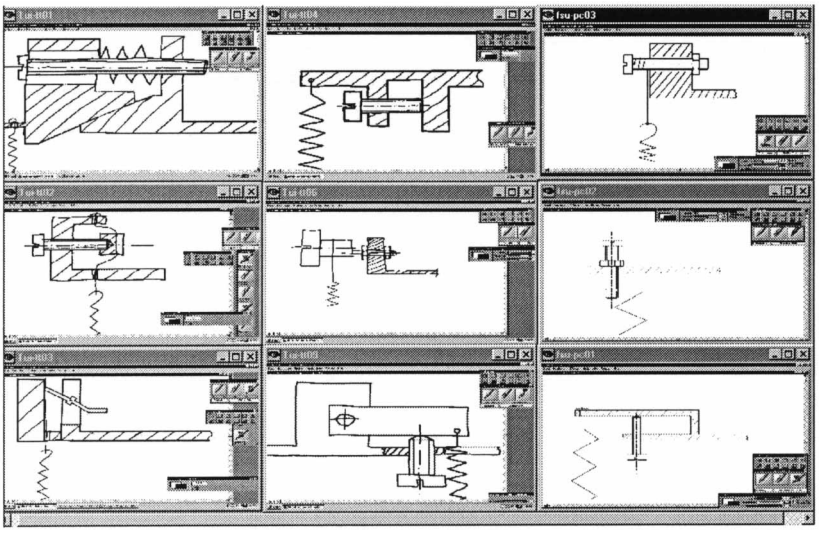

Figure 5. Control monitor of a computer-based tutorial with the students' individual solutions. (Task: adjustable fixing of a spring.)

3.2.3. Learning modules for private study

Software for this purpose needs to have the following features: guided teaching as well as free navigation through the material; interactive learning; the opportunity to use tools in solving problems; and support for a system of checking the actual knowledge transferred.

Figure 6 shows a screen shot of a learning program belonging to the module 'Structure and description of technical products' mentioned in table 1. It contains the procedure of the analysis, explanation of each step, interactive work on the system description at different levels of abstraction, a glossary with description of important terms and error detection with immediate reports to the student.

3.3. *Producing teaching materials and programs*

With the module concept as already established, the production of learning programs will follow the working steps in figure 7. Firstly, the teacher has to select and define the content of the relevant teaching module and relate it to the didactic form (lecture, private study or tutorial). Figure 8 shows the preparation for the animation of a casting process.

In the project reported here, the following tools and technologies have proved their worth:

- For lectures: Microsoft PowerPoint, Macromedia Flash, VRML, AVI-Movies.
- For private study: HTML, JavaScript, Macromedia Flash, VRML, AVI-Movies.
- For tutorials: CAD-Systems (AutoCAD and Pro/E.), Master Eye, MS Netmeeting.

The heaviest workload for teaching staff is the preparation of interactive learning modules for private study.

