Student experiments in object-oriented modeling

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Abstract Exploration modules (EMs) and structures of knowledge as essential components of the author's concept "Didactic system for object-oriented modelling (OOM)" for improving the OOM education are introduced as new learning aids for student-centered learning. The didactic criteria "Basic concepts on different abstraction levels" and "Synchronization, transformation and evaluation of views" for the design of EMs are developed. A methodology for designing a "didactic map" of object-oriented basic concepts as a process oriented learning aid is described. The activities of learners when using EMs with the solution of complex problems, e.g. modelling a library system, are illustrated. The strategy for inclusion in the Informatics teacher education is connected with some words on the concepts' efficiency.

1. MOTIVATION

Good career prospects in the Informatics field led to an enormous increase in the number of Informatics study beginners at German universities from the middle of the nineties. According to the German Federal Office of Statistics, the total number of Informatics study beginners (first university semester) has risen steadily from 4611 in 1995/96 to 11496 in 1999/2000. The Informatics faculties can hardly cope with this crowd. For example, in the semester 2000/01 the University of Dortmund had to schedule lectures repeatedly per week due to the entry of about 1100 beginners. The load on students and lecturers was enormous. According to information from the German "Fakultätentag Informatik" (steering committee of all accepted German Informatics faculties) the ratio of graduates in relation to study beginners has fallen from 50% in 1999 to 45% in 2002. This reflects an

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increase in the number of university dropouts and also in the study length of students. There is a need for a change in the study processes. In the year 2001, the German Ministry of Education and Research started to support about 100 university collaborative research projects in the field "New Media in Higher Education". About a fourth of these projects were Informatics projects. Multimedia e-learning materials were developed to support student-centered learning and to relieve overburdened Informatics faculties. The work of consortia like the "European Consortium of Innovative Universities" [4] extends this approach to an international level.

Besides the development and distribution of e-learning materials, the Informatics study must be developed further by including new learning forms and learning aids so that student-centered learning, self-paced learning, and the preparation for lifelong learning become essential structuring elements of the learning process. Learning concepts, which should be taken into account in this context more strongly, include active and explorative learning [5, p. 150]. Traditional learning scenarios in higher Informatics education do not include enough such natural learning forms. An auditorium is a difficult environment for learning by discovery. Within the approach of "discovery learning" the teacher should design the learning process as a sequence of problem situations, each involving a learning task, which stimulate the learners' research interest. Suitable result-oriented learning aids are necessary to support learners in their explorative learning process.

Brinda and Schubert developed a concept called "Didactic system for object-oriented modelling" as a combination of traditional and new studying concepts [2, 3, 7]. The concept addresses beginners in object-oriented modeling (OOM), selected for the study because of its relevance in a variety of Informatics areas such as software engineering and object-oriented databases. The main goal of the didactic system is to bring a new quality of learning to the OOM field. The didactic system makes it possible for learners to navigate in structures of knowledge, to construct solutions for exercises from exercise classes, and to learn by discovery with exploration modules (EMs). In the context of this paper, EMs can be thought of as software modules (small applets, applications and animations). In a wider sense, learning texts and other media are included to form more complex EMs. Here the main emphasis lies on structures of knowledge and the embedding of EMs in the social process of Informatics study. Exercise classes are discussed in [2].

2. EXPLORATION MODULES AS NEW LEARNING AIDS

Discovery learning strategies are often applied by Informatics students as a work reduction strategy. They discover and then reuse standard algorithms from textbooks. The same strategy is used with software libraries. Available solution parts are adapted and integrated in the solution of new problems to avoid repeated development. This intrinsic motivation, which lies within the subject, led to the concept of the EMs. Learners explore EMs in suitable learning scenarios and in that way learn about basic object-oriented concepts and object-oriented models.

Within the design of EMs, manipulative and perceptive ways of exploration have to be considered. Manipulative exploration allows the exploring person to change something and get immediate feedback. The EM has to provide specific manipulation and observation components, combined with check mechanisms. Perceptive exploration requires structures that can be discovered. Therefore, the EM has to offer multiple cognitive approaches, which show the explored object in different ways and combine or even synchronize different views to visualize complex structures. By didactic analysis of the OOM field indicates that beginners should get to know and design structures (static basic concepts) and understand and control processes (dynamic basic concepts). Starting from an application they should analyze, modify, construct, and assess object-oriented models in the stages of structure element, structure, and model. This results in the exploration promoting features of EMs shown in table 1.

