Demands on Digital Media in an Informatics Learning Lab -
Medial Aspects of an interactive Learning Environment for Software Engineering

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ABSTRACT

The focus of this paper is on the integration of digital media into an interactive learning environment for software engineering. It describes technical and educational demands on media to meet the requirements of appropriate tools in software engineering related learning processes in an Informatics Learning Lab (ILL). First, some basics about the theoretical and practical framework of an ILL are given. The article discusses the main components of an ILL and the types of media that will be used. Focal points of the paper are the integration of media into learning processes in the ILL and its concept of content management with learning objects. The use of different media like learning objects, tools and virtual educational advisors are presented. The importance of groupware in an ILL is discussed. Finally, some remarks on research activities concerning learning processes in the ILL conclude the paper.

Keywords: Informatics Learning Lab, Deconstruction of Software, Learning Objects, Digital Media and Software Engineering, Problem Based Learning in Software Engineering.

ORGANISATIONAL AND THEORETICAL FRAMEWORK

Designing and developing an ILL are main objectives of the Didactics of Informatics working group at the University of Paderborn. The research efforts for designing, implementing and evaluating such an interactive web based exploration environment for computer science students have been supported by several projects granted by the Ministry of Education and Science of the State of North-Rhine-Westphalia and the Federal Ministry of Education and Science of Germany. Especially the MuSofT project (Multi-Media in Software Engineering Education) has got the task to produce multimedia learning objects for purposes of teaching and learning about software engineering [1].

An ILL may be considered as an interactive web based exploration environment for learning 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 persons, who are interacting with the IS and with other people. 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 [2].

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, in many ways software is not only a product but also the result of a multilayered process:

- There is the process of the software life cycle which is characterised by the terms of request analysis, design, coding, implementation and evaluation. The process of software development of a product is never finished and records improvements version by version. When the process stops, the product will soon vanish from the market.
- The product 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 software of a socio-technical information system represents fundamental ideas and methods of informatics and also the concept of workflow and patterns of social action within the system. Social action, social roles of people and the workflow in the system's context will be influenced, e.g. by human computer interaction (HCI) with the technical parts of the system moderated by the graphical user interface (GUI).
- To create such a product there is an enormous need of communication, participation and co-operation between developers, customers and users. Design decisions and concepts of software models will be influenced by this communication processes. The product 'software' can be considered as a result of these communication processes.

Is there 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 system design? Beside the methods of teaching algorithms, developing a small software or constructing a tiny IS within a project informatics has a need of computer-based tools for modelling 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 for discovering new styles of learning and focuses in a special way on the modelling 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. Digital media in software related learning processes should students allow to get acquainted with the various aspects of product process relations of software development. They should also offer different views on the product as well as on the designing and developing process.

Therefore, the ILL consists of technical, educational, methodical and organisational components which provide students with a variety of tools, learning objects, content related modules and a didactical concept to establish and support learning groups within the area of software engineering. Students should use the learning objects, the software tools, the groupware functionality and the multimedia documents of the exploration environment to put constructivist learning concepts within a scenario of blended learning into practice. The collaborative learning processes in the ILL should be problem based, project oriented and

situated [3]. Learning communities of students in the ILL should be established by creating virtual companies, which have to construct information systems and face the competition with other virtual companies owned by students [4].

The didactical concept of the ILL is based on the assumption that processes of deconstruction of software have to alternate with phases in which students are developing a software collaboratively by themselves. Deconstruction allows students to explore a piece of software supported by the hypermedia elements of the ILL. This exploration can be organized as a guided tour by a multi-media document within in the ILL or instructed by a tutor. Students can also explore the multimedia documents of the ILL self-directed on their own or, last but not least, co-operative with others. The method of deconstruction offers students the opportunity to discover basic concepts of informatics and of software engineering and enables them to have a look on the social implications of information systems. They may examine the source code or UML diagrams and discover classes, methods, algorithms, programming language structures or basic informatics concepts like 'divide and conquer'. They might explore the GUI and learn about software ergonomics or discover basic design patterns. Deconstruction allows a kind of time travelling and offers a simultaneous look at different stages of the software development process: interaction context of future IS before developing the system, phases of software development according to the unified process, implementation and change of social context of the IS. Software design decisions may become a subject of discussion and alternative concepts of specification could be conceptualized. By deconstructing a didactical software students will gain methodical experience, a variety of different views as well on the product as on the developing process of software and acquire knowledge of basic concepts of informatics. In a process of knowledge transfer into a new area of application students may use their knowledge and their abilities to construct software for the needs of their virtual company.

