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USING THE INTERNET TO IMPROVE UNIVERSITY EDUCATION: PROBLEM-ORIENTED WEB-BASED LEARNING WITH MUNICS

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Running Head: Using the Internet to Improve University Education

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Abstract

Up to this point, university education has largely remained unaffected by the developments of novel approaches to web-based learning. The paper presents a principled approach to the design of problem-oriented, web-based learning at the university level. The principles include providing authentic contexts with multimedia, supporting collaborative knowledge construction, making thinking visible with dynamic visualisation, quick access to content resources via information and communication technologies, and flexible support by tele-tutoring. These principles are used in the MUNICS learning environment, which is designed to support students of computer science to apply their factual knowledge from the lectures to complex real-world problems. For example, students may model the knowledge management in an educational organisation with a graphical simulation tool. Some more general findings from a formative evaluation study with the MUNICS prototype are reported and discussed. For example, the students' ignorance of the additional content resources is discussed in the light of the well-known finding of insufficient use of help systems in software applications.

Keywords

Collaborative learning, dynamic visualization, problem-oriented learning, web-based learning, computer-supported collaborative learning

Using the Internet to Improve University Education: Problem - Oriented Web-Based Learning and the MUNICS Environment

In recent years, powerful educational approaches to web-based learning have been developed. Some schools have become knowledge communities where students assume the role of researchers by sharing knowledge with other student researchers through learning environments such as the Knowledge Forum (Scardamalia & Bereiter, 1996). High school science education has been both enriched and improved by approaches like COVIS, which tries to make use of ICT. COVIS attempts to bring students from different schools together with experts in the field and provides them with access to authentic data and material from the Internet to conduct projects in small groups (Gomez, Fishman, & Pea, 1998). In the same educational field, online controversies in WISE projects (Linn & Slotta, 2000) are aimed to give high school students access to scientific thinking. They discuss questions on genetically modified food or on water quality, using scientific explanations, evidence from their own experiences, or web resources.

Up to this point, however, university education has largely remained unaffected by developments in web-based learning technologies. Too often, multimedia applications in university lectures are restricted to Power Point slides and the Internet is used merely for e-mails or to present some Web pages containing staff information and lecture content. Thus far, university students have not profited extensively from ICT use to facilitate learning processes. Online seminars are often constructed within the constraints of specific group ware, rarely using design principles derived from theoretical approaches to learning. Tele-teaching applications, for example broadcasting lectures through one-to-many videoconferencing often simply attempt to emulate traditional practice with new media.

In this paper, we describe a principled approach to using the Internet to improve university education. We start by introducing five principles, which are both theoretically rooted in recent approaches to problem-oriented learning and have been evaluated for their effectiveness in empirical studies on technology-based learning environments. We illustrate the principles using the MUNICS learning environment. MUNICS (Koch, Schlichter, & Tröndle, 2001; Troendle et al., 1999) has been a joint project of the Department for Computer Science at the Technische Universität München (Jürgen H. Koch, Johann Schlichter, Gunnar Teege) and the Department of Educational Psychology at the Ludwig-Maximilians-Universität München (Pamela Tröndle, Frank Fischer, Heinz Mandl). Finally, we report on a small-scale formative evaluation study concerning the five principles, conducted within computer science university education.

Principles for Problem-Oriented, Web-Based Learning and their Application in the Design of MUNICS

In problem-oriented environments, (1) authentic problem contexts are seen as the starting points of learning processes. Ideally, (2) learners engage in collaborative knowledge construction when dealing with these problems, discuss different perspectives and share their prior knowledge. They use appropriate (3) tools to represent the problem as well as the domain concepts. (4) If they experience they lack the necessary knowledge to solve the problem, they may actively search for learning resources, which may help them to come to an adequate solution to the problem. In case they need further assistance they have access to an expert or a (5) tutor whose task is more to give advice concerning the learning processes than to provide the right answer. We describe each of the five aspects in turn and report on how we applied them in the design of the MUNICS learning environment.

(1) Providing authentic contexts with multimedia. It is one of the core elements of problem-oriented learning to work on a problem that enables authentic activities. Active exploration of the problem and increasingly self-directed problem solving become the key elements of the learning process. To increase authenticity, the combination of pictures, text, sound, or video in interactive multimedia is seen as highly suited (Bransford, Brown, & Cocking, 2000). Learning with authentic multimedia contexts may foster motivation (Cognition and Technology Group at Vanderbildt, 1993) and help make sense of the often complex nature of real world problems (e. g. Mandl, Gräsel, & Fischer, 2000). MUNICS is based around an authentic multimedia case. As the content area is "distributed work groups", the case is about the inefficient distribution of information within an organisation. This case study represents a typical class of problems in computer science and a real-life scenario. The students' work with MUNICS usually starts with information about the problem they have to solve. The necessary information is not provided in a ready-made presentation; instead, the presentation of the problem is designed for interactive use: The students are encouraged to actively request the information they need, instead of just passively absorbing what is presented. They have to decide which of the offered topics may be useful for solving the problem. The students have to navigate within the “virtual organisation” as a computer professional would navigate within a real organisation. While interviewing different employees of the organisation, students try to gather the information, which they consider to be important for solving the problem. Figure 1 shows a screenshot of the Interactive Problem Context during an interview.

