On Benefits of Interactive Online Learning in Higher Distance Education

Case Study in the Context of Programming Education

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Abstract—**The advent of the world-wide web has challenged traditional distance teaching to supplement custom textbooks, video broadcasting and limited personal interaction with computer-based learning technologies, multimedia systems and compter-mediated interaction between geographically dispersed students and teachers. In this paper, we report on a project that aims to identify potential for improving learning outcomes of distance learners on the subject object-oriented (OO) programming through the use of new media and online learning technologies. We performed a quantitative and qualitative study based on a competence model for OO modeling and comprehension with two groups of distance students: a control group using classical textbooks and an examination group using a standard learning environment enhanced by digital interactive tools and re-purposed learning materials. In addition, we tracked the behavior of the online study group and analyzed the log data with the help of SAS Business Analytics to detect conspicuous learning behaviors.**

Keywords-distance learning; online learning; web log mining; learning analytics; competence analysis

I. Introduction

Traditionally, European distance teaching universities used prepackaged self-instructional correspondence courses that allowed their students to study at the time and location of their choice. Starting out in the early ‘90s, this teaching model was challenged by the advent of the worldwide web and, in succession, a rich world of digital learning and collaboration tools. This opened the opportunity to tailor course design to interactive online learning. As an intermediate step, we supplemented existing print courseware with interactive multimedia systems that allowed students to experiment with simulated or animated virtual worlds and get meaningful feedback on student-system interactions in real-time [1]. Asynchronous e-mail, chat tools, or text forums and synchronous webinars allowed us to narrow the distance between fellow students and teachers concerning social interaction possibilities.

Several studies have compared online and face-to-face learning, partly with contradicting result [2], [3], [4]. There is, however, a paucity of original research dedicated to understanding 1) whether information and communication technology (ICT) is perceived beneficial for distance education, 2) what the impacts of the use of digital interactive learning and communication tools on the outcomes of distance students in higher education, such as grades and test scores, is and 3) how learning designs should be tailored to meet the needs of these students.

A research project funded by the European Union [5] addressed the first question. It examined the impact of on learning in adult education, lifelong learning and, in particular, distance education. Research instrument was a series of randomized controlled trials using questionnaires and statistical analyses. The studies demonstrated conclusively that technology does, in fact, have a positive impact on learning. Major reasons include: technology facilitates easier access to material for those studying part-time; online communication facilitates the interaction with teachers, learning technology supports the development of higher level thinking skills, such as synthesis and problem solving, and digital learning materials including multimedia and interactive elements can enhance learning.

A first step towards answering the second and third question was recently undertaken in a joint project between FernUniversität and the University of Paderborn, Germany. The project set out to find answers to the following research questions:

1. To what extent can the learning objectives of a course be achieved with traditional custom textbooks and asynchronous tutoring activities using email, text forums, and phone?
2. Is there a significant difference in learning outcomes between students relying on traditional distance learning settings and online students?
3. Do students prefer online learning technologies to traditional correspondence courseware?

During summer semester 2012, we invited all 693 students enrolled in the distance learning course “Object-oriented Programming” for beginners to participate in a pre- and posttest evaluating the students’ modeling and comprehension competencies in the topic area. Further, we asked for a smaller group of volunteers who agreed to study a new interactive version of a course module and allow us to

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log their online behavior. The competencies analysis used the Modellierungskompetenz-Modell (modelling competencies model, MoKoM) model that the researchers from Paderborn had developed in another research project that was financially supported by the German Science Foundation [6]. In a collaboration of computer scientists and psychologists, a theory based and empirically refined competency model for the domains of system application, system comprehension and system development was developed and tested by means of a competency test instrument [7].

In the following section, we present the project layout and sketch the research methods and tools used in the experiment and analysis of the data gathered by observation, competency testing, and surveys. Section III discusses the results of the competency, behavior, and the online learner satisfaction analysis. Section IV critically scrutinizes the validity of the results and outlines a modified design for a repetition of the experiment.