Developing an ILL also means to develop a socio-technical information system. This is an evolutionary process with alternate phases of empirical and theoretical research. Research has to pay attention to the mutual dependence of technical and educational aspects of the learning environment as well as to the relationship between the learning environment and the learning processes of students. A very important problem to solve is the selection of appropriate media, of content and of groupware functions to foster efficient individual and co-operative learning processes in the ILL.

TYPES OF DIGITAL MEDIA

ICT based learning designs for an ILL have to take several important aspects of 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 *organisational 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 among other things with
- technical support for group interaction and communication
- a content management system
- a user and account management
- digital media with a variety of functions for learning processes.

It is necessary to co-ordinate the different influencing factors of learning processes to guarantee an efficient learning design in the ILL. The main focus of interest of this paper is the technical context and especially the demand on digital media for the needs of computer science education and learning about software engineering.
With regard to digital media and their contribution to learning processes we generally have to distinguish between cognitive tools, learning software and intelligent tutorial systems.
Tasks of cognitive tools may be described as follows: visualization, presentation and publishing, modelling, 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. The mode of presenting information with a cognitive tool can be textual, graphical, pictorial, animated or cinematic. In order to ease students' efforts to comprehend cognitive operations the tools should offer an interactive mode for manipulation of information representations and the chance of individual exploration of the topic.

According to these general remarks, in an ILL there is a need for common cognitive tools as well as for 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 visualisation 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 [5].

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 three specific content modules. For a course and a special learning group only one has to be chosen. For a storekeeping example not only topic related animations and video sequences of a mindstorms model of a storekeeping system with autonomous fork lift trucks are available. The students can also access the mindstorms model itself and explore different modelling concepts of this embedded system. Thus, they learn about the relations between software, hardware and mechanics on the basis of a small model which is very similar to the real system. It is also necessary to integrate real world experience into the exploration environment. For the needs of requirement engineering it is important to provide students with video sequences of a real world information system including its technical and social components. Therefore, video sequences of technical aspects of real storekeeping systems are also available as well as interviews with employees who work in this area.

Beside various cognitive tools some types of educational software are useful as well to explore the media offers of the ILL.

In contrast to cognitive tools learning software also contains paths and strategies to explore the interactive computer-based learning environment. Sequences of content modules, a preselection of learning objectives and a selection of digital media guide the learner in a predetermined manner through the exploration environment. In the ILL navigation advisors like guided tours will serve this function of digital media in an interactive exploration environment.

Computer-based tutorial systems that could analyse the learners' behaviour, their learning style, weak spots and strength and propose individual types of content presentation and problem solving as well as adapted learning objectives are hardly available on the market and have therefore not been included in the ILL so far.

The technical context of an ILL should be completed by a content management system, a user management system and groupware support. The following part of the paper describes important components of the technical context of the ILL with regard to their media functions. In particular, the cognitive tools and the educational software of the ILL are presented and the interaction between content modules, learning objects, content management and groupware functions of the ILL are examined

COMPONENTS OF AN ILL

The ILL consists of several main components: content modules; learning objects related to the topics of computer science, software engineering and didactics of informatics, software tools; an educational advisor unit and, last but not least, groupware components. The tools and the multimedia materials should be used by the students in order to learn about informatics and later on to solve similar problems related to the complex assignment of their virtual company. They will discover e.g. basic concepts of software engineering which may be useful for the development of the software for their virtual company.