Fig. 1

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(2) Supporting collaborative knowledge construction. Collaborative knowledge construction is a major element in approaches to situated learning and the application to educational activities in the Internet (Gomez et al., 1998; Linn & Slotta, 2000; Scardamalia & Bereiter, 1996). Interacting with other students offers students the opportunity to gain different perspectives on a problem, to discuss different solutions and different problem-solving strategies, to get important hints, to argue about difficulties and to support each other with feedback and other forms of help (Salomon & Perkins, 1998). Sharing one's own learning activities with other learners requires the articulation of thoughts and offers an opportunity to reflect on cognitive concepts and problem-solving strategies. Moreover, modelling effects can foster overt activities as well as cognitive process (Mandl, Gräsel, & Fischer, 2000).

In MUNICS, learners collaborate in small learning groups (three to five students). These small groups are set up at the beginning of a working session. In discussions with their learning partners, the students articulate and reflect upon their plans and actions and thus may gain a deeper understanding of the problem and its context. MUNICS offers three types of communication tools, which support co-operation among the learners and their common construction of knowledge and also facilitates co-operative problem solving. First of all, MUNICS provides a chat tool for synchronous communication. Students can use it for online discussions. To provide some privacy, all participants of a discussion must be members of the same learning group. Secondly, a shared document repository is integrated in MUNICS that facilitates co-operative document management. Every learning group has its private document repository that enables the group to upload text documents produced by any text editor. Thus these documents can be made available to all members of the learning group as downloads from the repository. Thirdly, there is a shared blackboard, which is a plain display that can be used to post messages or for discussion purposes. It has roughly the same functionality as Usenet news but it is restricted to MUNICS users.

(3) Making thinking visible with dynamic visualisation. Especially when dealing with complex problems, visualisation may enhance the construction of mental models of the topic and lead to deeper understanding. The SenseMaker-Tool is an example of web-based, collaborative visualisation. It helps organise evidence and counter-evidence concerning scientific theories (Linn & Slotta, 2000). The scope of dynamic visualisation is even broader: Dynamic visualisation or modelling can help students better understand the interdependent structure of complex and dynamic systems (e. g. de Jong & van Joolingen, 1998). According to Roschelle and Pea (Pea et al., 1999), it is the next challenge for web-based education to make these already existing “advanced visualisation, simulation, and modelling tools (...) work with multiple students collaborating over the web.” (p. 24).

MUNICS includes the Modeler Tool (Koch, Schlichter & Troendle, 2001) in order to provide an advanced tool for dynamic visualisation for collaboration over the web. The Modeler Tool enables modelling, analysis, simulation and visualisation of the flow of information. It offers valuable assistance for the students during the whole process of solving a problem, which has its roots in inefficient information flow. The first step of that process is to analyse the existing information network presented within the problem context. Using the Modeler Tool, students can start this analysis by constructing a graphical model of the given information network (Fig. 2). In the Modeler Tool, real-world information networks are modelled as directed graphs: The components, which receive, submit and process information, are the vertices (e.g. persons or technological components, like a server) and the connections between these components are the edges (e.g. telephone, transmission of data...). Each vertex and each edge has attributes assigned to it. These attributes should be defined by the properties and the behaviour of the real-world counterparts.

Fig. 2

The students can model information networks by adding or deleting components (vertices), connecting or disconnecting components (via edges) and changing attributes of components and connections in order to align the components of the model and the information network presented in the problem context. This process of modelling requires that the students organise their ideas and verify their comprehension of the problem. The process should finally result in a visual representation that may further enhance the students' understanding of the situation. Once the students have defined a graph that models a real-world information network, they can use their model for an analysis of the network. The Modeler Tool provides analysis modules to analyse both static properties (e.g., how a person deals with incoming messages) and dynamic aspects of the information network (e.g., change of attributes over time). The results of the analysis of the static properties are visualised in small displays on the screen and provide information about the attributes of each element (components and connections) of the network (Fig. 3). This should help students to recognise their own misunderstandings as they are being supported in building up a mental model of the network. The analysis of dynamic aspects is realised by the simulation of the information network's behaviour, where the students can see how it works (Fig. 4). First and foremost, this should facilitate the identification of critical points within the information flow. Secondly, it may be of use as a starting point for the improvement of the network.

Fig. 3

Because students become aware of the flaws in the design of the existing information network, they can also test different group ware systems in order to find the one that best fits the given organisational setting. On the basis of the workflow model, an adequate group ware has to be selected and integrated into the current workflow model. This is another challenge, for sometimes a redesigned information network that should work quite well in theory, does not perform well in its implementation and has to be revised several times. The Modeler Tool supports synchronous collaboration for modelling and restructuring information networks by the means of application sharing. It allows the students to create, analyse and modify the graphical representation of the information network together. An essential prerequisite of this co-operation is some level of activity awareness. MUNICS realized the awareness support in the following way: as one member of a learning group modifies the information network, the learning partners receive an immediate update. On the other group member's display, the selected component will be marked as "currently in use". Ideally, all members of a learning group should see the same picture in the Modeler Tool and work on the same data so that students can see what their learning partners are currently working on.

Fig. 4

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(4) Quick access to content resources via ICT. In problem-oriented learning, increasingly self-directed exploration of the problem and the task domain is emphasised. Learners should come to detect knowledge gaps and explore resources such as libraries or hypermedia glossaries (Gräsel, Fischer, & Mandl, 2001) to bridge those gaps. For example, in the WISE environment, students can explore selected web pages on the topic of discussion to find out whether a certain piece of information or phenomenon could serve as evidence for a theory or scientific concept (Linn & Slotta, 2000).

