Using Learning Objects in an ICT-based Learning Environment

Johannes Magenheim Olaf Scheel
University of Paderborn
Fürstenallee 11
D-33102 Paderborn
jsm@upb.de olasch@upb.de

Abstract: The Didactics of Informatics research group at the University of Paderborn is involved in efforts to design implement and evaluate an ICT-based learning laboratory for informatics (ILL). The ILL mainly serves the purpose of an open interactive learning environment for software engineering. First the article discusses the main components of an ILL and the types of media that are used. A didactical concept, learning strategies and the efforts to create self-organizing learning communities in the ILL are also topics of the paper. Students are supposed to use the learning objects, the software tools, the groupware functionality and the documents of the open learning environment to put constructivist learning concepts within a scenario of blended learning into practice. Therefore, collaborative learning processes in the ILL should be problem-based, project-oriented and situated. The article deals also with the construction and the granularity of learning objects, their integration into learning processes in the ILL and the evaluation of the learning processes.

Introduction

During the last two years several projects with participation in the Didactics of Informatics research group at the University of Paderborn have been granted by the Ministry of Education and Science of the State North-Rhine-Westphalia and the Federal Ministry of Education and Science of Germany. Thus, the idea of the Informatics Learning Lab occurred and was put into practice. Major tasks of the ILL are

- to integrate the various results and activities of the working groups projects into learning and teaching practice in didactics of informatics at university and thus foster a sustainable development towards student-centred learning concepts;
- to offer students an interactive web-based multimedia exploration platform to enable constructivist types of blended learning at university;
- to link learning communities and communities of practice in the area of computer science and didactics of informatics;
- to create a forum of didactical open source materials for university courses and classroom works in informatics to which students, university staff, software developers, teachers and pre-service teachers may contribute;
- to construct learning objects and to investigate their integration and their use in self-organized learning processes in an open collaborative learning environment.

Creating Learning Communities in the ILL

Dimensions of Learning Design

To meet the requirements listed above and to enable students to realize strategies of self-directed learning we need an interactive web-based learning environment. In a preliminary specification we may say that the ILL consists of an open exploration environment containing a technical learning platform with a variety of digital media and a design for blended learning. After having a closer look on an ILL we have to take several important aspects of ICT based learning into consideration:

The *didactical context* which has to care about

- models and roles of learners according to learning theories,

- the decision about objectives of the learning process,
- the selection of content.

The *organizational context* which regards

- the methodical concept of the learning processes,
- the use and integration of media into learning processes,
- the interaction inside and between learning groups and the creation of learning communities.

The *technical context* which has to provide tutors and learners with a learning platform for

- technical support for group interaction and communication,
- a content management system,
- a user and account management system,
- digital media with a variety of functions for learning processes,
- content-related documents and individual data collection for students,
- assessment tools.

Designing a learning scenario within the ILL requires decisions in these different areas. It is also conceivable to describe scenarios like that with items of an educational modeling language (EML) (Allert et al. 2002).

Content and Objectives

An ILL serves the purpose to impart knowledge about fundamental concepts of informatics. Students should learn about software-engineering and designing socio-technical information systems. By socio-technical information systems (IS) we may understand the unity of software including the graphical user interface (GUI), the hardware, embedded systems for control and regulation of peripherally technical processes and for communication with other IS and, last but not least, the associated social action system of people, who are interacting with the IS and with one another. The technical part of an information system is exceedingly connected with its social part, by human computer interaction (HCI) and further direct or indirect technical functionalities of the information system, affecting the interactions of humans with the system and the interaction between people.

Designing a socio-technical information system means to create a model of a part of social reality, to code it into a programming language as a text and to implement and evaluate it. Therefore, it is necessary during learning processes not only to have a look at the product 'software' but also to pay attention to the process of its development.

This means to examine different phases of the software life-cycle, to learn about quality assurance and usability tests of software in practice. Students ought to learn that software represents and materializes social processes from its social context. In the process of software development a model of the future system's functionality and its integration into the working and social context has to be generated. The product 'software' also can be considered as a result of communication processes between developers, customers and users.