Table 1. Exploration promoting features of EMs

Feature	Description
Basic concepts on different abstraction levels	Structures, their elements and models must be explorable on different abstraction levels to give learners with various pre-knowledge a cognitively demanding entry to object-orientation, i.e. the complexity of views ought to be adjustable. It has to be possible to switch on or off selected views. For beginners as a minimum of one static view (class diagram) and one dynamic view (interaction diagram) are necessary to describe the structure and the time change of an object-oriented model.
Synchronization, transformation and evaluation of views	Synchronization represents a "didactic bridge" between different diagrams. This makes it possible to bring the single views together to a picture of the complete system and to overcome a known cognitive barrier. For some educational purposes, it should be possible to synchronize different views automatically. If learners do this manually, model check functions must be provided to prove the model's consistency.

In the study year 2001/2002 the author was leader of a student project group which developed EMs as a “Learning Environment for Object-oriented modeling – LEO”. At the University of Dortmund the “project group” is a compulsory course for advanced Informatics students. For two semesters and 16 hours per week, eight to twelve Informatics students work in a team on the solution of a large programming task. The collection of EMs, which the group developed, is based on the features discussed before. Within LEO, learners can select “scenarios”, e.g. “mobile communication” or “library”. In traditional learning processes, it is hardly possible to discuss all solutions discovered by the learners. EMs can help in that more learners get individual feedback. In section 3 the inclusion of EMs in the study process will be discussed with concrete examples.

2. DEVELOPMENT OF A DIDACTIC MAP

Discovery learning results in a qualified structure of knowledge. Not very much is known about the process of its development. A didactic map is a process-oriented learning aid on which individual exploration paths between concepts can be marked. The map provides better orientation in and self organization of the learning process. The didactic map is also helpful for learners to reflect on and to assess their individual knowledge construction [1].

Table 2. : Procedure of development of the didactic map for object-oriented basic concepts

Phase	Activities
1. Construction of a list of OOM concepts	Analysis of textbooks, journals, internet resources on OOM and extraction of typical concepts
2. Filtration of the concept list	Definition and application of didactic selection criteria: <i>Affiliation to OOM</i> : Concepts, which do not belong to the OOM core e.g. memory principles, are removed. <i>Redundancy</i> : Only one representative of synonymous concepts remains in the list. <i>Generic terms</i> : Generic terms are preferred to specializations. <i>Language specificity</i> : Language specific concepts are removed. <i>Relevance</i> : Concepts without relevance for the target group are removed.
3. Structuring of the concept list	Identification of concept classes and sub classes in the list (e.g. object, class, variable, method, relationship, diagram) and classification of the concepts of the list
4. Visualization as a mindmap	Visualization of the structure and the neighborhood relationships within the list as a mindmap
5. Transformation of the mindmap to a didactic map	Mapping of classes to continents, subclasses to states and concepts to cities and description of possible connections between concepts of different quality as e.g. roads or highways

Phase	Activities
6. Connecting the map with EMs	Provision of EMs, which allow discovery of neighbored concepts, each in one area of the map
7. Discovery journeys through the lands of OOM	Planning of discovery journeys within the lands of OOM Technical support by colorization mechanisms that indicate which areas have already been visited

The analogy between structures of knowledge and a map is useful: neighbored concepts can be connected with roads, learning barriers can be visualized, for example as rivers and hills. A more formal mode of didactic maps called “And-Or-Graphs” has been introduced in [2]. The explication of the relationships between concepts stimulates learners to build up their own structures of knowledge by using EMs, which help them acquire a set of covered concepts by exploration. Depending on the phase of the learning process, a didactic map can be given by the teacher or be developed in the team. Beginners, who need orientation in the learning process, will be given a version of the didactic map to see which EMs cover which parts of the map. Advanced learners can refine and enhance a given map or develop new ones to explicate their structures of knowledge.

Within the scope of the LEO project a didactic map has been developed for the field of object-oriented basic concepts. In table 2 the procedure of its development is described. Educational phases, which make this possible, are designed as a discovery process to promote the learners’ individual knowledge construction. The teacher requires the structuring of the individual findings of the learners and their connection with the theory of object-oriented modelling. Learners are not left alone with their problems; they become integral an element of the discussion. This concept is suitable for exercises, seminars, and traineeships; but in the context of notebook universities, it is also suitable for lectures.