In the MUNICS environment, background knowledge is provided through the hypermedia material of two lectures on the topic under consideration. These are lectures on “Computer Supported Co-operative Work” and “Distributed Problem Solving” that have been held at the Technical University of Munich. For both lectures, lecture notes in HTML are available online. Munics includes hyperlinks to these lecture notes, so the students can quickly access background information and theoretical concepts that are useful for solving the problem and also obtain hints on how to proceed. Moreover, MUNICS offers help pages for the use of the learning environment. This integrated feature contains descriptions and operation instructions for each element of MUNICS. The students use this guidance whenever they have difficulties with the handling of the learning environment.

(5) Providing flexible support by tele-tutoring. Apart from content resources, the most flexible support today can be provided by a "personal resource" - a human tutor or an expert that the learners can consult with during the working process, who provides them with support according to their needs. For example, in the Cognitive Apprenticeship approach (Collins, Brown, & Newmann, 1989), flexible support by an expert is one of the core elements of the situated learning process. The modelling (Mandl et al., 2000) and scaffolding (Wood, Bruner, & Ross, 1976) of a more advanced learner or an expert are among the well-known and well-investigated methodological elements of instructional support. These "personal resources" offer information concerning the topic at hand, the use of the learning environment and the learning process itself – everything with great flexibility. Recent approaches to tutoring and tele-tutoring specify more clearly how such interaction should take place in order to advance the learner's knowledge and skills (Person & Graesser, 1999). With the goal of utilising the advantages of "personal resources", there is a tutor available during MUNICS sessions. In contrast to the content-resources, the tutor is able to become involved in a learner's question or problem in a more specific way so that the learner can quickly receive an answer that is precisely adjusted to his needs. Students use the chat tool in the MUNICS environment to get in touch with the tutor by clicking on the "Tutor Button" in the chat tool. The students may also exclude the tutor from the chat conversation by pressing the Tutor Button again.

Goals of the Formative Evaluation Study

We implemented a prototype of MUNICS and conducted a formative evaluation study. The primary goal was to assess the extent to which the principles were realised in the first prototype and what modification of MUNICS could further improve learning processes as well as promote acceptance of the problem-oriented learning environment.

Method

Sample. Eleven computer science students from the Technical University of Munich volunteered to test the learning environment. The participants – two female and nine male students - were asked to form learning groups: Four groups of two, and one group of three students completed their working sessions. All participants had already passed their intermediate exams.

Data sources, variables, and instruments. (1) Observation Protocol. During the working period of two hours, the experimenters observed the working process of every student with regard to the following categories: Overall learning situation, the learners' interaction with the modules of the learning environment, and the learners' collaborative behaviour. (2) Knowledge Test. Before and after collaboration, students worked on an individual knowledge test, consisting of two open questions: (a) "Which methods for the analysis/modelling of complex systems (e.g. business transactions, distributed systems) do you know? Name them and describe the most important properties of these methods!" (b) "Which technologies would you consider to be suitable to support team co-operation? Please explain your choice!" The students' answers were rated independently by two domain experts with respect to both quantity and quality. (3) Questionnaires: (a) With a Personal Data Questionnaire we asked for information about age, gender, number of completed terms, number of visited lectures referring to the contents of MUNICS, and practical experiences with these contents. (b) Questionnaire concerning acceptance. Students were asked to complete a questionnaire concerning their acceptance of the learning environment. It consisted of 33 items measuring the acceptance of the learning environment as a whole (4 items), of the content under consideration (6 items), of the design of MUNICS (14 items), and of the collaborative (3 items) and problem-based learning scenario (3 items). Moreover, motivational effects of MUNICS are measured with additional 3 items. (4) Interaction Protocols. During the working session the students‘ electronic communication with each other and with the tutor was recorded by means of log files. In order to analyse the discourse data, we developed a content-oriented coding scheme. Functional aspects of the discourse were not analysed (see Cowie & van der Aalsvoort, 2000) for detailed theoretical and methodological discussions of the analysis of social interaction). We distinguished the following categories: (a) co-ordination of the teamwork, (b) problems with the learning environment (Interactive Problem Context, chat-tool, document repository, Modeler Tool, the overall system), (c) case information, (d) scientific concepts and , (e) personal statements, and (f) empty messages/typing errors. The students' discourse was segmented according to speech acts. The segments were classified according to the categories above. The analysis of the discourse helps discern which topics the students were mostly involved with during their work. (5) Work report. The students had to individually give a short written report on their work within MUNICS. As support for the composition of this report, the students were asked to describe (a) the problem they had been working on, (b) the method they had used to solve the problem, and (c) the concepts they included in their solution. Computer science experts assessed these results by considering the quality of problem understanding, the adequacy of methods applied, and the adequacy of concepts applied for solving the problem. (6) Group discussion. At the end of the session, a short group discussion was conducted to give the students the opportunity to express their subjective perception about the learning environments and their learning process

Procedure. The session started with a short introduction informing the students about the origin of MUNICS, the purpose of the study and its course. Then students were asked to complete the questionnaire on personal data, followed by the prior knowledge test. After an extensive introduction into the functionality of MUNICS, the students started to work on the problem. The learning group members were located in different rooms, each equipped with a computer. Communication was supported through the communication tools within MUNICS. The Modeler Tool was used to collaboratively represent, analyse and modify the information network of the organisation, as has been described in the interactive problem context. After collaboration (approx. 2 hours), the learners were asked to complete the work report, the knowledge test, and the questionnaire on acceptance. Finally, members of the learning group discussed their experiences with MUNICS.

