A Knowledge Map Tool for Supporting Learning in Information Science

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Abstract: Large classes at universities (>1600 students) create their own challenges for teaching and learning. Audience feedback is lacking and fine tuning of lectures, courses and exam preparation to address individual needs is very difficult to achieve. At RWTH Aachen University, a course concept and a knowledge map learning tool aimed to support individual students to prepare for exams in information science through theme-based exercises were developed and evaluated. The tool was grounded in the notion of self-regulated learning with the goal of enabling students to learn independently.

1 INTRODUCTION

The Institute of Information Management in Mechanical Engineering (IMA) of the RWTH Aachen University (RWTH) offers a lecture about information science in mechanical engineering (see fig. 1) that is combined with a lab, a group exercise and exam preparation courses. The lecture focuses on object-oriented software development and software engineering (more details in (Ewert et al., 2011)). In a previous semester more than 1600 students attended the lecture. It received good evaluations from students as well as staff. This feedback was taken into account to revise the lecture, the lab and the courses a little further for the summer term of 2012. Here are some of the challenging questions of the revision: (a) How can the student's learning process be supported in a better way? (b) What are the main obstacles the students face when learning programming concepts and techniques of object-oriented programming and software engineering? (c) Which resources are needed to improve the learning process and are these available? (d) How can student-by-student communication be used for peer instruction to relieve the tutors?

The e-learning system L2P[1] of the RWTH is already widely used as a Learning Management System (LMS) in the lecture, the group exercises and the lab. However, additional learning support was requested to assist students in and out of class, but particularly when learning autonomously. Therefore, a Web-based e-learning test bed was designed and implemented which supports different kind of learning situations as autonomous learning, peer-instruction learning as well as e-mail support by tutors. It extended the L2P learning room with interactive and autonomous learning capabilities.

Figure 1: Lecture for information science in mechanical engineering ©David Emanuel.

Additionally, a tool test bed evaluation was designed to analyse how the test bed impacts the students' learning processes. Some research questions addressed were: (a) Are the students willing to use

[1]http://www2.elearning.rwth-aachen.de/english

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interactive e-learning tools? (b) Is the students' feedback to the teaching staff supported by the test bed, e.g. regarding learning interests and obstacles? (c) Is the test bed capable to support students and tutors in the learning and teaching process? (d) How can the additional challenges of large classes (user management, anonymity etc.) be managed within the test bed?

The rest of the paper is structured as follows: Section 2 will describe the general course design. In section 3, related research is discussed, followed by an explanation of the self-regulated learning concept. Then, the ROLE environment will be introduced (section 4). Finally, in section 5 we will present the evaluation and conclude in section 6.

2 COURSE CONCEPT

The lecture period of the summer semester 2012 started in April and ended in July, followed by a time of exam preparation courses starting in September. The time between these two blocks was used for autonomous, self-regulated learning (SRL). The environment for individual exam preparation was implemented consisting of three ROLE (Responsive Open Learning Environments) widgets, namely a knowledge map, a chat widget and a history widget. In the lab students were able to experiment and actively apply the fundamentals of object-oriented programming with Java. It took place together with the lecture during the summer term from April to July (see fig. 2). The exam preparation courses in September offer the students the possibility to train the addressed competences in smaller audiences.

In addition to renewing the lecture format, the course organisation was updated and supplementary digital material was provided to the students via

Week	Lecture	Lab	Group Exercise
1	Java Basics		
2		Java Basics	Java Basics
3	Object-oriented Programming		Object-oriented Programming
4		Intro NXT	
5		NXT Sensors	
6			
7		NXT Actors	
8	Software Engineering		Software Engineering
9		Final Exercise	
10			
11			

Figure 2: Schedule of lecture, group exercise and lab during the summer term 2012.

the RWTH learning management system L2P. The course's L2P was then enhanced by a selection of ROLE[2] widgets, more specifically by widgets supporting self-regulated learning (SRL). Furthermore, another Technology Enhanced Learning (TEL) aspect was introduced into the course by adding a Personal Response System (PRS) sometimes also described as an Audience Response System (ARS). This TEL tool complemented the ROLE technology as it enhanced the opportunity of further active learning prospects for students and also offered an increased interactive setting in terms of the pedagogical delivery.