Methodical Aspects of an ILL

To mediate comprehension of these aspects of system design specific methods of teaching and learning are necessary. We need a didactical and methodical approach to make these important processes that are hidden behind the products surface perceptible in order to gain a better understanding of informatics and concepts of software development. Beside the methods of teaching algorithms, developing a small software or constructing a tiny IS within a course-project informatics has a need of computer-based tools for modeling and for the exploration of existing IS. In complement to the method of constructing a software, the method of deconstruction of software is not only a methodical alternative in informatics courses but also offers students the opportunity of discovering new styles of learning and focuses in a special way on the modeling and design process as well as on the social implications of information systems.

Software has different forms of appearance and allows different views to discover it: We may have a look on the source code and see classes, methods, algorithms, programming language structures or even informatics concepts as e.g. the problem-solving method 'divide and conquer'. We might look at the GUI and learn about software ergonomics as well as about the functionality of the software. We might learn about the organisation of work within the IS and the abilities people must have to handle this product. UML diagrams and documents which have been generated during the phase of design decision complete the arrangement. It is like a puzzle and students are supposed to look for the pieces and put them to a whole. Deconstruction allows a kind of time travelling and offers a simultaneous look at different stages of the software development process. Software design decisions may become a subject of discussions, and alternative concepts of specification could be conceptualized.

Digital Media in the ILL

The Multimedia Exploration Environment of the ILL consists of several main components: content modules, learning objects related to the topics of computer science, software tools and groupware components which serve as elements of a learning platform. With regard to digital media and their contribution to learning processes in the ILL we generally have to distinguish between cognitive tools and learning software.

Tasks of cognitive tools may be described as follows: visualization, presentation and publishing, modeling, calculation, simulation, creating common containers, referring, connecting physically and spatial depiction of logic and causal relations. Computer-based cognitive tools enable people to manipulate and rearrange data and visualize them in order to gain new information and to communicate with others on the basis of a new understanding (Keil-Slawik 2002).

According to these general remarks, in an ILL there is a need of common cognitive tools as well as of specific ones. Beside office tools for the needs of documentation and communication within a learning group an IDE (integrated development environment) for purposes of software development and the visualization of source code structures is an indispensable media for the ILL. Annotations tools offer students the chance for meta-communication by expressing their opinions via digital media on topic-related texts. In addition to that, specific tools like UML-editors and dynamic object browsing systems are desirable. With these tools students may interactively explore software design concepts, visualize relevant passages of source code and gain experience with the consequences of alternative implementation variations. Animations, e.g. of the functionality of design patterns or the sequence of an algorithm can foster the students' understanding of major topics in software design. Especially interactive animations are considered to be very supportive for learning processes (Albalooshi & Alkhalifa 2002).

Learning objects are the kind of learning software that is used in the ILL. Their classification and their contribution to learning processes will be discussed later on. Due to the constructivist demand that learning scenarios in an interactive learning environment should be problem-based and situated, the content which will be presented by the digital media in the ILL should represent a concrete example of application. Therefore, the ILL provides students with four specific content modules. For a course and a special learning group only one has to be chosen.

The content modules describe a problem-based scenario of a socio-technical information system and contain beside didactical open source software a lot of multi-media documents that refer to the systems social and technical aspects. To enable students to deconstruct the didactical software and to achieve a multiple view on the process of software development and the software components it is necessary to provide them with a variety of different digital document types (Magenheim 2003).

Figure 1: Elements of a Content Module

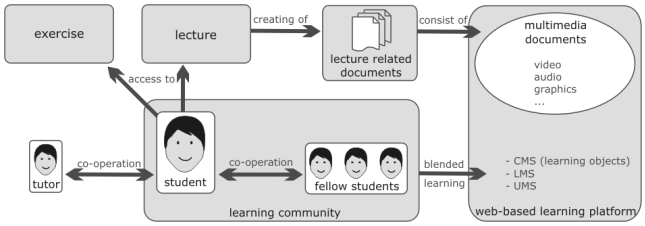

Figure 2: Students view on the ILL

One of the content modules represents a flexible automated storekeeping system. It consists of a LEGO-mindstorms model of a high rack storekeeping area (HRSA) with autonomous units. It also offers html-documents which contains embedded video-sequences and animations of the fork-lift-truck movements as well as of the communication system between the units. In addition to that, students will be provided with information about communication protocols, technical control of the autonomous units, the class and object structure of the storekeeping system and the interaction between hardware, software and mechanics of the system, called mechatronics. Another important part of this content module is the software that controls the storekeeping system. Its object-oriented design is freely accessible and can be analyzed under a source code view or on a UML-level. For those purposes a Java -IDE and UML-tools are available. Furthermore, simulation software is available, for purposes of developing and testing during phases of modeling a new LEGO-mindstorms system. Software tools, web browser and multi-media documents are relevant digital media of the ILL and their integrated and co-ordinated deployment represents an important cognitive