Results

Providing authentic contexts for learning. The observation protocols revealed that all participants used and explored the Interactive Problem Context intensely – this part of the work occupied about half of the overall working time. This observation is in line with the subjective evaluation of the learners: Questionnaire results showed that 7 of the 11 students rated the case study as good or better than expected when learning about the subject within a computer-based learning environment. Problem-oriented learning as a method was rated fairly high with an average score of $M = 4.96$, $SD = 1.11$ on a 7-step-rating-scale; 1=not satisfying, 7=completely satisfying. The final group discussion revealed some reasons for the successful use of the Interactive Problem Context and its high degree of acceptance: 7 of 11 students appreciated learning in a setting so close to the real setting of their future jobs and believed that it has a motivating effect. In addition, some students explicitly stated that the fact that the information that is actively sought rather than provided in a ready-made presentation or text provides flexibility and stimulates their "spirit of adventure". Observation protocols revealed that students had some problems with orientation and navigation within the interactive problem context. Most of these observations were supported by statements from the group discussions. For example, the navigation in a 3D-like building using special mouse actions had its motivating aspects, but took time and was not reliable enough. 7 of the 11 participants evaluated the navigation as time-consuming.

Supporting collaborative knowledge construction. Collaborative learning in small groups was accepted by the students to a high degree (M = 5.23, SD = 0.60 with 1=not satisfying, 7=completely satisfying). Despite this general evaluation, they rated the quality of collaboration for their own learning group as relatively low (M = 3.91, SD = 1.18 on the same scale): As some students explained in the group discussion, they related this judgement directly to the success of their chat communication. Observations indicated that the chat tool was the most frequently used communication tool. The analysis of the interaction protocols revealed that the central focus of students' discourse was about the co-ordination of their collaborative work (57.1 % of the talk). The following turn sequence represents a typical example of that verbal co-ordination: The learning group members Axel and Bernd talk about the steps they will take and distribute the tasks that have to be accomplished within the Interactive Problem Context (acquiring information by talking to certain employees of the organisation):

Axel: “Did you already get all the information from Mrs. Mayer, or should I ask her more questions?” ...

Bernd: ”I think I’ll talk to Mr. Müller again. So you ask Mrs. Mayer and I’ll go to Mr. Müller!”

Axel: “Okay. And we could start to set up our list, couldn’t we?”

Bernd: “Okay!”

Apart from co-ordinating their work, the learning group members also discussed domain concepts and possible solutions for the problems (9.9 % of the chat speech acts). The following section of a conversation is an example of how the collaborative construction of a problem solution takes place:

Axel: “What do you think that we should do? I thought of...”

Bernd: “Just a moment. List of needed services...”

Axel: “...a database-server, where all can read – even the agency for the assignment of

lecture halls.”

Bernd: “A database with authentication. And a web-interface for servicing and for registration of changes! That means GUI!”

Axel: “Okay! I also thought of a web-interface for the input of data...”

Bernd: “Okay!”

Axel: “...so that the professors can register their lectures.”

In talking about their task to specify the technical services that are necessary to optimise the given work flow, students Axel and Bernd both explain their ideas. One idea leads to the next and finally results in the merging of their ideas into an optimised solution. However, such sequences were relatively rare in a discourse mostly dominated by co-ordinating activity. Although frequent use of the communication tools was observed, the user-friendliness ratings for these tools were quite low (M = 3.55, SD = 1.21 on a 7-step-rating-scale: 1=not satisfying, 7=completely satisfying). As it has been observed, the chat communication during the learning sessions was impaired several times by delayed transfer of communication data, which is quite normal in web-based communication. Group discussions showed that this can partly be traced back to difficult handling and some malfunctions of the document repository. The document repository was frequently impaired by technical deficiencies. Thus in some cases the students opted to transfer the content of their documents using the chat. More importantly, it was revealed in the final group discussions that students had the impression that they were not being provided with enough information about what their learning partners are doing at any given time or whether they were ready for communication or not. This lack of awareness information was a subject in three of the five group discussions. For example, this phenomenon was labelled as "a feeling of insufficient communication".

Making thinking visible with dynamic visualisation. All participating students used the Modeler Tool. While working with the Modeler Tool, 7 of 11 students used the facilities of application sharing. Nevertheless, in the acceptance questionnaire, they evaluated the functionality (M = 3.64, SD = 1.75) and the usability (M = 3.64, SD = 1.44) of the tool to still be in need of improvement (average score of 3.64 and 3.64 respectively on the 7-step-rating-scale, 1=not satisfying, 7=completely satisfying). The group discussion revealed some reasons for this rather low rating. In 4 of the 5 group discussions the students explained that they felt their work was restricted by the tool, which offered too few degrees of freedom for designing an adequate information model. For example, the tool did not provide the possibility for students to create new connections or add components that had not yet been included in the tool. Moreover, the students reported some specific difficulties in handling the Modeller Tool. On the other hand, the group discussions also revealed some positive impressions of the Modeler Tool. Students found the dynamic representation and the easy modification helpful in understanding the complex information system. Moreover, most students believed that the transfer of information from the interactive problem context into a graphical model had been facilitated through the representational correspondence between the two components.

Fig. 5

As collaborative outcomes, the final models were evaluated. Figure 5 shows the collaborative modelling result of one of the groups. The model is a fairly adequate representation of the complex problem in that it includes all relevant elements and specifies the relations between them. Moreover, it includes the first steps for improving the information flow with groupware elements. The quantitative evaluation through the experts showed that the products were of rather high quality (M = 5.05, SD = 1.61 on a 7-step-rating-scale, 1=bad, 7=very good). A striking finding from the observation protocols was that the students ceased their chat conversation almost completely during the simultaneous use of the Modeler Tool. This is in contrast to what had been expected (that collaborative work requires a higher degree of verbal co-ordination activities between the participating members). Achieving such good results in modelling suggests that the students acquired action-related knowledge about the modelling of information networks during their working sessions. Evaluating the results of the knowledge tests and comparing the pre- and post-tests, the experts stated that the students – at least had improved their theoretical knowledge about methods for analysing and modelling complex systems by the end of the working session. However, the mean improvement was rather modest (M = 2.82, SD = 1,55 on a 7-step scale with 1 = no improvement to 7=very high improvement).