II. Setting the Scene

Distance students own above average experience with self-directed learning. They are used to organize their learning freely but have limited time to participate in synchronous learning events, which requires the barriers for group learning actions to be kept low.

To challenge students in the online group to perform more demanding learning activities, we redesigned both the instructional design and the content of one module of the course substantially. The selected course unit dealt with exceptions, testing and program documentation. We developed a number of interactive learning objects in Adobe Flash that allowed the students to experiment with alternative solutions of program designs, explore, modify and explain the behavior of given program solutions rather than just sketching a single program on paper and submitting it as their solution to a homework assignment. To provoke teamwork, we designed learning tasks that involve 2-4 students playing different roles, such as a programmer or tester, and tasks whose solution was composed of several modules contributed by different students.

A. Competence model for informatics modelling and system comprehension

To define the important competencies for the considered domains, the MoKoM project derived a theoretically founded competency framework from relevant national and international curricula and syllabi. This framework was used as a basis to develop specific problem scenarios. They could be used to conduct qualitative interviews with experts in different fields of computer science education [8]. The analysis of the transcribed interviews led to an empirically refined competency model with six dimensions: K1 System Application, K2 System Comprehension, K3 System Development, K4 dealing with system complexity and K5 Non-Cognitive Skills.

For each competency described in these dimensions, a test item was developed for assessing it in large-scale competency tests. After some tests with smaller populations, the MoKoM project currently evaluates the results of an assessment of around 600 students. To deal with the large amount of tests, the instrument was split into 6 booklets with 30 to 40 items that could be completed in roughly 90 minutes each.

To use the instrument in the study at hand, we transformed the competency measurement instrument into an online version. Each item was adapted as close as possible into the online survey system LimeSurvey [9]. Due to the nature of the questions, some items could not be transformed properly (e.g., drawing a diagram). For each of these items, a decision had to be made, whether the associated competency was appropriate for the field of OOP and, if so, a new item had to be developed. As we wanted to exploit the breadth of the competency model and expected a high number of participants in the test, the partition into six booklets was kept for the online survey.

To allow for an anonymous survey, an additional item was added to ask for a unique code. This code was generated individually for each student based on personal information.. This allowed for the association of pre- and post-test without revealing the students' identity.

B. Study Groups

In a first step before the course started, we invited all 693 students enrolled in the course to evaluate the online test. To raise the students' interest in the study, we announced to give away three books in a raffle based on voluntarily provided email addresses. The 146 students who followed this request and worked on the test with different degrees of completion formed the study group for the competency test.

Then we invited students who agreed to study the online course module and allowed us to track their behavior. 12 volunteers formed the online student group whose behavior we analyzed and whose satisfaction with the e-learning version of the course we studied.

At the end of the course, we asked the whole student population again to evaluate the post-test marking it with the same code they had used in the pretest.

Finally, we aimed to differentiate between online and textbook students among those who participated in the obligatory written exam, which is held at the end of the course, in order to find possible differences in the learning outcomes of both groups. 199 students took the exam including 6 of the 12 online students. Both groups were truly comparable because they are all distance students enrolled in the same study program. In addition, the online students also have experience with textbook study materials from other course units of the test course and other distance courses in the curriculum.

C. Digital Learning Environment and Learner Satisfaction Analysis

The online course unit addressed exactly the same course topics as the textbook version but included more experimental learning components and a few cooperative tasks. Figure 1 depicts an interactive learning object, which is called crash lab. It allows students to explore the behavior of programming exceptions by pulling selected program statements from a pile underneath a program window into a code-frame provided in that window, compile the resulting code and run it if the compiler succeeds. Students are supposed to predict whether the different programs they build this way will fail or terminate successfully. The results of the test runs are collected in the two boxes labeled “aborted” and “regularly completed” at the bottom right.

An example of a team problem is a simple game with a treasure being hidden in an area of 24 cells in which a player to find the treasure by moving in this area strategically. One student has to develop the program component controlling the game; the partner has to implement the behavior of the player. Some constraints are imposed on the behavior of both components, which may lead to program exceptions. Raising and handling exceptions properly are key learning objectives of this course unit.