Content Modules

The content modules describe a problem-based scenario of a socio-technical information system (IS) 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 document types: description of use cases, description of the social context of IS (patterns of interaction, types of workflow), video sequences of social action representing the use cases, interviews with future users, interviews with developers and applicants, video sequences of technical processes and interaction between employees, different CRC-modelling results, parts of documentation of the concrete IS, fragments of source code, elements of the GUI of the software, description of methods to develop, modules of software to develop, UML class and sequence diagrams, GUI prototypes, alternative software design concepts, scalable prototypes of software to develop, animations of technical processes and workflow in the IS, technical models of the IS and so on.

Up to now, two content modules have been developed: a small merchandise management and control system that represents the socio-technical information system of a kiosk, a flexible automated storekeeping system with a high rack storage area for media products that will be supplied with boxes by autonomous automated fork-lift trucks. A third one will be developed later on with the topic 'advertising agency'. The content modules in addition to that also contain special information about computer science concepts they use e.g. object oriented modelling techniques or algorithms, and special information about didactical concepts to integrate the modules topic into informatics classroom work in secondary education [6]. This is a special offer for teacher students in computer science.

The content modules can be accessed with a groupware tool. They are mostly developed as dynamic html-documents with plug-ins, if necessary. The content module of the flexible automated storekeeping system e.g. consists of html-documents which contains embedded video-sequences and animations of the fork-lift-truck movements as well as of the communication system between the autonomous 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 like togetherj are available. Software tools, web browser and multi-media documents are relevant digital media of the ILL and their integrated and coordinated 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.

The content module of the merchandise management and control system is related to the following specific subjects within the area of software engineering: concepts of object-oriented modelling, requirement analysis and workflow processes, concepts of a object-oriented programming language (JAVA), analysis of a management and control system, design principles of graphical user interfaces, use of design patterns in object oriented programming.