Quick access to knowledge resources through hypermedia. The hypermedia knowledge resources included the online lecture notes whose content was directly related to the domain of the problem context. According to the expert ratings of the knowledge tests, the students' prior knowledge about methods for analysing and modelling complex systems and about technical support for group work, was at a medium level (M = 3.63, SD = 1.66 on a 7-step-rating scale, 1 = no domain knowledge, 7 = extensive domain knowledge). For this reason, procuring additional expert knowledge on the subject for working on the tasks would have been beneficial for most of the learners. But what actually happened was in sharp contrast to this. Most of the students hardly ever used the knowledge resources. Observation protocols showed that almost every learner used the hypermedia resources just once for a short time. Hence it was not surprising that the students did not even mention the online lecture notes in the final group discussions. They preferred to work on with a knowledge gap instead of consulting the content resources at their disposal.

Providing flexible support by tele-tutoring. Besides the hypermedia knowledge resources, a tutor was at the students' disposal. The tutor could be asked for advice concerning the technical functioning of the learning environment as well as the organisation of the co-operation. The following section of a conversation presents a typical example of how the support from the tutor was utilised:

> Axel: "I have a question: How can I download the document being posted by Bernd?"
>
> Tutor: "How to open a document: First you have to choose the version of the document by pushing the right mouse-button. (...) Oh, I forgot: Before that you have to click on the document in the document-tree. After that you choose the version!" ...
>
> Axel: "Okay, I got it!"
>
> Tutor: "Does it work?"
>
> Axel: "Thank you!"

The facility of consulting the tutor was frequently used: Talking to the tutor made up about 10% of the entire chat communication. In both the questionnaire and the group discussions, students emphasised the importance of the tutor. Moreover, they were satisfied with the support they received. The students explicitly mentioned in the group discussion how much they had appreciated the "Tutor Button" allowing them to include the tutor in their conversation for as long as they wanted. These subjective perceptions were further supported with more objective data from the observation protocols: Almost all difficulties could be resolved rather quickly through the specific advice from the tutor.

Some More General Conclusions

Providing authentic context by using multimedia. The interactive problem context was rated favourably by the students. Despite some navigation difficulties, they felt motivated to explore the virtual organisation.

Support collaborative knowledge construction. Although learners generally had a positive attitude towards collaborative learning, there were at least two major problems with the collaboration in MUNICS. We believe that both of them could be viewed as more general issues. Firstly, there was not a high degree of collaborative knowledge construction. Literature on co-operative and collaborative learning in educational settings provides extensive evidence of the necessity to provide instructional support in order for the collaboration to be efficient and satisfying for the learning partners (O´Donnell & King, 1999). We had decided not to constrain the student's interaction, because we operated on the assumption that advanced university students of computer-science would not readily accept the externally imposed structure. However, results clearly indicate that there is room for improvement of the collaboration. It is possible that scripted co-operation may provide the structure that adequately enables and constrains learners' collaborative activities, while at the same time gaining acceptance by the learners. A main question is, how detailed or on which granularity level should the script guide the interaction (see Cohen, 1994). This question might be even more relevant to web-based learning environments. In web-based learning, this additional structure often results from the interaction within the constraints of specific ICT tools. Designing a tools suite for collaboration is a more invasive instructional activity than providing face-to-face learning groups with a script because isolated learners hardly have the opportunity to escape these structures. More controlled research on this issue is urgently needed. Secondly, in web-based collaborative learning on such an extensive level as collaborative modelling, a complex information flow is highly sensitive to technology failures. For example, the frequent delays in synchronous communication or application sharing resulted in the rapid decrease in the acceptance ratings. Related research shows that both the delay and failure phenomena, coupled with loss of motivation are rather typical in technology-based collaboration scenarios. At this point, we can only speculate on the collaborative and cognitive effects of these disturbances. Our findings point to the importance of awareness information at any stage and with any tool of the collaboration. However, we have to consider both points very seriously. In designing ambitious web-based collaborative learning environments, we expect students to work together in using the complex tools for representation, to co-construct knowledge on a high discourse level. We should aim to provide adequate structure and should help students deal with the shortcomings of technology.

Making thinking visible: Adequate constraints on shared external representation. The learners complained that the Modeler Tool constrained their representational activities too much. This can be seen as the more general problem of finding the right specification level in designing representation tools. There is a trade-off between accuracy of representation and usefulness for the specific information processing needs of the individual user. Domain-specific structures might facilitate individual learning by building up a kind of scaffold for the task.(Zhang & Norman, 1994) argued that working with an external representation might change the entire task from the students' point of view. Domain-specific structures might facilitate collaboration by providing a kind of initial common ground, i. e. common categories and relations between them that could be used to work on the problem (Fischer, Bruhn, Gräsel, & Mandl, 2002). However, they may possibly hamper the development of a collaboratively constructed common ground, as they are less flexible in assimilating co-constructed knowledge. This might be especially true for more advanced learners who already have some strategies for representing the problem at hand. A highly specified structure, as is the case with the Modeler Tool, might force the student to change the strategy. There is hardly any systematic research on the interaction between the degrees of freedom of a representation tool and the students' prior knowledge.