tool in the area of software engineering. The subject matters of the three content modules complement each other dealing with different but related contents of software engineering.

Creating Learning Communities

According to cognitive and constructivist learning theories learning is not only a process of students' passive reception of subject material in a teaching scenario or of achieving information via communication with other students. Learning is also an individual activity of knowledge construction. Acquisition of knowledge and adoption of methodical skills are determined by individual efforts and active examination of the subject-matter. Learning should be self-determined with regard to content, learning methods and schedule. Nevertheless, individual knowledge has to be negotiated and shared with others for reasons of its consolidation and enhancement (Savin-Baden 2000).

Therefore, learning design in the ILL is aligned on learning theories which give reason for that kind of learning strategies. The tutor's role may be organized in accordance with the Cognitive Apprenticeship Model (Collins et al. 1989). The tutor's task is to support learning processes and give advice. During the learning processes in the ILL the importance of his or her teaching responsibilities are 'fading out' while the tasks of the students are increasing. The tutor's role is changing 'from the wise at the stage to the guide by the side'. The Vanderbilt Group emphasizes that learning scenarios should be problem-based, offer different solutions and should be anchored in authentic situations. Open learning environments which allow explorative learning, should be organized and the exchange of information and knowledge between members of a learning group should be fostered. Last but not least Cognitive Flexibility Theory demands to allow students a variety of different views on a subject area to foster associative thinking (Spiro et al. 1992). The tutor's advice, digital media and learning objects offered in the ILL should serve these purposes.

An Informatics Learning Lab should also be based on the recognition that the intellectual capability of a single person is limited whereas the collaboration with other humans opens the chance to solve complex problems together successfully. In a 'learning community' students should share their knowledge with others, increasing the communities' pool of knowledge and thereby improving their own skills and abilities (Hung 2002).

Based on these assumptions the didactical concept of the ILL requires that processes of deconstructing software have to alternate with phases of constructing pieces of software. Phases of exploring the hypermedia elements of the ILL may be self-directed, guided or co-operative and be embedded in some topic related exercises. By deconstructing a didactical software students will gain methodical experience, a variety of different views on the product as well as on the developing process of software and acquire knowledge of basic concepts of informatics.

According to pedagogical theories mentioned above virtual companies should be founded. The student owned companies are in competition with each other and their purpose is to meet the demands of a complex assignment given by a customer. Thus, a project-oriented, blended learning situation will be created that could last for a whole semester. Students will be allocated to the role of software developers; the tutor should play the roles of a user and a customer. Beside the co-operative learning processes via the learning platform of the ILL social interaction will take place. The students are placed in a business environment, which is comparable with a real world situation. Thus, types of problem-based, situated learning will be generated.

Real world experience and the social interaction within information systems are captured in the video clips and the interviews of the LOs. But this is only a second-hand experience. It also is necessary that the student members of the virtual companies meet staff of a real company, talk to them, explore their professional assignments and study workflow processes of the real world company. An excursion will be the most suitable activity for students to gain such experience.

Summarizing these different aspects of learning designs used in an ILL we have to state that the ILL may be considered as an explorative ICT-based open learning environment.