Previous student evaluations had shown a demand for more self-contained programming occasions as well as practical "hands-on" tasks to try out. The newly designed lab sessions thus offered palpable tasks that the students could carry out completely on their own. The setup for these object-oriented programming lessons was based on working with LEGO Mindstorms NXT (see fig. 3) robots for use by large classes. To support the Java programming language implementation on the NXT controller, LeJOS was used (Solorzano, 2001).

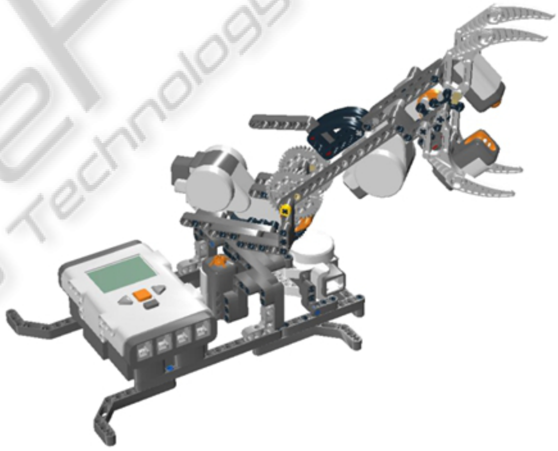

Figure 3: Model of the LEGO Mindstorms NXT robot used in the laboratory (Ewert et al., 2011).

The RWTH ROLE test bed work in 2012 was initiated with a Web-based survey that aimed to collect details about the students experience with e-learning and SRL at the beginning of the lab in April 2012. The ROLE widget environment was introduced to the students during the second week of their studies. The enriched ROLE-based learning environment offered additional support for improvement in SRL opportunities. It also provided particular information about programming in general, related tools, modelling, as well as Java itself. Around 1,600 students participated in the course. All students were informed about the

[2]http://http://www.role-project.eu/

ROLE-enhanced learning environment offer via several announcements during lectures and labs and via email. During the standard midterm teaching evaluation, a short ROLE-related survey was issued. At the end of the lecture period, the ROLE test bed was also adapted for individual exam preparation during summer time. Finally, after the exam educational staff was interviewed to evaluate the environment and its application within the course.

The lab sessions took place in the largest computer pool of the RWTH which is equipped with approximately 200 workstations. This, however, restricted the maximum number of students that could attend the lab in parallel to 200 students who then worked with 100 Mindstorms NXT robots. Since those 100 robots could not be dismounted and reassembled in each lesson, the lab was based on a standardised and pre-assembled robot model as depicted in fig. 3. This allowed for several student teams to work with the same robot set in consecutive classes and improved the comparability of the students' achievements. (To increase motivation, it would have been desirable that each team had their dedicated construction set. However, this would have resulted in an order of 750 robot construction kits.)

The second part of the lab sessions was based on the principle of problem-based learning. The students were requested to program a robotic gripper inspired by industrial robots. This resemblance to "real" robots was meant to result in a better understanding of mechanical engineering principles by the students. The assigned task was to get the robot to scan their surrounding area for coloured balls, picking them up and putting them into a box. In order to get the robots to detect the balls, students could make use of an ultrasonic sensor, a light sensor and a touch sensor located within the gripper. The robot arm could be moved up and down as well as left and right by directly controlling the corresponding motors. The third motor controlled the gripper hand. The students implemented this task during the remainder of the lab. To allow for progress tracking and giving weaker students a chance to catch up, the overall goal was separated into four sections as described below.