Quick access to the knowledge resources. At first glance, the phenomenon of neglecting knowledge resources might be attributable to the bad design of the online lecture notes. This might be partly true, because the resources mostly consisted of lecture slides and elaborating text. However, we argue that the problem points to a more general issue, which could be labelled the "background knowledge unwanted"- phenomenon. Students often do not use background, glossary or help information provided by learning environments, even when experiencing knowledge gaps in dealing with a problem (Mandl et al., 2000). The effect might be reduced to some degree by improved structure and design of the knowledge resources (Gräsel et al., 2001). However, the phenomenon remains, that learners do not adequately use knowledge resources in problem-oriented learning environments. The exploration of knowledge resources in order to better deal with the problem can be seen as a crucial factor in problem-oriented learning: The problem should serve as an anchor point to construct new domain knowledge. We speculate that in addition to structure and design issues, two other aspects might be responsible for the phenomenon: Firstly, a kind of local learned helplessness effect concerning help systems in software applications. Users with sufficient experiences with help functions in text editors and other standard software might generalise that a search in such systems is time consuming and too often does not lead to the required information. Second, the "spirit of adventure" might lead some students to solve the problem under "real world conditions". There is an area of research on the complex relations of motivation to learn and motivation to achieve indicating that learning environments that emphasise problem solving might emphasise the motivation to achieve and, in so doing, reduce the motivation to learn.

Provide adaptive support by tele-tutoring. From our results, two conclusions can be drawn. Firstly, students used this facility extensively. Secondly, we used only a small portion of the tutor's potential. Our tutor was restricted to helping the students with questions on the learning environment and the collaboration. More content-related aspects did not belong to the tutor's task. For technical and co-ordination problems, simply stating the right answer might be the best way. Any other dialogue structure, e.g., Socratic dialogue, might be perceived as mere hindrance by the students. However, more effective tutoring should include content-related aspects as well. In order to achieve this, other dialogue structures have to be developed. Beyond the effective interaction patterns for one-to-one tutoring, (Person & Graesser, 1999) we have to explore an area so far neglected in research: The effect of an expert or tutor participating in peer collaboration. One might speculate that the quality of collaborative knowledge construction might be strongly influenced by a participating tutor. On the one hand, this might be detrimental to intensive and high-level negotiation processes, because there is someone who knows the right answer (so why have an argument?). On the other hand, a tutor can introduce the "relevant themes" into peer discourse, reducing the risk of collaborative construction of misconceptions as well as thematic vagabonding.

We believe that the problem-oriented approach can provide a framework for the design of web-based learning environments. However, more research on web-based problem-oriented learning is urgently needed to help designers to make the right decisions within the context of the five broad principles. Decisions have to be made regarding questions of structuring collaboration, designing shared representation tools as well as hypermedia knowledge resources and regarding the adequate role for a human tutor within collaborative settings.

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Figure captions

Fig. 1. An interview within the Interactive Problem Context: The video window shows an employee of the organisation that is called “Uni Garmisch” (see heading). In the right part of the display there is a site plan of the virtual organisation showing the office rooms of the different employees (the yellow smiley indicates the user location). The window in the lower part of the display contains questions to be asked. When clicking on a question the video starts and the employee will answer the question.

Fig. 2. Building up a graphical model with the Modeler Tool: The series of Modeler Tool screenshots show an example of building up a graphical model of the information network represented by the Interactive Problem Context. Starting with a few components and connections in figure 2.1, the graphical model is developed into a complex representation in figure 2.3 containing the main part of the information from the Problem Context.

Fig. 3. Analysis of static properties: By clicking on the menu of every component (right mouse button) the Modeler Tool provides information about its properties. The smaller display (under the headline “Behandlung von Nachrichten”), for example. provides information on how the selected person “Herr Müller” deals with incoming messages. It shows his varying preparedness (second and third column of the table) to receive different types of messages (column one) and the probability that these messages finally reach him (fourth column).

Fig. 4. Analysis of the dynamic properties: The display of the Modeler Tool shows a complex model of the information network. It can be brought to action by means of a single step-simulation: Step-by-step the flow of information can be simulated from the beginning till the end of the information process. The small display on the right of the screen allows the user to control of the single steps of the simulation. During each step of the simulation the components that are actually involved in the flow of information change their colour to green.

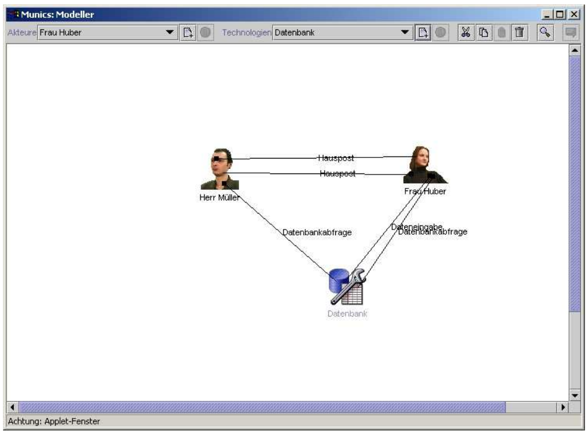
Fig. 5. Good modelling result of one working group: This graphical model being made by one of the working groups during the working session is the result of trying to represent the problem they were working on. Apart from the icon “Herr Berger” which is not correctly connected the representation is complete and correct.

