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Instructional Use of Engineering Visualization: Interaction-Design in e-Learning for Civil Engineering

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Abstract

The main course at the Institute of Structural Concrete (IBB) of Graz University of Technology has been supported by the e-Learning project iVISiCE (Interactive Visualizations in Civil Engineering) using a web-based course management system since the year 2000. Within this project a large number of animations, simulations and visualizations have been created that are used as Learning Objects (LO). The most interesting part, however, was the creation of Interactive Learning Objects (ILO). These require the students to operate the visualizations interactively by themselves. During the design and development of these ILOs we considered aspects of Human-Computer Interaction (HCI) and User Centered Design (UCD).

1 Introduction

The lecture Structural Concrete (Sparowitz (1995, 2001)) is a required subject for the study of civil engineering. It is one of the largest lecture elements of the whole course. Every year about a hundred students attend the lecture to learn more about structural concrete buildings. The basic content is the design and construction of reinforced or pre-stressed concrete structures using the European Standard Norm (EC2 (1992)). Because of the non-linear behavior of concrete it is very difficult to describe engineering models and to understand the complex connections between, for example stress and strain. All too often it is not possible to explain such problems with a few words or only a drawing on the blackboard (see section 2). To show the coherences between load and required reinforcements many complex images are required. As a course management system we rely on the “Hyperwave e-Learning Suite” (eLS, http://www.hyperwave.com).

2 Animations and Visualizations

Our considerations were that the most common mode of instruction is verbal. In explaining how the reinforcement of a concrete beam works, for example, an instructor is most likely to rely on printed or spoken words. There are several findings which show that lectures supported by animations are advantageous for a positive effect on learning (Mayer & Moreno, 2002), (Tversky, Morrison, & Betrancourt, 2002). Although the effect on learning is disputed, the motivation of the student can be enhanced and thus an indirect positive effect on learning occurs (Holzinger, 1997, 2001a). Thus it is important that the animations point out the basic matter without showing all the details. The goal is to improve student understanding of engineering problems by animating essential topics. Furthermore, animations save valuable lecture time because it is not necessary to draw all the explanations on the blackboard. The simulations can be shown via laptop and projector, followed by a discussion about the main topic. Consequently and having in mind that learning processes can be activated by doing, we decided to take further steps towards Interaction.

3 Interactive Learning Objects (ILO)

Our guiding principle for the development was “Learning By Doing”, where (Dewey, 1916) argued that one learns through direct experience which means by engaging in authentic tasks. Learning is thus not a process of transmitting information from someone who knows to someone who doesn't ~ rather, learning is an active process on the part of the learner, where knowledge and understanding is constructed by the learner (Holzinger, 2000). Moreover, we consider learning also as a social process: learning proceeds by and through conversations.

3.1 Development

During the development of the first interactive learning objects the main idea was to create visualizations that require the students to act independently. It is important that the exercise be defined very precisely for the students because a learning process can only be activated when the student operates the objects themselves. Therefore the animations are designed so that the students can interact with them, thus aiding learning in real-time. The interactions were designed and programmed with Macromedia Flash (http://www.macromedia.com) by using the programming language Action Script, which is an object-oriented language comparable with a very small version of java but it is possible to make the output dependant on user interaction.
An advantage of Flash is the vector based technology, which generates small files for the internet, a very important aspect for students who only have very slow connections to the internet. The Flash environment also allows visualizations of experiments and descriptions of the corresponding calculations to be designed very easily. The didactical concept of the interactive learning objects is in accordance with the principles of instructional design of Gagne (1992).

3.2 Major Parts of the ILO

3.2.1 Information and Learning-material

There are 3 elements that must be presented to the student for a structural learning process: the information to be learned (advanced organizer), the core material and a carefully selected problem. The first screen of the ILO is a start screen comparable with a homework assignment. Only a few words sketches explain the problem. The explanation must be understandable for the target group. It is particularly important to gain the attention of learners at the beginning of a lesson (Gagne, 1985; Wilson 1993) so the students can focus on the main instructional points of the lesson. With the aid of a noticeable button, the learner can navigate to the next screen. Here, the tool is explained. First the learning target of the tool is pointed out and then an overview of the screens is given. The necessary previous knowledge and the estimated learning time are also provided. The main part of the ILO consists of the main screen, where the exercise must be solved by the students. As a result of the user based input, the tool calculates and animates the engineering model. Thus learning in real-time is made possible. It is very important, that the exercise be randomly generated, allowing the students to practice the lesson repeatedly. The next screen is the help-screen. Here the main principles of the interactive example are explained. The students are provided with information about the basics of the engineering model, but are not given the solution. The content of this screen shows the theoretical background in sketches and formulas.

3.2.2 Communication

The second part of our tool consists of communication and co-operation. The great possibilities of the internet have been used to give appropriate assistance during the learning process. With the aid of the learning-management system, discussion forums on the several topics dealt with in the interactive objects were opened. Chat and e-mail have also been used extensively to discuss problems that occurred. Only after numerous discussions in the newsgroups were the real problems in understanding the content of the course material properly identified. Due to this intensive conversation, the quality of learning has been noticeably increased. Communication via the Web and the learning-management system became the main focus for the lecture course because these tools also enabled the tutors to address misunderstandings during the learning process.

3.2.3 Assessment

The last part of the ILO is a multiple-choice test where the major points of the example are tested. The questions are carefully worded and require the students to understand the entire coherences of the tool. This allows the students to monitor their progress and determine where they need more practice on their own.

4 Methods

Observation and testing our work with real end-users proved to be the best way to understand the effectiveness and suitability of our ideas. During the development of our ILOs we committed ourselves to User-Centered Design (Carroll, 1987), (Vredenburg, Isensee, & Righi, 2002), including thinking aloud, cognitive walkthrough and video analysis and incorporated knowledge from the area of interaction design (Preece, Sharp, & Rogers, 2002), (Shneiderman, 1997) following the recommendations of (Stephanidis et al., 1999). Concerning the research in motivation and learning we relied on qualitative methods including interviews (Gall, Borg, & Gall, 1995). We are currently carrying out a quantitative research using the pretest/posttest experimental control group design with questionnaires, but the results were not yet available at the time this paper was printed.

5 Results and Discussion

Generally it was interesting to notice the similarity between Civil Engineering and Medicine - learning in both fields are supported well by using ILOs. Especially the mix of (real) lectures together with the online material proved to be successful. The basic findings were that through the use of ILOs the students were able to understand the content more in-depth. Some students and teachers argued that "it is more play than serious and hard studying". Most of the students and teachers, however, urged us to carry on. A further perspective is that our ILOs are internationally reusable by applying the concept of metadata (Holzinger, 2001b).

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