3 RELATED RESEARCH AND SELF-REGULATED LEARNING

The presented approach addresses different recent research issues such as teaching and learning in large classes as well as using cloud services and Web 2.0 applications for e-learning support. The challenge of teaching large classes has been a research issues for many years (cf. (Leonard et al., 1988; Knight and Wood, 2005)). The more technical background of building e-learning tools from Web 2.0 components is being discussed in (Palmr et al., 2009). The approach uses six dimensions for the mapping of Web 2.0 applications to personalised learning environments. The capabilities of ROLE-based cloud learning services are investigated in (Rizzardini et al., 2012). The evaluation shows that cloud-based learning support with ROLE environments is possible but the learners may need introduction and time to be familiar with interactive e-learning tools. The particular aspect of navigation guidance for learning questions in Java programming is discussed in (Hsiao et al., 2010).

Self-regulated learning (SRL) denotes a learning process where the learner herself decides what to learn, when and how (Zimmerman, 1998). Different scholars have attempted to develop SRL models such as the five-component SRL model of (Efklides, 2009), which comprises cognition, meta-cognition, motivation, affects, and volition.

SRL is a central pedagogical focus for higher education in general and the project ROLE in particular. SRL empowers the learners to manage their own learning irrespective of organisational interventions. According to (Steffens, 2006), the quality of learning outcomes varies with the extent to which learners are capable of regulating their own learning. In addition, SRL is considered a core competency for a professional career because of several reasons. Firstly, to keep abreast with the rapid social and technical development of a dynamic society requires life-long learning skills, which entail high autonomy. Secondly, the border between working and learning is getting blurred: we learn while we work by resolving issues in the workplace and we work while we learn by directly applying what we have learnt; SRL skills enable us to integrate seamlessly the knowledge and experience from both realms. Thirdly, it has been shown that self-regulation improves learning outcomes (Steffens, 2006).

Nonetheless, the advantages of SRL can only be realised provided the learner is able to follow a SRL approach. Self-regulation manifestation is a continuum rather than all-or-none. It ranges from an entirely independent pursuit for knowledge and skills to a structured coaching with a teacher working alongside with a learner. In the latter, it could be challenging for both teachers and learners. Amongst others, some salient issues include: learners are not accustomed to deciding learning goals for themselves and thus need some even highly structured guidance; teachers might not be prepared to give freedom to learners while they are still held responsible for their learning progress; organisations might not be prepared to engage learners and teachers in learning scenarios that are relatively open, rendering accreditation or any kind of formal assessment of learning outcomes difficult.

Specifically, in ROLE, the SRL process model is defined as a learner-centric cyclic model consisting of four recurring learning phases (see fig. 4): (i) learner profile information is defined or revised; (ii) learner finds and selects learning resources; (iii) learner works on selected learning resources; and (iv) learner reflects and reacts on strategies, achievements and usefulness (Fruhmann et al., 2010).

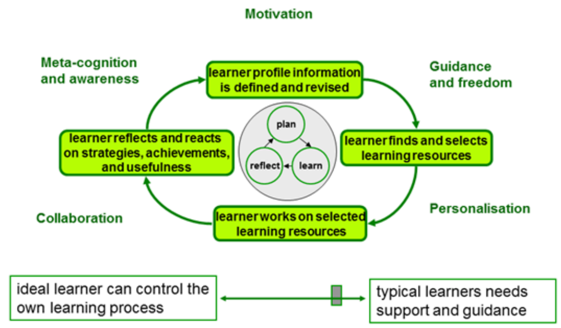

Figure 4: The SRL concept (Fruhmann et al., 2010).

To enable the fulfilment of these learning phases, a learning environment and sets of learning activities should be provided where learners can practice how to learn in a self-regulated manner. The aforementioned learning environment can provide additional learning material (knowledge map) that can be browsed independently, provide help by lecturers and tutors, provide communication channels to exchange with others. That is, support plan and learn. Evaluating the extent to which the students acquire the SRL skills in this way can effectively be measured through a well-designed survey.

4 THE ONLINE LEARNING ENVIRONMENT

In the test bed there are three ROLE widgets: the Web 2.0 Knowledge Map widget (WKM, (von der Heiden et al., 2011), see fig. 5), the chat widget and the history widget. The test bed scenario was deployed for the lab and also for the individual exam preparation of the students in August and September.