Figures 1-5

Fig. 1

Wie genau erfolgt denn die Zusammenstellung der Veranstaltungsangebote?
Auf welchem Weg gelangen die Veranstaltungsdaten ins Uni-VV?
Wie gelangen die Veranstaltungsankündigungen ins kommentierte VV?
Wie gelangen die Veranstaltungsankündigungen auf die Info-Sites im WWW?
Was ist Ihrer Meinung nach das Hauptproblem im Planungsverlauf?

Fig. 2

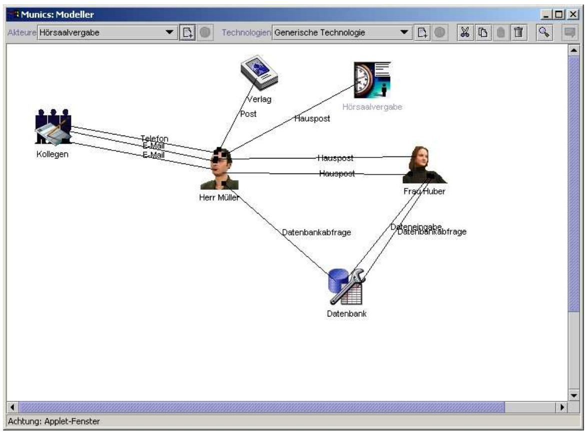

Munics: Modeller

Akteure: Frau Huber

Technologien: Datenbank

Achtung: Applet-Fenster

Figure 2.1.

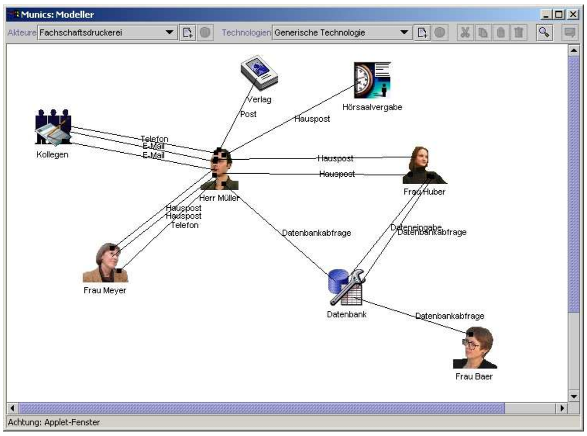

Munics: Modeller

Akteure: Hörsaalvergabe

Technologien: Generische Technologie

Achtung: Applet-Fenster

Figure 2.2.

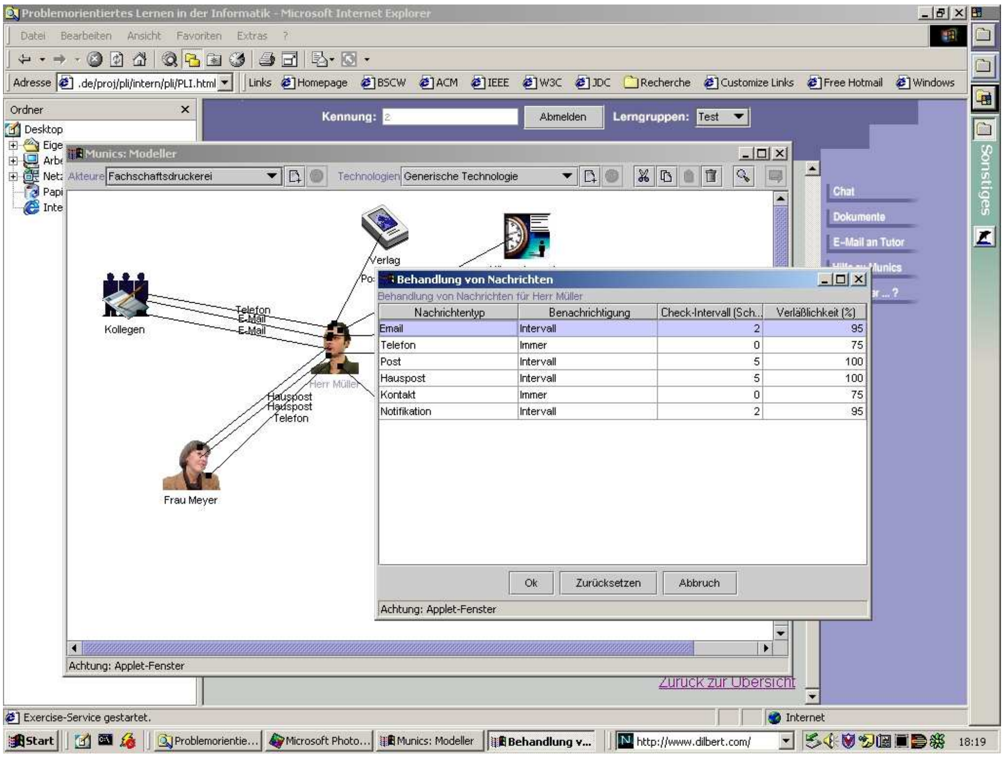

Munics: Modeller

Akteure: Fachschaftsdruckerei

Technologien: Generische Technologie

Achtung: Applet-Fenster

Figure 2.3.