The online course was delivered through the learning management system Moodle and was supervised by the same faculty who also taught the textbook version. The installation of Moodle we used in the study was seamlessly connected to the learning object repository edu-sharing [10], [11]. This repository enabled the online students to share and collaboratively work on their contributions. The repository functionality allowed them to control which access rights to their personal workspace they wanted to grant selected peers.

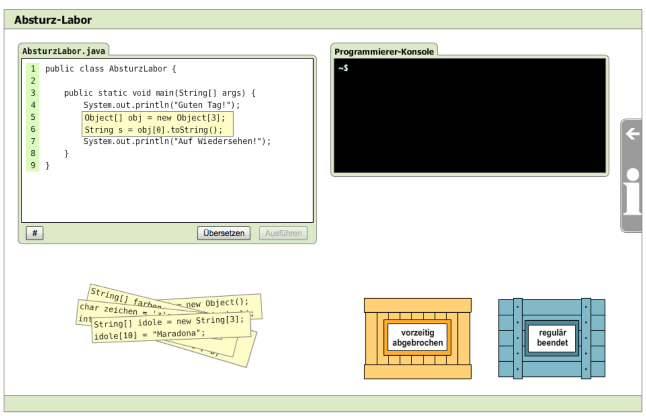

Figure 1: Crash lab supporting explorative programming experiences

Besides the students’ online behavior, we also wanted to understand their satisfaction with the online course material and with the learning environment we provided. For this purpose, we designed an online questionnaire with 28 questions addressing the following issues: preferred computer equipment, experiences with e-learning, usability of the online course and tool environment, subjective judgement of the discipline knowledge, communication and cooperation competencies gained in the online course, and a comparison of the effectiveness of the study process with traditional textbooks and the online study material.

III. Analysis of Results

A. Competence Analysis

To assess the competency gain of the students, they were asked to complete the online survey created from the MoKoM measurement instrument twice: Once at the start of the term and once at the end. The students were randomly partitioned into six groups, each having access to one of the six test booklets provided in a LimeSurvey installation at FernUniversität in Hagen,

Unfortunately, the participation in the survey was not very good. Of the 693 students registered for the course, only 57 started their pretest booklet and just 19 students in total finished more than 75% of all items. This number got even worse for the post-test with 30 started booklets and only 5 finished surveys. At both tests intervals around 150 users visited the survey page but only one third and one fifth, respectively, started the first item at all. Since the participants who finished their booklet were spread across the six variants, the useable data for each test item is too low to get any meaningful results regarding the competencies of the students. Only one student completed both tests, what makes propositions about the competency gain through the course impossible. Even tendencies supporting or falsifying any of the hypotheses we started from are hard to state.
To at least get a notion what to change for subsequent tests, the answering habits of the participants were examined. By counting the number of students who tried to solve an item over all 87 datasets it is easy to see that the completion rate drops to 60% after only four items (see Figure 2). The eighth item was completed by only 50%.

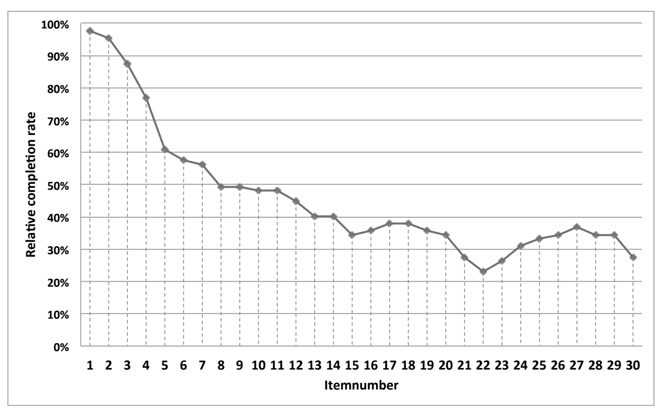

Figure 2: Relative completion rate of survey items

A reason for these results might have been the length of the competency test. Tailored to be conducted in a German classroom setting, where two successive lessons equals 90 minutes, it seems the time a student is willing to spend on his own in answering the survey is considerably shorter. Examination of the response rates for online surveys even showed that the ideal length for an online survey is thirteen minutes or less [12]. This ideal timeframe is too short for a competency test, but without the constraints of a school environment, 90 minutes seem much too long.