The WKM aimed to provide the students with information covered in the lecture and the lab. It was filled with additional SRL-adapted content thus focusing on typical SRL situations such as the exam preparation phase. It contained explanations and motivations for notions, definitions or examples, e.g. for basic Java programming constructs. Background information, e.g. about the installation and usage of the Eclipse programming environment, was provided as well. Exercises for exam preparation were associated with content. These entities of content are called knowledge objects. The presentation and organisation of the WKM followed the paradigm of object-oriented analyses and design in software development. Relations between objects and classes of objects were visualised (see fig. 5) to underline knowledge associations. Functionalities for annotations, remarks and feedback were provided to support individual SRL. For the first time in the course's history, the WKM gave students an opportunity for individual support during their time of exam preparation.

The second widget, a chat widget, was embedded to offer students the possibility to ask and answer topic-related questions. Other students answered the posed questions and, additionally, a tutor also moderated the chat. Finally, a history widget was embedded into the learning environment. It supported the backward navigation within the environment by offering the last five activated knowledge objects. Based on inter-widget communication (IWC, (Renzel, 2011)), the widget used data from the WKM widget to support the learner with his or her own learning history. The WKM was maintained by the IMA, the test bed was hosted by the department of information science at the RWTH and access to the WKM was granted via the login for the lab.

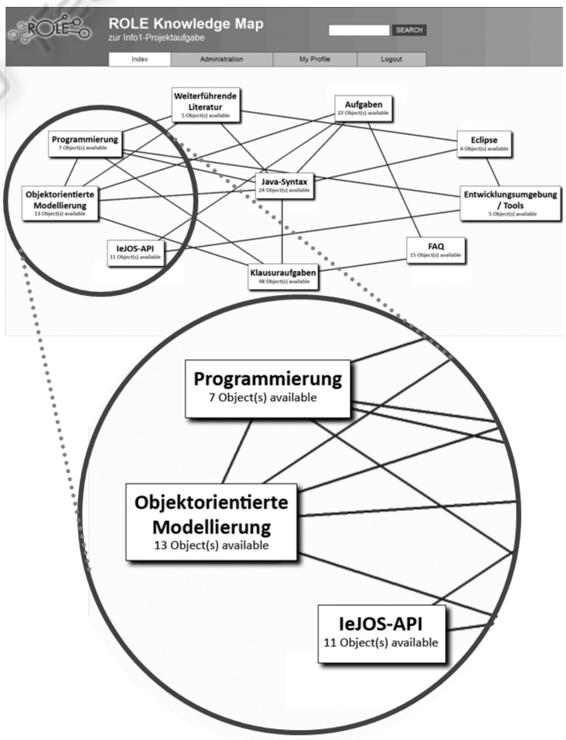

Figure 5: Screenshot of the RWTH WKM (start page).

5 EVALUATION

The ROLE environment was used to some extent during the lab time from April to June. Usage has grown significantly some weeks before the exam in September when the students started their individual preparation. Additionally, the existence and purpose of the learning tools were announced by an email to all students. The access peak was reached in the days just before the exam when students switched to "power learning". This is illustrated by fig. 6 showing the number (by day) of accessed knowledge objects. A knowledge object is a small piece of content as a notion explanation or an exercise. Figure 6 thus underlines the exam-oriented learning during the exam preparation that restricts the leeway in learning and thus the autonomy of the learner. The e-learning environment consisting of knowledge-map, history and chat enables independent and cooperative learning. Moreover, it offers learning flexibility since the environment is accessible at any time; students can use it outside the course hours.

