On Benefits of Interactive Online Learning in Higher Distance Education

Repeating a Learning Analytics Project in the Context of Programming Education

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***Abstract* - All generations of the Web have given rise to new technologies and services for teaching and learning. Ample research projects have investigated their impact on educational processes and students' learning outcomes. This is especially true for the comparison of online and face-to-face learning or distance and classroom instruction. There is, however, very little original research and evaluation evidence about the impact of incorporating web-based learning technology and multimedia content in higher distance education. This article presents the results of two studies with distance students of FernUniversität. These results address four strands: the students' competence gain on key course topics; an analysis of the learning behavior of a subset of online students; a performance comparison between online students and a control group using classical correspondence learning materials; and online student satisfaction with the online version of the course and the e-learning environment. Authentic comments from two students who were involved in all evaluation strands supplement the formal findings.**

Keywords - distance learning, Web-based learning, learning analytics, competence analysis, learning performance, technology assessment.

I. INTRODUCTION

Distance education describes an organization of educational processes in which teachers and students are separated in space and time and communicate with each other mainly asynchronously. Traditional teaching media were and still are prepackaged self-instructional correspondence courses that allow distance 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. The initial Web of Information opened up the possibility to exploit interactive multimedia content and deliver learning materials electronically. It also allowed their adaptation to different learning styles by drawing appropriate learning objects from the Web or content repositories. Hypermedia structures in online courses could be used to lead students on different paths at the students' own paces through the course content, depending on their individual performances in intermediate online tests and quizzes.

The Web of Services then brought about the possibility to include all kinds of collaboration and communication services in online learning activities. More recently, the Social Web offered a range of social software tools that allowed students to participate actively and in real-time in educational processes, independent of any physical proximity.

Numerous studies have compared online and face-to-face learning to understand the impact of web-based learning technology on higher and extended education. There is, however, very little original research and evaluation evidence about the possible advantages and disadvantages of incorporating web-based learning technology and multimedia content in higher distance education. To fill this gap, an interdisciplinary group of researchers from FernUniversität in Hagen and the University of Paderborn performed a quantitative study and experimental research on online learning. Subjects were volunteer students from FernUniversität in Hagen, the only German language distance teaching university. The project set out to find answers to the following research questions:

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

During the summer semester 2012, we invited all 693 students enrolled in the distance-learning course on "Object-oriented Programming" (OOP) to participate in a pre- and post-test evaluating the students' modeling and comprehension competencies in the topic area. Further, we asked for volunteers who would agree to study a new interactive version of a selected course module online and allow us to log and evaluate their online behavior anonymously. The group of online students was also asked to perform a technology assessment at the end of the course.

Study settings, evaluation methods and tools, and preliminary evaluation results of this project were published in the proceedings of the Sixth International Conference on Mobile, Hybrid, and On-line Learning [1]. Due to the small number of subjects participating in all phases of the study, these results were, however, statistically not reliable. Therefore we decided to repeat the study in the winter semester 2013/14 with the same course but a different group of students.

In the following section, we summarize the evolution of higher distance education over the last two decades. We also provide a brief review of significant research close to the work reported here. Section III sketches the learning setting in which the study was performed, including course content, learning objectives, and the newly designed digital learning environment. Section IV presents the quantitative study design and sketches the research methods and tools used in the analysis of the data gathered in the form of log data and surveys. This section also describes the modifications applied to the competence test used in the second survey. Section V summarizes the results of the competence analysis. The interpretation of the log data collected from online students is described in Section VI. Key results of the technology acceptance test are reported in Section VII. Then, Section VIII relates the test scores of those students who attended the final examination to their online retention times and interaction with learning objects. Here, we also compare the examination results of the online students with those of a control group of offline students. The latter used traditional correspondence materials for learning. Section IX summarizes the feedback from two online students who were interviewed 6 months after the end of the course. Section X concludes the paper and presents the lessons learned from the two projects.

II. Background and Related Research

The new technological and communicative options of the Web allowed educators at distance-teaching universities to tailor course design and instruction to interactive online learning [2]. As an intermediate step, existing textbooks were supplemented with interactive multimedia systems. They were delivered electronically through the Web and allowed students to experiment with simulated or animated virtual worlds, access remote labs, and thereby get meaningful feedback on student-system interactions in real-time [3]. Asynchronous e-mail, chat tools, or text forums and synchronous webinars allowed educators to narrow the distance between fellow students and teachers concerning social interaction possibilities.

Ever since distance education emerged, researchers and educators tried to answer the question whether distance learning can be as effective as learning in face-to-face settings. T. Russel has summarized a rich body of literature addressing this question in an annotated bibliography entitled “The No Significant Difference Phenomenon” [4]. The essence of this work is not the claim that distance education and classroom education are equally effective for all students, courses, and instructors but that individual variations and extraneous variables may render many of the findings in related literature inconclusive. A huge meta-analysis of empirical literature on the comparison between distance education and classroom instruction basically supports Russel’s conclusion [5].

More than thousand empirical studies can be found in research literature comparing online to face-to-face learning, measuring student learning outcomes, or proposing innovative learning designs. The meta-analysis in [6] found that, on average, online students performed slightly better than students who attended face-to-face instruction. In detail, opinion is divided, however. Ferguson and Tryjanowski can show that students in their face-to-face class scored significantly higher than online students [7]. In contrast, Cooper’s study on a “Fundamentals of Computer Applications” course with 94 in-class and 37 online students, could not observe any significant difference in scoring between the two groups [8].