3. INCLUSION IN THE STUDY PROCESS

An explorative approach is not a trial-and-error strategy. The learner’s ability to form a hypothesis is sharpened, because with the help of EMs they build up hypotheses that they later refute or validate. This requires the discussion of systematic exploration strategies as well as basic knowledge of OOM.

In the example case, the first aim of the learners was to simplify the work processes in a library with an informatics system. Previous knowledge of the learners consisted of the static- and dynamic basic concepts of OOM and the script language Python. The learners work with EMs, which support the exploration of models and process steps within the library example. They transfer their findings about model elements and the construction of model views onto their own designs and the models thus take on a tactical role [6]. An EM provides a possible textual specification of the library system and identifies object, class, method, attribute, and relationship candidates within

Figure 1: LEO - object view of the library scenario

the text by application of text based heuristics. The learners explore steps of a process model, which results in a first version of a class diagram. They rediscover the concept of inheritance with the example of the two similarly structured lists: titles and users. In the class view, the EM therefore inserts an abstract list class as a super class over the specialized list classes. At first, the list class does not contain any attributes or methods. That allows learners to “move” suitable attributes along the inheritance relationships. To understand how system objects cooperate in the final library system in order to realize the system aim, an EM is provided that visualizes the usually hidden message exchange. Starting from a class diagram learners instantiate

objects and construct an object diagram (figure 1). They then check whether an object diagram is consistent with a class diagram.

In the object diagram, they invoke methods of the objects, observe and check the state changes and simulated message exchange between the objects. Accompanying to the explorative phases, the group constructs solution parts of the library problem in the team. Assumptions of the learners regarding the problem specific objects, attributes, and methods are collected and systemized in the team.

In the following, each learner selected a field for which he or she wanted to design an informatics system. They proceed strategically because they identify the problems and rediscover methods with EMs to solve them. The learners work on their chosen problems and construct a class diagram and a sequence diagram for each essential method. Here the change and the combination of model views play an important role. To become aware of the consideration of consistency and completeness of models, the learners use an EM with which they construct class and sequence diagrams for their models. On demand, the EM checks the consistency and indicates missing model elements (e.g. missing methods in the class diagram or contradictory signatures of methods) based on the constructed models. The learners evaluate these reports and understand how completeness and consistency can be achieved. Logical mistakes or missing classes cannot be identified by the EM. The learners present their results, analyse and discuss them with other students. The evaluation of this reflection helps them with the solutions of their own problems. Moreover, the learners select and apply EMs of the library example to refresh their knowledge about the interplay of the different views. A better picture of the relationship of static and dynamic models is achieved, which the learners transfer to their own problems.

EMs have a pedagogical double function because they can be learning aids as well as the lesson object. Advanced learners analyse EMs and their development documentation (analysis, design, and source code documents). Successful structuring ideas are identified and generalized within the group. The learners reflect these findings and include them in the solution of their own problems. In project groups, they can also develop new EMs, which will be used as learning aids for following student generations.

The concept “Didactic System for object-oriented modelling” has proven its success in a number of fields. It has been used successfully at the University of Dortmund for the education of student teachers of Informatics [3]. In several in-service training sessions for Informatics teachers in Germany as well as in Denmark the author received positive feedback. Materials distributed within the author’s departmental electronic library (<http://ddi.cs.uni-dortmund.de/iml/>) were praised by German Informatics teachers. These materials have also been used successfully for a lecture

called “Introduction to Informatics for arts scholars”. The underlying development concept has successfully been adapted for a German government project and a European project on e-learning.

4. BIOGRAPHY

Torsten Brinda was born in 1972. He received his diploma in computer science from the University of Dortmund (Germany) in 1998. In 1998 he became assistant professor in Didactics of Informatics at the University of Dortmund. From 1999 to 2001 he was manager of a multimedia project in teacher education. From 2001 to 2002 he was the leader of the LEO project. His research interests are concepts for e-learning and learning and teaching object-oriented modelling in secondary- and higher education. In 2001 he received the “best paper award” of the German national conference on “Informatics and School – INFOS2001”.

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