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B. Behavior Analysis of Online Students

It is obvious that the small number of cases (12) cannot provide statistically valid results. Even so, some insights gained are worth mentioning.

The database for the behavior analysis of the online students was compiled from the log data provided by Moodle and edu-sharing and the log data captured by the Flash-based interactive learning objects. The latter allowed us to a) relate student results to assignments, b) see errors he or she trapped into, and c) find repetitions performed in the attempt to solve an assignment. As user identities for the login to Moodle and edu-sharing (single-sign-on), we used the personal code the students had defined for the pre-test. All log data were time-stamped. These time-stamps helped use to integrate the data coming from different sources. The raw data were cleaned and integrated to a single database that was then analyzed with the help of the business analytics software SAS. SAS was particularly used for structure and usage mining. Structure mining relies on the links between information pages and links from within course pages to self-test examples, homework assignments, forum entries, and objects maintained in the repository and workspaces.

The objective of structure mining is to identify recurring patterns of behavior, e.g., in the form of paths through the learning materials or repeated experiments with exercises and programming problems. These paths form a network that visualizes how students navigate through the course material and the learning environment. The open source software Gephi Data Laboratory [13] was used for network analysis and result plotting. Particular indexes of the network analysis are the weighted in- and out-degrees of course elements, which indicate the frequencies of visits. The master solutions to self-tests in the sections about exceptions and program testing and a quiz about program comments had the highest values: 35, 34 and 30, respectively, while the average was 9.9. Another index is the connection intensity between elements. It records navigation steps leading from one to another element in the graph. A high index value between an information page and a self-test indicates multiple trials of this test and suggests a higher degree of difficulty of the problem exposed. This index may help the course author to vary the degree of difficulty of self-tests in a distance-learning course as it is perceived by the students. The index “page rank” also identifies the master solutions for self-tests on program testing and exceptions as top candidates. A path analysis shows that students work through the first part of the online course mostly following the structure provided by the course author. In later parts, however, their behavior is more flexible.

Usage mining provides useful descriptive statistics. This includes:

- information about the number of page visits,
- time spent on a page, exercise, or problem, usage depth or
- typical entry and exit pages.

The usage depth in this experiment tells us that, in the average, 35 course elements were touched in a single visit.

The quantitative analysis described above was complemented by a qualitative analysis based on the log data captured from the interaction with Flash objects. For instance, five students worked on the explorative problem depicted in Figure 1 and all five predicted the behavior of the 8 different program snippets correctly. This result suggests that the difficulty of the problem was too low. A test of the students’ ability to understand the semantics of exceptions, which was composed of 4 sub-tests, shows that the success rates diminish with each sub-test. This observation confirms the author’s intention to increase the difficulty of the sub-tests step by step. An investigation of problems in which students had to write code reveals that one student performed significantly worse than his or her peers. His behavior seems to exhibit a trial-and-error strategy as opposed to the structure procedures the other students applied.

C. Test Scores

Originally, we wanted to relate the test scores of the exam to the competences test to investigate whether the self-evaluation of the students correlated with the examination scores and whether we can find significant differences between textbook and online students. We also hoped to see whether an initial difference in competences in the topic area has a significant impact on the exam result. In addition, we were curious whether the course can even out such competency differences in the student group. Further we were looking for differences in test scores between textbook and online students.

Figure 3 shows a plot of the frequencies of scores for the 199 students who took the exam. The best score (1.0) was achieved by 8 students, 57 students failed with a score higher than 4.0. The lower curve shows the frequencies for the six online students, which roughly follows the shape of the other curve with 4 students scoring between 1.3 and 3.0 and two students having failed.