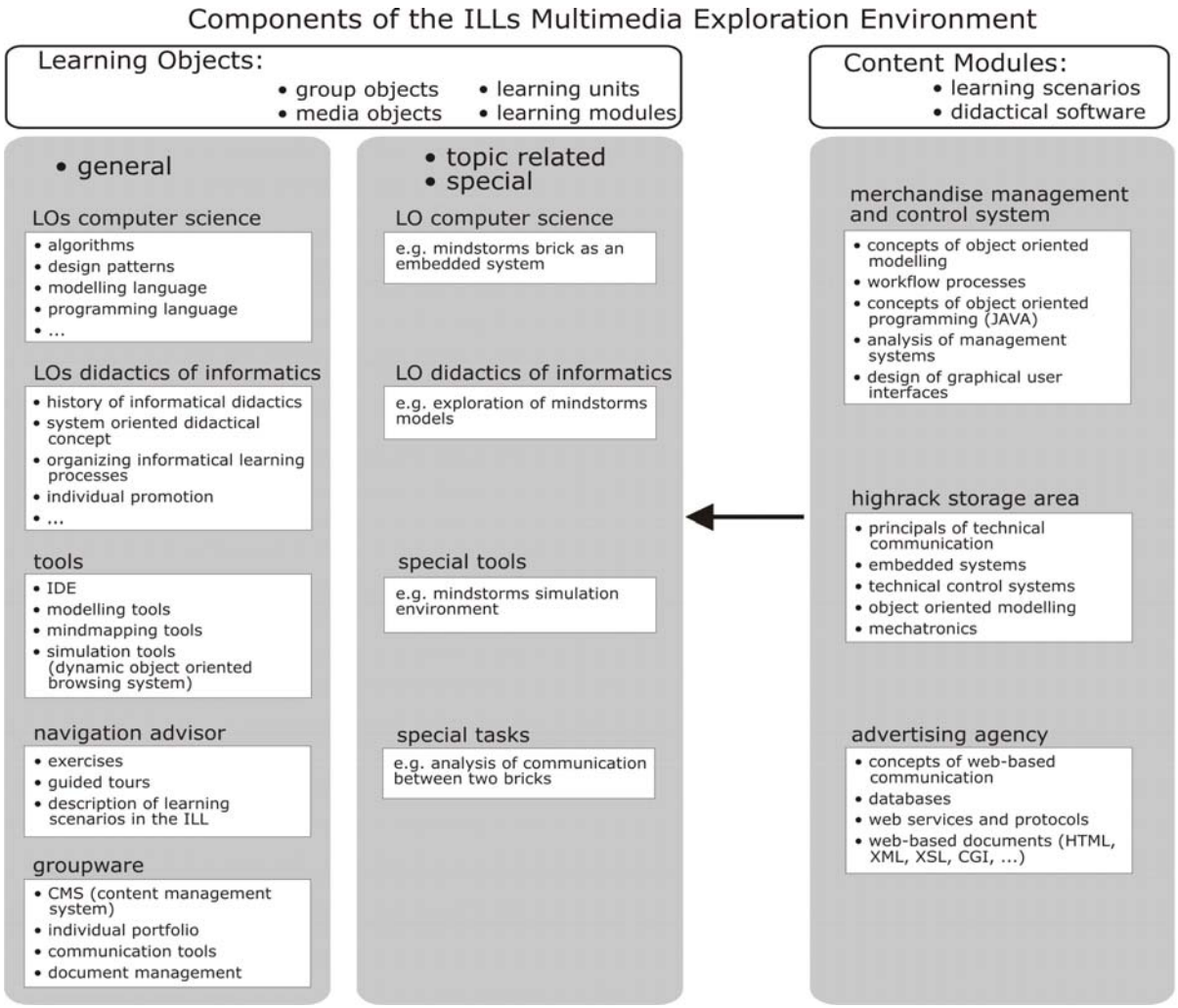
The content module of the advertising agency being developed later on includes the analysis of web-based communication, database concepts, web services and protocols, standards for production and exchange of web-based documents, e.g. XML, XSL…)

Learning objects

In addition to the content modules the multi-media exploration environment of the ILL consists of different learning objects (LO) with general information about computer science and didactics of informatics as well as special topic-related information units. The special topic-related learning objects are elements of the content modules and will be integrated into the set of more general learning objects whereas the general learning objects represent fundamental concepts and therefore have continuance for all the topics dealt within the ILL. 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." [7]. The LOM draft standard also defines a set of Metadata which may be useful to reuse and exchange learning objects depending on the conditions of learning in different educational scenarios. Especially the category 'educational' allows specifying the pedagogical aspects and the contribution of the learning object to learning processes with a set of items. In the ILL we use a subset of LOM Metadata for these purposes. We also 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 objects 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. Some characteristic scenarios of application of the learning objects will be shown in the navigation advisor unit of the ILL. Teachers may learn from these typical course scenarios and transfer some experience to the educational and scientific settings of their own courses. The use of learning objects in these characteristic learning scenarios should be described in a later version of the ILLs exploration environment by a type of educational modelling language (EML) [8].



Learning objects for didactics of informatics: The target group for learning objects in the area of didactics of informatics are mainly lecturers of computer science courses, teachers and teacher students of informatics on secondary level. General learning objects for didactics of informatics offer fundamental information about different didactical concepts of informatics. They also provide users with an overview of the historical development of the didactical discussion in the area of computer science. Especially the system oriented didactical concept is explained and its demands on computer science education are described. In addition to that, didactical learning objects contain evaluation documents of classroom work and information about organizing learning processes in informatics lessons at school. There are also methodical instructions for concepts of knowledge acquirement in informatics as the object game or the concept of CRC-Card modelling. Some of the learning objects are dedicated to gender aspects of learning informatics and to methodical concepts of individual promotion of learning processes. Beside the didactical learning objects of a more general type there are several which show examples of classroom work with topics represented in the content modules, e.g. classroom work with the mindstorms bricks. This kind of learning object also give information about possible objectives of the classroom work with mindstorms models and explain organisational and methodical aspects of the learning process with this tool.