Using Learning Objects

Types of Learning Objects

To support such types of self-directed learning in addition to the content modules the multi-media exploration environment of the ILL includes different learning objects (LO) with general information about computer science and didactics of informatics as well as special topic-related information units. Learning objects are digital media which partially may be classified as educational software, because they include instructional elements

The IEEE defines a learning object as 'any entity, digital or non-digital, that may be used for learning, education or training' (IEEE 2002). In the ILL we have defined a hierarchy of learning objects to characterize their complexity and thus increase the possibility of their reuse. Media objects are the elemental entities and consist of only a single media product like a video clip, an animation, a picture or an audio file. Group objects combine different media ob-

jects in one or more hypermedia document. Learning modules consist of several group objects and own a description of educational processes related to their deployment in an educational scenario. Finally, several learning modules may be joined to a learning unit. A learning unit might describe a whole course or a complete scenario for individual self directed explorative learning. To increase the reusability of the learning objects some characteristic scenarios of application of the learning objects will be shown in a didactical unit of the ILL. Tutors may learn from the descriptions of these typical course scenarios and transfer some experience to the educational and scientific settings of their own courses.
Topic-related learning objects more than the general ones serve the purpose to prepare students for self-directed learning in an open learning environment. Beside the instruction of a tutor in a course and co-operative styles of learning in a group the individual or collaborative reception of the content of a learning object e.g. in a web-based training situation may strengthen the students' abilities to exploit the subject matter by themselves later on. Topic-related learning objects are applied to problem-based scenarios within the subject area of the content module and offer problem solving strategies as well as attached solutions to the students. The specific learning objects include e.g. web-based training courses with main emphasis on a more scientific approach to the problem-based scenario. For the storekeeping scenario the following learning objects are developed: mindstorms brick driven autonomous fork lift trucks as embedded systems, guided exploration of specific technical aspects of the storekeeping system, analysis of communication protocols for the technical data exchange between the bricks, interaction and exchange interface between the different software layers running on the mindstorms brick.

Constructing Learning Objects

Learning objects in the ILL usually are constructed on the learning unit level and consist of several selected media objects, a limited number of objectives and explanatory text with regard to the problem-based task. We have to distinguish between open and closed learning objects.
Closed learning objects are constructed conventionally like web-based training units. They include training advice and a guided tour putting forward a proposal for sequencing the subject areas. Exercises are offered and some of them have to be completed successfully before reaching the next subject area. Nevertheless, students are often allowed to choose their own way to deal with the subject of the learning object. Thus, behaviouristic as well as constructivist concepts of learning may be realized by using that type of LOs.
Open learning objects are similar to an exploration assignment in the ILL. An assignment document will be handed out to the students and they have to deal with it. To achieve the objectives of the task, they have to explore different media objects within the ILL. They also have to do some exercises and answer questions asked on the assignment sheet. Finally they join a group meeting of students with their tutor and present and discuss the solutions which they have found. The group discussion should lead to a problem solving concept they considered to be the best. Thus, an open problem-based learning scenario with learning objects will be created where the achievement of learning objectives will be verified conjointly by the whole group. Furthermore, students in majority of cases will be provided with an opportunity to evaluate the performance of products they have created as an indicator for the quality of their learning processes.

Level of Perception and Abstraction		Real World IS (HRSA)	Three Dimensional Real Model (Lego Mindstorms)	Software Model (Lego Mindstorms)
Type of Coding				
Symbolic	Static	• system related text • development related text	• documents with LM related background information	• source code • documents of API • development related text
	Dynamic	---	---	• animated source code
Drawing	Static	• plant layout	• construction plan	• UML diagrams
	Dynamic	• animated workflow • diagrams of IS	• animated workflow diagrams of LM • interactive simulation environment	• animated (interactive) UML diagrams
Picture	Static	• photographs of HRSA	• photographs of LM	• screen shots of GUI
	Dynamic	• videos of the HRSA (technical, social aspects)	• videos of special tasks of LM (technical)	• screen video of using software

Figure 3: Levels of Perception and Coding Types of Media Objects

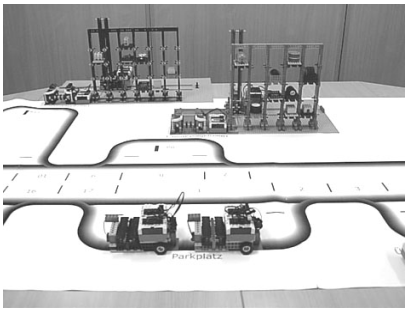

Figure 4: LEGO model of a HRSA

Figure 3 represents a construction kit for learning objects referred to the high rack storage area content module. It shows examples of media objects as atomic media units of the ILL which could be used to design learning objects. The collocation of the table is based on the assumption that there are different levels of perception and abstraction to