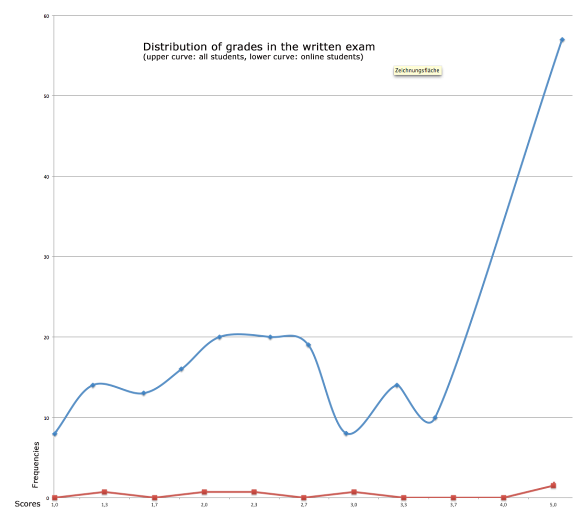

Figure 3: Scores of 199 students in the final exam

Knowing that this interpretation is, indeed, daring, we hope to perform better in an ongoing second experiment with about 100 online students.

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D. *Learner Satisfaction*

In order to analyse the online-students' needs and their satisfaction with the online version of the course, we developed a web-based questionnaire that was also accessible via LimeSurvey. We adopted and enhanced the Technology Acceptance Model (TAM) [14], and the System Usability Scale (SUS) [15]. Both were already successfully applied to analyse e-learning environments [16], [17]. The questionnaire provides 28 Likert-scaled statements and covers 9 analytical dimensions. They are:

- use of the learning environment's technical functionality,
- potential to convey expert knowledge,
- potential to convey methodological skills,
- usability of the learning environment,
- patterns of usage,
- types of exercised co-operative learning,
- use of platform's communication tools,
- students' motivation, and
- students' technical affinity.

The questionnaire was delivered at the end of the term to those students, who attended the online-course and also agreed to participate in the behaviour-analysis study based on their log-files. Unfortunately, only six students responded. Thus, it does not make sense to deploy statistical methods of quantitative data analysis on this sample. Nevertheless, the students uttered some interesting statements, which might contribute to the comprehension of existing problems. The addressed categories were: importance of a good mentoring service, necessity to be aware of the system's functionality, students' personal situations and missing pressure to succeed lead online-learners to drag behind the schedule of the course, this additionally creates barriers for co-operation and communication with fellow students.

IV. Conclusion and Future Work

The underwhelming results of the first survey led us to conduct a second iteration with a slightly different concept during the winter term of 2013. To get more students to finish the test, it had to be possible to complete it within 60 minutes. For this reason, instead of testing the complete range of competencies of the MoKoM model, a collection of items especially tailored to the requirements of the course at hand was selected. To choose the appropriate test items, the desired learning outcomes for the programming course were matched to the competency descriptions of the MoKoM model. This way, a selection of relevant test items could be accumulated and combined into one competency test. This also eliminated the need for several test booklets and will allow for a bigger set of data for each test item.

Since the complexity of the item did not allow for a test with the suggested optimal length of thirteen minutes, an additional incentive had to be made to complete both tests. For this reason, we decided to offer bonus points up to 10% of the total number of credit points that can be achieved in the exam. Up to half of admissible bonus points will be given for participating in both pre- and posttest, the amount depending on the degree of completion of each test. The other half will be granted for participating in the online study group, depending on the degree of activity and collaboration. Those students who want to compensate their bonus points with the exam result have to give up anonymity against the examiner, but their personal data will not be accessible in the competency analysis. The bonus points can only be used in the exam offered immediately after the end of the course. This constraint renders us quite optimistic that the students who volunteered for the competency test and online behavior analysis will take the exam and thus give us the chance to compare the learning outcomes of a reliable sample.

So far, the measures seem to be successful, since the pre-test performed late September 2013 showed a tremendous increase in the number of participants, with around 180 complete or nearly complete datasets.

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