Learning objects for computer science: Learning objects for computer science provide students with fundamental knowledge about basic concepts of informatics like algorithms, design patterns, modelling and programming languages, concepts of the object oriented paradigm, software development strategies, considerations with regard to complexity, and so on. These learning objects can be used by students either to improve their basics in informatics or help them to resolve problems in the context of the specific content module.

They contain text documents, graphics, animations and interactive exploration models. There are more general and special learning objects which are related specifically to the prevailing content module. To represent real word problems in the ILL the learning objects also contain annotated video sequences of workflow and interaction processes within an information system in practise. For the needs of requirement engineering interviews with customers and users are provided.

Topic-related learning objects: Topic related learning objects more than the general ones serve the purpose to prepare students for self directed learning in the ILL. Beside the instruction of a tutor in a course and co-operative styles of learning in a group the individual reception of the content of a learning object 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 web-based training courses with main emphasis either on a more scientific approach or on didactical problems connected to the problem based scenario. For the storekeeping scenario the following learning objects will be 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 two bricks, interaction and exchange interface between the different software layers running on the mindstorms brick (Java Code, Byte Code, binary file, firmware, BIOS).

Software Tools

The toolbox of the ILL contains several software products which mainly have a knowledge representational function. They either deal with the process of software development or have a supporting task for the learning processes in the ILL. Integrated development environments, a Java development kit, an object browsing system and other CASE tools belong to the first group of supporting facilities and should enable a better understanding of e.g. relation between classes and objects through visualisation. Mind mapping tools, interactive simulation environments and technical models of an information system belong to the group of knowledge achievement tools.

Special topic-related software tools complete the ILLs tool box. In case of our storekeeping system we provide students, for example with an interface tool that converts UML diagrams generated by 'togetherj' into Java source code which can directly be executed on a RCX (mindstorms brick). In addition to the mindstorms models a mindstorms simulation environment will be developed which allows student to test different mindstorms systems in a virtual environment before they are even constructed. The simulation environment visualises the bricks' reaction in different system control settings within the storekeeping scenario.

Navigation Advisor

The ILL offers students the chance of exploring its content individually or to follow guided tours. The navigation advisor component of the ILL provides students with site maps, which allow them to choose between different learning objects and guided tours. The navigation advisor provides students not only with a list of learning objects and content modules that are currently available but also supplies them with short description of their content or rather with objectives of the learning objects. To set learning activities within the learning communities in motion there are also a variety of tasks and exercises in regard to computer science problems and designing lessons in informatics in school. The navigator represents an interface of the computer based multimedia learning environment in the ILL which enables students in the learning community to interact with the system. In addition to that, it mediates the interaction in the learning community by stimulating the group's discussion. Exploration endeavours will be encouraged by confronting students with problem-based scenarios they have to discuss and to solve. Thus, situations of blended learning in the ILL are generated.

GROUPWARE AND CONTENT MANAGEMENT IN THE ILL

Blended learning naturally includes some kind of e-learning. Members of a learning group not only co-operate in face to face meetings at university but also via local and global area networks. To organize blended learning within the area of software engineering at universities it is necessary to use a learning platform which provides students with groupware functionality for collaborative learning. Technical aspects like accessibility of data and exchangeability of formats have to be considered as well as the pedagogy of collaborative learning.

To support learning processes web-based guided tours and communication facilities for synchronous and asynchronous information exchange are indispensable. Therefore, initially groupware in the ILL should provide students with basic communication and interaction capabilities. Students should be able to access the multimedia documents and use elementary communication tools like email and news for the needs of technical supported communication within the learning group. A CVS (Concurrent Versions System) support for the needs of collaborative software development in phases of software construction by order of their virtual companies is also desirable.