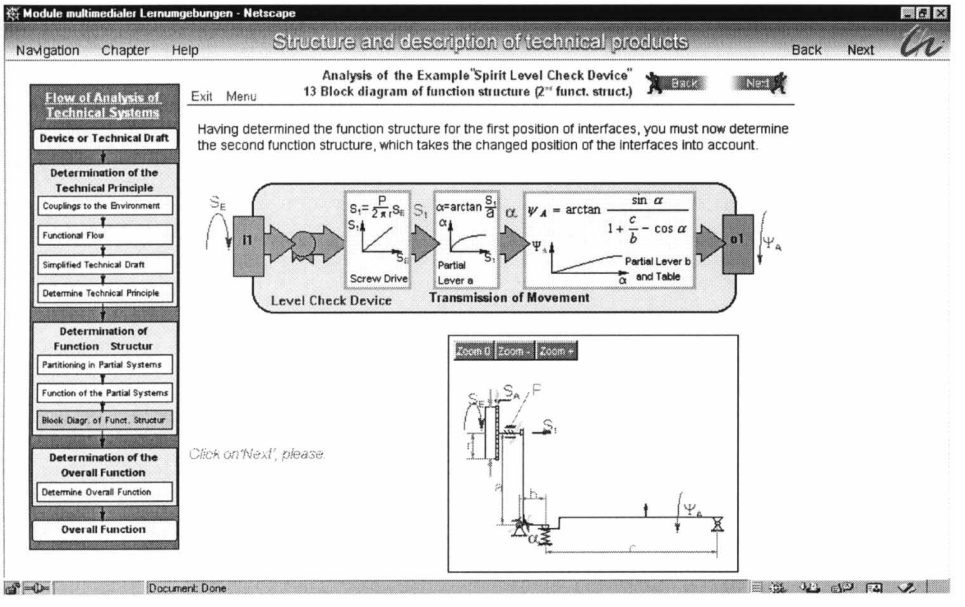

Figure 6. CBT program to train students in abstracting and modelling for design purposes. The block diagram on the left describes the steps for the interactive learning procedure.

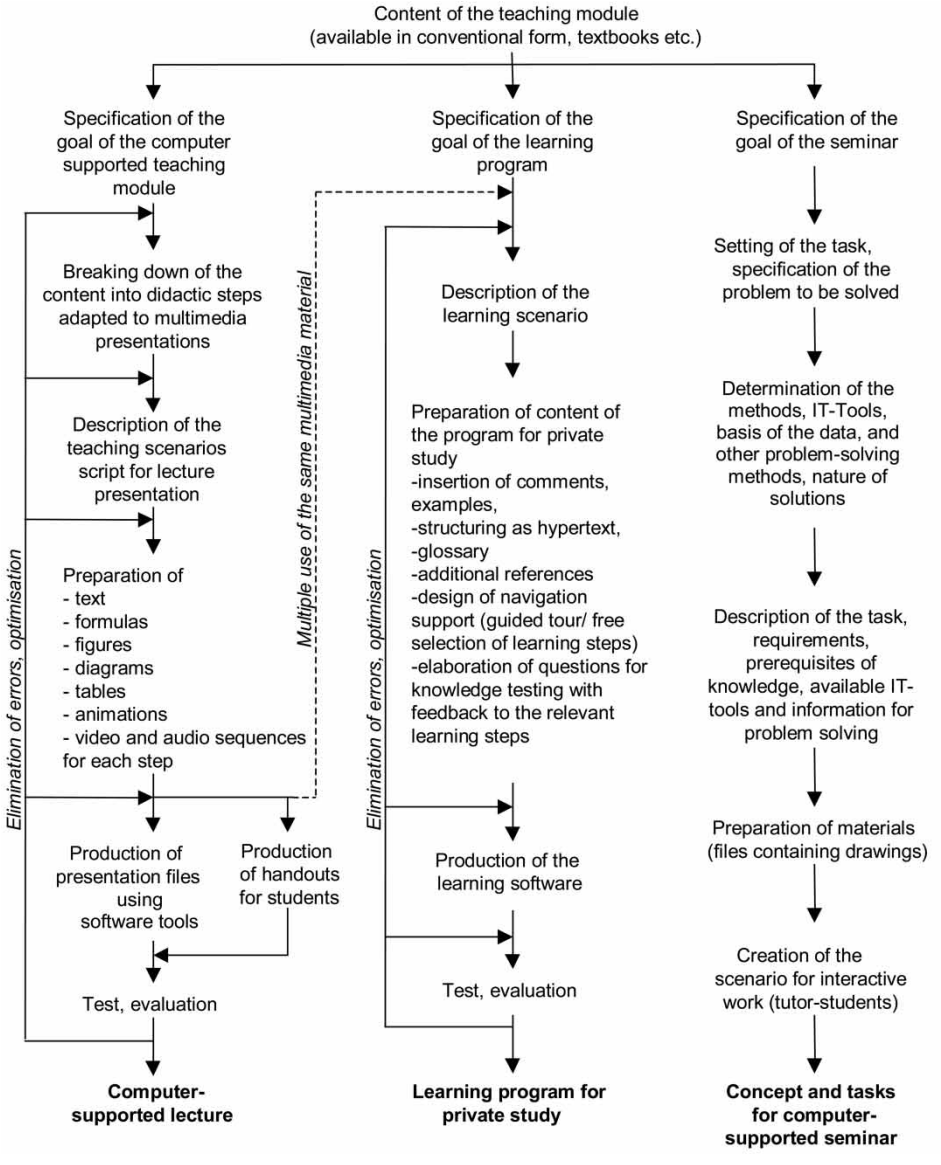

Figure 7. Producing the teaching materials and programs.