deal with a socio-technical information system. First there is the real world scenario itself, which may be discovered by excursion and provides us with real life experience. Then there is a technical model of the real world system –in case at issue the Lego mindstorms model, which could be explored by the students directly as well. Last but not least we have the software model of the information system. It can be accessed only via the media documents, which are mapping its structure and functionality.
For all levels of abstraction and perception the ILL provides students with different types of media, which should enable them to gain comprehension of relevant facts and structures of the ILL. In regard to the media we have to distinguish between different types of encoding: symbolic (dealing with signs and symbols e.g. in a text), drawing (abstract mapping of facts in a chart) and picture (lifelike mapping). These types of encoding in each case are cut into two different areas: static and dynamic types of information representation at the different levels of abstraction.
The construction of learning objects in the subject area of a high rack area means to select media objects mainly from the software model or physical model level (mindstorms) and put them to the whole by completing them with learning instructions and objectives. Using this 'construction kit' with media objects of subtle granularity allows creating different types of learning objects with varying complexity.

LOs and self-directed Learning
There are different phases of learning in the ILL. During the term the teacher's role has to be reduced to the role of a mere advisor whereas the importance of student's self-organized activities is increasing. The learning phases for the high storage area content module are:

- foundation of a virtual company with students as the owners, assignment to build an automated commissioning unit;
- exploration and deconstruction of the physical and software model (guided, self-directed supported by LOs);
- modelling a software model with CRC-Cards and UML;
- exploration of the modelling concept of the mindstorms model, comparison and assessment with regard to the model concepts created by the students;
- acquiring a deepened knowledge of the three perception models by using open and closed LOs (source code, technical functionality);
- operating re-engineering tasks related to the mindstorms model (variation of sensors, different types of racks),
- exploration of the communication protocol used by the bricks and of the layered architecture of the software (using LOs);
- cooperative construction (modelling, encoding, assembling Lego components) of the commissioning unit by the students, transfer of knowledge on different levels, self-directed use of LOs according to their needs of support;
- presentation of the product, quality assessment, reflection on the learning process and self-evaluation regarding the achievement of objectives.

Thus, learning objects in the ILL used in a problem-based learning scenario serve the purpose of exploration and deconstruction of a socio-technical information system. They should offer the students the opportunity to use different levels of abstraction and different types of media encoding to gain their experiences in processes of guided and self-directed learning. The use of learning objects within a problem-based scenario enables learning communities to assemble a mind map of perceptions of the subject area. One of our research interests is to find out, which type of media support (abstraction level, encoding type) will be necessary to optimise students learning success. Especially the students' preference to abstraction levels during the process of knowledge transfer is on the focus of our research efforts.

Evaluation

The basic concept of the ILL was subject of a first evaluation during a course at the University of Paderborn in summer 2003. This was a preliminary study in order to prepare a second one, which will be based on the results of the first and be focused on the relations between behaviour pattern of using digital media on different levels of perception and the learning outcomes of students in the ILL.
The course was organized as a presence seminar with weekly meetings. Students also had access to our groupware with the multimedia elements to be explored. The group, examined during the summer course 2003, consisted of teacher students of informatics in at least the 3rd year of their studies. We focused on the content module of the Lego high rack area mentioned above and the digital media connected to it, such as videos, animations, (UML) diagrams

and source code and learning objects. In the first part of the seminar the students had to analyze the existing LEGO model and the controlling software on different levels of perception and abstraction. In the second part, they were supposed to develop a hardware and software model from an automated LEGO commissioning unit on their own. At that time, we neither had sophisticated research questions nor a differentiated theory concerning the transfer of knowledge from the exploration of the example provided into the problem-solving process during the system development of the commissioning unit. For that reason our evaluation concept is close to the grounded theory (Glaser & Strauss 1967). Its components are initial questionnaires, group discussions, screen videos, a guideline oriented interview, product analyses and also the observation of the students' activities.

Questionnaire at the beginning of the course

Eight participants attended the course. Therefore, there was no need to apply a standardized questionnaire. We rather asked open questions to generate a guideline for an interview.

The major topics of the questionnaire were: the students' expectations, their previous knowledge about concepts and methods of software development, their experiences with computer-supported learning environments. Most students had already had contact with multi-media based learning material, but not with material for the concept of learning by example. Furthermore, they had previous knowledge of design patterns.