In connection with educational demands the way of media presentation in the platform is an essential part for the success of learning processes. With regard to the different functions of digital media and to foster effective co-operative learning processes it is necessary to provide students not only with tools for collaborative reading (e.g. browser) but also with facilities for collaborative writing (annotation tool) which is not custom in a hypermedia environment.

Therefore, the groupware includes content management functions for administrating the documents and handling the access management. The CMS should also allow an individual, a group related and a common view on the learning objects and other documents and enable the members of the learning group to create their own portfolios of documents. Further on, there will be a tool to annotate web based documents for purposes of net based group discussions. In this way, the ILL groupware supports processes of appropriating and negotiating knowledge in the learning community. It also provides the students with a graphical presentation interface to get access to the multimedia objects of the ILL.

For purposes of information retrieval and reusability we use the concept of learning objects and Metadata according to the LOM draft standard. Because of the large scale of the LOM items and the assigned keywords it was more practicable to reduce the applied items on a LOM subset. Especially the educational item with its categories (interactivity, types, context, semantic density, difficulty, description) will be used. This strategy allows the possibility of data exchange with other learning platforms on the basis of the IMS content packaging concept or on a SCORM standard. [9].

Another problem we face in regard to the use of Metadata is the importance of an ontology accepted by the scientific community. In lack of better solutions we currently use the ACM computer classification system [10]. Especially the keywords for software and software engineering are helpful but not sufficient. They

mostly fail if it is necessary to describe software engineering related learning scenarios. In this area a lot of work is still ahead.

At present, the ILL is based on the sTEAM (structuring information in a team) groupware which is developed in the department of computer science at the University of Paderborn [11]. Up to now, basic functions of the environment are realised, others still have to be developed.

RESEARCH ACTIVITIES TO INTEGRATE DIGITAL MEDIA INTO LEARNING PROCESSES

The media of the ILL should contribute to efficient individual and collaborative learning. Particularly, concepts of learning designs which enable blended learning with partially self-organising learning groups according to the theory of learning communities should be encouraged by the ILL [12]. To foster this endeavour the digital media of the ILL serve different purposes and learning styles:

- learning objects and guided tours provide learners with basic as well as with specific knowledge and gradually enable them to explore the multi media exploration environment on their own. Thus, individual and self-directed learning is fostered.
- the communication tools and the groupware functionality of the ILL support the communication between and within learning groups and thus, encourage different types of co-operative and blended learning.
- the cognitive tools of the ILL may be used for individual as well as for collaborative types of learning and working. Particularly, the software tools are suitable for the collaborative construction of new pieces of software.

Learning with digital media in a multi-media exploration environment is a very complex process.. Collaborative learning cannot be initialised only by several people who are using the digital media of the ILL individually. There is still a need of initialisation of collaborative processes by a tutor. A tutor's task in the ILL is also to monitor and mentor individual as well as common learning processes and to stimulate collaborative activities within the learning scenarios. Tutors also have to assist and support students in case of personal difficulties in learning. Thus, we meet in the socio-technical system 'ILL' a variety of multi-layered processes of social interaction as well as of human computer interaction and technically supported communication between group members. We discover a typical case of system development which should be organised evolutionarily and participatively. According to different concepts of software development and learning theories system development should be accompanied and evaluated by empirical research.

Therefore the use of the ILLs tools and digital media by students is currently subject of a formative empirical evaluation. Questionnaires are used to perform the data collection; they are delivered to the students at the beginning and the end of their course in the ILL. Group discussions concerning the use of digital media, the quality of individual and collaborative learning processes complete the empirical tools of the evaluation. To evaluate the use of specific tools key strike recording software is applied which provides the researchers with screen videos of the students' activities on the computers. One of the main questions concerning the research is whether it is possible to transfer software engineering related knowledge and experience, acquired by the students in the ILLs specific learning scenario to the software construction assignments of their virtual companies. Results of the evaluation will be available at the end of the year.

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