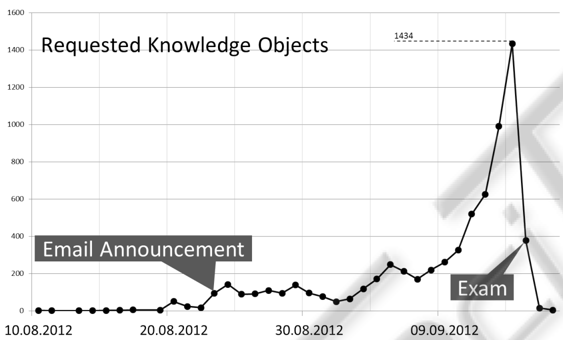

Figure 6: Requested knowledge objects by day.

In June 2012 before the summer break (i.e. at the end of the lab session but before the exam preparation), the students were asked about the usefulness of the e-learning environment and rated it positively. 162 stated that the application of the computer-based learning environment was useful. On the given scale from 1 (strongly disagree) to 5 (strongly agree), the arithmetic mean of the results was 3.7 with a standard deviation of 1.3. Since 3 would be neutral, the students evaluate the environment positively without being stunned.

After the course, the environment has been evaluated by the teaching staff. We conducted four interviews. Three of them with student assistants who acted as tutors within the practical exercise and the exam preparation and who were also responsible for adding contents to the knowledge map and solving technical issues. One interview was conducted with the lecturer who was responsible for the overall coordination and involved in the planning and conception of the whole course.

In the interviews we asked the participants to rate several statements on a scale from 1 (strongly disagree) to 5 (strongly agree) and explain their ratings. Moreover, we asked them to comment on the strengths and weaknesses of the environment and to suggest improvements. The students' positive judgement of the environment has been corroborated by the teachers. For each statement the arithmetic mean (AM) and the standard deviation is given (SD) (in interpreting these measures one has to keep in mind that only 4 persons rated the statements):

- *The environment was useful for the students.* AM: 4.25, SD: 0.43
- *The environment was useful for me in my role as a lecturer/ tutor.* AM: 4.00, SD: 0.71
- *The students reached the learning goals better because of the environment.* AM: 4.00, SD: 0.71
- *I reached my teaching goals better because of the environment.* AM: 3.50, SD: 1.12
- *I would advice the students to use such environments more often if they had access to them.* AM: 4.75, SD: 0.43
- *I would use such environments more often for teaching if I had access to them.* AM: 4.67, SD: 0.47
- *I would use such environments more often for learning if I had access to them.* AM: 3.25, SD: 1.79 (This is an interesting result: Why do the lecturers / tutors rather advice their students to use such an environment than use it themselves? The Interviewees answer that their personal learning style is not optimally supported by such an environment, because firstly they prefer not to browse through learning contents but to study text books and other material, in particular exercises and exam questions from previous semesters, from beginning to end. Secondly, they prefer using pen and paper over doing all exercises with the computer. Therefore, they request an export to PDF so that they can print selected parts of the material.
- *I consider the environment used within his course as a didactically sound means.* AM: 4.50, SD: 0.50

According to the interviewees, the strengths of the environment were, firstly, that the knowledge map gave a clear overview on the course contents and their inter-relationships. The students got a starting point for browsing through the material and exploring the themes independently. Questions could be answered by pointing to specific objects on the knowledge map, and students could (and did) answer their follow-up questions themselves by exploring the surrounding/linked objects. Thereby, the autonomy of the student was effectively supported. Secondly, the chat widget allowed fast feedback from the students. Questions could be immediately answered. Since all students could read the answers, questions did not have to be answered twice. Thereby, the tutors' explanations became more efficient. The tutors saved time for helping with truly individual problems. Thirdly, the environment improved the communication among the students and thereby collaborative learning. After a short time span the students began to answer questions of other students. Fourthly, the environment rendered the students more flexible regarding their time management and learning speed. They were able to repeat lessons and exercises without losing track of the course or thwarting others.