Teaching modules as shown in table 1 have been applied and obligatory courses involving tele-teaching lectures as well as tutorials with a set of modules have been introduced into university teaching at TU Ilmenau.

About 30 students of basic course filled in a questionnaire to evaluate the courses. The questionnaire was on quality of the presentation of knowledge compared to conventional courses. The evaluation by students gave the following results:

- Using multimedia function as animation, simulation, interactive operation, etc. improves the presentation and clearness of the subject.

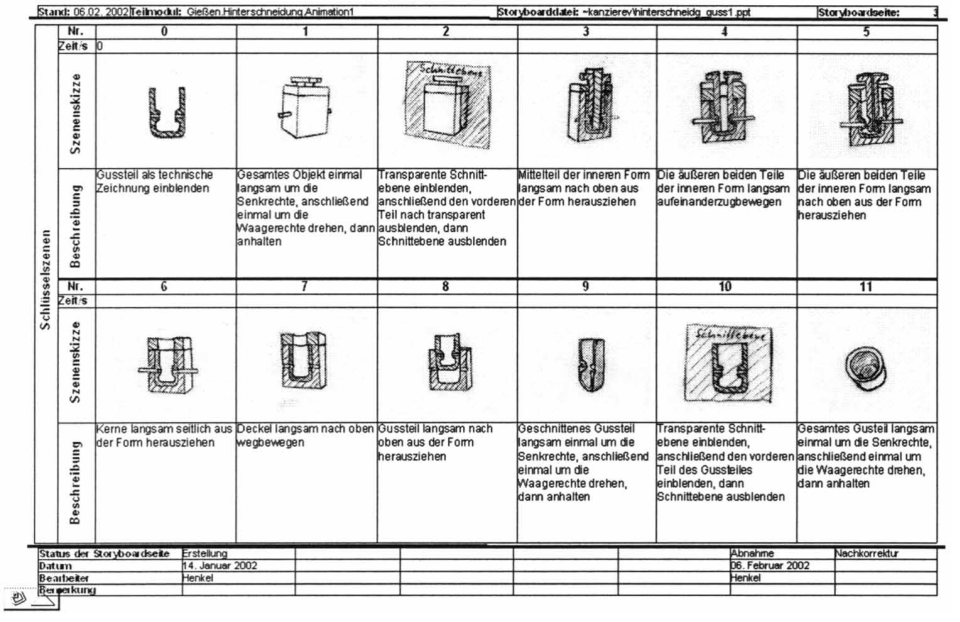

Figure 8. Storyboard of an animation describing the sequence of important states by key frames.

- Students acquire familiarity with information, network and communication technologies, and with engineering software tools (CAD, calculation, simulation, database, etc.).
- The use of different software tools supports interdisciplinary working.
- The students prefer computer-supported teaching to conventional forms.

4. Conclusion

Employing multimedia in the transfer of knowledge for the teaching of engineering design improves effectiveness of learning, understanding and problem-solving in complex technical subjects, and supports the development of skills in the use of engineering software packages and the information technology environment.

The introduction and use of a computer-based learning environment imposes new requirements as to teaching approaches, and involves exact preparation of the didactic steps in so far as they necessitate sophisticated means of interactivity, visualization, data manipulation, etc.

The preparation of lectures and the development of learning software do require considerably more work on the part of the teacher than unsupported work (approximately 200 h of preparation are required for 1 h of private study, and about 100 h for a lecture hour).

Putting ICT to use means that subjects and courses have to be modularized. This gives the opportunity of introducing teaching modules step by step with feedback so that they can be optimized. The workload can be shared to good effect between teachers and universities in co-operative projects.

In the next period, the focus of work is on developing learning programs, their application to practice, the completion of the necessary learning modules, the installation of

platforms for effective management of the computer-based courses and the exchange of modules between universities. In Germany networks of universities have been established for this purpose. The projects include co-operation with industry.

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