Adresse: .de/proj/pli/intern/pli/PLI.html

Kennung: 2

Lerngruppen: Test

Akteure: Fachschaftsdruckerei

Technologien: Generische Technologie

Behandlung von Nachrichten für Herr Müller

Nachrichtentyp	Benachrichtigung	Check-Intervall (Sch...	Verläßlichkeit (%)
Email	Intervall	2	95
Telefon	Immer	0	75
Post	Intervall	5	100
Hauspost	Intervall	5	100
Kontakt	Immer	0	75
Notifikation	Intervall	2	95

Achtung: Applet-Fenster

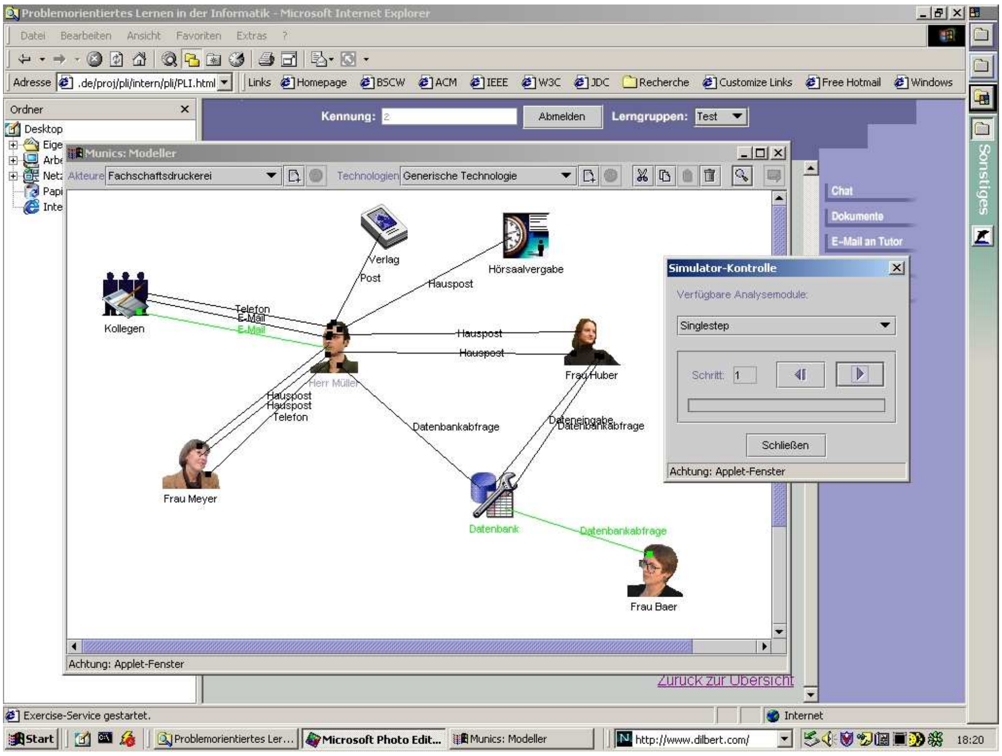
Achtung: Applet-Fenster

Exercise-Service gestartet.

http://www.dilbert.com/

Fig 3

Fig. 4



Problemorientiertes Lernen in der Informatik - Microsoft Internet Explorer

Adresse .de/proj/pli/intern/pli/PLI.html

Kennung: 2

Lerngruppen: Test

Munics: Modeller

Akteure: Fachschaftsdruckerei

Technologien: Generische Technologie

Achtung: Applet-Fenster

Simulator-Kontrolle

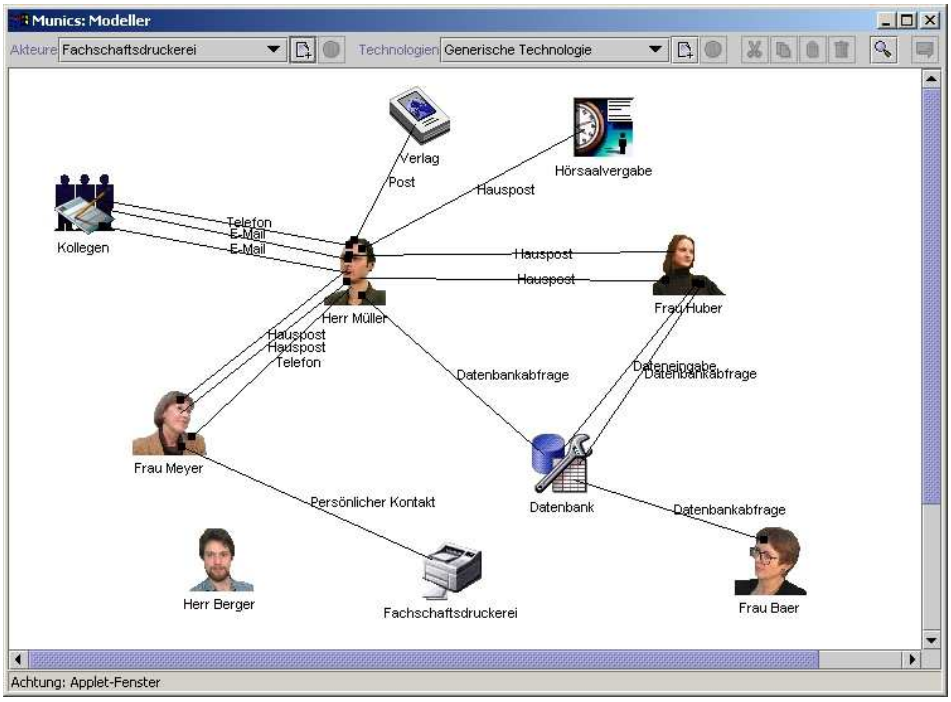
Verfügbare Analysemodule: Singlestep

Schritt: 1

Achtung: Applet-Fenster

Exercise-Service gestartet.

Fig. 5


Munics: Modeller

Akteure: Fachschaftsdruckerei

Technologien: Generische Technologie

Achtung: Applet-Fenster