Concerning the weaknesses, the interviewees found technical and usability issues, in particular regarding the administration of the environment and the adding of new contents to the knowledge map. These issues have to be solved but do not affect the concept and general design of the environment. Moreover, the interviewees propose the following extensions of the environment:

- The chat widget should be exchanged or supplemented by a forum for general questions and by a commentary function for the elements of the knowledge map. This would improve the linking of contents with questions and comments.
- They consider a learning planer, consisting of a simple to-do list with links to exam-related material and topics, self-tests and a visualisation of the current level of knowledge/ exam preparation progress (related to the self-test results) as extremely useful.
- The interviewees agree that the contents are the most important feature of the environment. These have to be updated regularly.
- So far the contents of the knowledge map are explored by browsing. An additional search engine for the direct search of specific content would be reasonable.
- One interviewee deems a recommender system that recommends related external material useful.

One aim of offering the ROLE environment was to support SRL. Has this goal been reached, that is, did the environment effectively support self-regulation? The interviewees claim that this is in fact the case. While in the beginning a lot of trivial questions were asked, the students were able to find the answers to such simple questions themselves soon. (The question is, however, whether we can attribute this development to an improvement of self-regulation or rather to a learning effect regarding the course contents.)

The interviewees considered it important to support SRL. They estimated that by far most of their students had medium SRL-level. They correlated the SRL-level with the general knowledge level and acknowledged that students with a high SRL-level learned better and faster. However, as tutors and lecturers they generally preferred to teach students with a medium SRL-level over students with a high SRL-level. They justified this preference as follows:

- A tutor was supposed to lead interesting discussions with high SRL-level students. However, they did not need a tutor that much and therefore did not get in close contact to them. Teaching often did not really take place. Moreover, these students tended to be good students that asked difficult questions. A teacher had to be well-prepared and feel certain on the course topic to cope with these questions. This made it sometimes harder to teach students with a higher SRL-level.
- Medium SRL-level students were intelligent but still requested interaction with a teacher. The teacher got in contact with them, observed the learning progress and saw the positive effect of explanations and assistance. The interviewees found this very rewarding.
- The interviewees considered that a low SRL-level is correlated with rather low learning success. Teaching students with a general low level was considered to be cumbersome and not very rewarding.

Feedback given through the environment was recognised by teachers as very important. The interviewees emphasised the role of the chat (or a forum). Feedback was deemed important for estimating the students' progress and thus adjusting interventions. Moreover, it makes teaching more satisfying.

6 CONCLUSIONS

A course design for information management in mechanical engineering was presented. The course had been re-designed to better support SRL. Therefore, an e-learning environment with several ROLE widgets was provided to the students. The environment aimed to support individual exam preparation. In comparison to the lecture of 2011, the evaluation showed the necessity of intensive promotion for new and additional e-learning tools. Tool objectives and advantages must be clearly communicated (at the right time) to the students. Nevertheless, only a minority of all students had used the test bed for a longer time. Here, guidance with learning questions as in (Hsiao et al., 2010) may motivate students and foster communication. Until now, overview and learning guidance is given by the visualisation of topic relations on the start page, the hierarchical and object-oriented organisation of knowledge in the map and the linking of knowledge objects.

To take stock, the evaluation of this test bed has shown that the environment supports SRL and collaborative learning in large classes. The answering of student questions was easier via the chat widget than by email as all students were able to see the answer. Additionally, the chat fostered student-to-student support. Even if the test bed offered support for early learning, the peak of usage was reached just before the exam. It indicates the students' remaining in power learning.

The test bed was implemented as a cloud learning application combining widgets as services in an overall application and using IWC for communication between the widgets. Since different people were responsible for the particular widgets, it was sometimes hard to fix problems e.g. when server were not accessible.

Until now, the test bed was aimed to demonstrate the possibilities of ROLE technology in large classes. The demonstration was successful and further development has to focus more on the learning requirements of students. Therefore, future improvements are seen in better communication and feedback support to strengthen e.g. learning motivation. Suggested improvements are firstly better collaboration support by adding improving topic-related communication (forum, notepad linked to contents of knowledge map) and secondly better SRL-support by adding a learning planer that supports planning (to-do list) and reflection (self-tests, visualisation of progress). The offering of learning strategies such as learning questions (Hsiao et al., 2010) within the learning tool may offer new advantages and motivation for the students.

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