Though they had a basic understanding of design patterns and process models of software development they did not have much experience with these concepts. There were positive expectations concerning both, the training in computer science and the transferability of the HRSA to school lessons in informatics.

Interview

After the first two lessons and having filled in the first questionnaire the students joined a group discussion. Objective of this empirical method was to refine the results of the questionnaire and to receive more precise statements. Another interesting outcome of the evaluation of the questionnaires was the hint given to how multi-media documents influenced learning processes. This leads to further questions concerning the design of the multi-media materials and the learning objects in the learning lab.

Only if the real Lego model was absent the students regarded the multimedia simulations of the model as necessary. They also could be helpful in the case that complex processes need to be simplified or important information need to be stressed extraordinarily. They also suggested that even short animations should be equipped with a navigation bar in order to stop them anytime or to move them to certain positions during the animation for repeating sequences.

Questionnaire at the end of the course

After having finished the seminar, the students still rated the quality of the seminar as good in regard to the didactical education and the scientific training in computer science. But they were more critical towards a possible transfer of content and methods into class room work. Half of the students regarded the HRSA in the existing stage of expansion as too complex. The estimation of the methodical concept and the layout of the seminar were in general highly positive. Especially the method of guided exploration was mentioned as helpful, although two students with fewer experiences in software development asked for more subtle orders. The range of computer science related problems presented in the learning scenarios was denoted as sufficient.

Process Evaluation

Observations: In the course of the entire Seminar the students' autonomous work was systematically surveyed by the tutors. Observations were noted down and if necessary, according to action theory, directly put in practice in the next session. The students' insufficient experiences with object orientated software development turned out to be a disadvantage: on the one hand, while analysing the exemplary information system and on the other hand, when designing their own plans. Concerning this fact, students of future seminars need either to have better previous knowledge or additional in modelling techniques background information should be provided.

Students mainly used the three dimensional Lego Model itself and static drawing encoding (UML diagrams) to gain an overview of the system's components and functionality. In addition, transfer of knowledge happened on the symbolic static encoding level (source code), especially when they went into details of source code construction for the commissioning unit. The tasks of the open and closed learning objects proved themselves as supportive in processes of students' acquirement of knowledge.

The expense of time obligatory for the construction of a new Lego-model which functions mechanically was underestimated. Thereby, the course lost time to realize the actual learning targets of the seminar. This statement was proved by the questionnaires. Consequently, in the future some constructions plans will be explained more detailed.

Screen Videos: The analysis of the students' work with screen videos, produced during the two seminars, partly supported the findings of the group interview. The animations included in the learning objects which showed some workflow processes of the HRSA were not completely used by the students..
Furthermore, differences were recognized between students with much and with less experience in object-orientated programming, especially concerning the development of some parts of the RCX: Advanced students used class diagrams for orientation in the source code, whereas students with small experience rather searched unsystematically in the Java source code documents. These differences influenced their abilities of analysing the system.

Product Evaluation
The product developed by students in the second half of the seminar was a LEGO model of an automatic commissioning unit and the accompanying controlling software for six RCX units. To analyze the outcome and the quality of the learning processes during the seminar a final product analysis, especially of the software model, was carried out. The result was that the students tended to integrate parts of source code, they found in the rack example, into their own java source code by 'cut and paste' instead of adapting whole software components. That's why the functionality of the code was partially incorrect (especially the communication between the RCX units). The students had exchanged these parts of the software with the original classes of the high rack communication concept. At the end of the seminar the commissioning unit operated well, except for inferior functionalities. One of the seminar's main goals was achieved.

Conclusions

The didactical concept of the ILL and the use of learning objects and digital media by the students proved on the whole to be an appropriate method of learning. Students were highly motivated and reached most of the learning objectives of the course. Unfortunately, most elements of the media encoding of the real world model were under construction last summer so that their impact, especially on the social issues of an informatics system, must be tested in the second phase of evaluation. During this second course with the HRSA content module evaluation should concentrate more precisely on the students' behaviour pattern issue in the use of media encoding types during processes of knowledge transfer. Thereby, more information about the way of constructing learning objects should be acquired.

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