Today, many people equate distance learning and online or e-learning, but, in fact, these concepts do not refer to the same thing [9]. Physical distance is not a defining feature for e-learning, but it is for distance learning. The target population of distance universities is students who are unable to regularly attend on-campus classes due to family or work commitments or because of personal limitations. These students depend on the institution “distance-teaching university” because it offers:

- Complete distance learning programs,
- Learning materials especially designed for self-study,
- Effective asynchronous communication media,
- Flexible examination conditions,
- Well-trained tutors, and
- A network of study centers.

Against this background, the key question is not: “online or face-to-face learning”. Rather, the issue is how online learning solutions can be effectively used in higher distance education.

III. Setting the Scene

In this section we introduce the learning setting both for A) traditional higher distance learning with correspondence material and established distance learning support tools and B) a newly designed online version of a selected course module.

A. Course Objectives, Structure and Learning Support

Since 2004, the course OOP is taught on the basis of correspondence materials consisting of 41 chapters summing up to a 500 pages textbook. The course objectives claim that by the end of the course, successful students will be able to:

- Identify, explain, and properly apply at least 10 core concepts of object-oriented programming. They include: object, class, class relationships, single and multiple inheritance, interface, constructor, method and method invocation, variable, array, data and object type, program flow statements, and package.
- Design appropriate data structures and algorithms solving a given problem.
- Govern the essential sequential programming concepts of Java.
- Develop the data structures and algorithms of a design solution into a correct Java program.
- Understand and modify a given Java program.

- Distinguish between and implement iterative and recursive algorithms.
- Read and interpret simple UML diagrams.

The course content is divided into 7 course modules that are processed every other week. Besides course-related learning objectives, more detailed learning objectives are set for each module. Questions and self-assessment exercises with sample solutions and software-based self-tests providing real-time feedback aim to provide stimuli and learning guidance.

In distance education, regular task blocks, course-related newsgroups and forums replace exercise hours of on-campus instruction. Students edit the optional task blocks in a 14-day cycle. To this end, they use FernUniversität's online exercise system to submit their solutions and get automated responses. Student solutions can be IMS QTI-type interactions, but in this course they mostly consist of program snippets or small programs the students have to develop themselves. Once a program is uploaded, it is automatically compiled on the remote university server. If the compilation succeeds, the resulting code is run through a style checker and a sequence of pre-defined test cases. The style checker and test results provide a quick feedback and aim to motivate the student to improve his or her solution if some test cases failed or the programming style is weak. This edit-compile-test cycle can be repeated as often as needed until the final delivery schedule is reached. A tutor then corrects the submitted final version of each student program manually to provide individual feedback.

B. Digital Learning Environment

Distance students possess 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. This 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 module deals with program exceptions, testing, program documentation, and error handling. The learning objectives of this module require both conceptual knowledge and practical skills. According to Bloom's taxonomy of learning objectives [10], these are, in particular, application, analysis, and synthesis skills. Concept knowledge is needed when students must:

- Recognize the benefits of meaningful program documentations.
- Understand the difficulties and limitations of program testing.
- Identify and properly apply error-handling techniques.
- Avoid typical programming errors.

Practical skills are needed when students must:

- Document their own and foreign Java programs in a meaningful way using Javadoc.
- Write Java code that raises meaningful exceptions and properly intercepts them or passes them on to a higher level of exception handling.
- Plan test cases, perform program tests, and interpret test results.

The online course module, which can be access at [11], addresses exactly the same course topics and learning objectives as the textbook version. Besides short reading passages in the form of HTML pages capturing basic factual knowledge students need to learn, the online module includes ten interactive learning objects. They are implemented in Adobe Flash and allow the students to experiment with alternative solutions of program designs, explore, modify and explain the behavior of given program solutions, evaluate their own solutions, or grasp the semantics of certain programming concepts in a trial-and-error fashion. To encourage teamwork between physically remote students, we also designed a few new learning tasks that involve 2-4 students playing different roles in the programming task, such as a programmer or tester. Furthermore, we proposed homework assignments whose solution was composed of several program modules to be contributed collaboratively by several students.

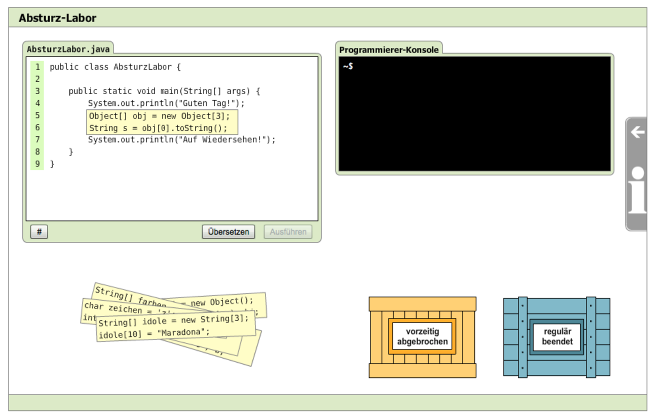

Figure 1. Crash lab providing explorative programming experiences.

Fig. 1 depicts one of the interactive learning objects, called crash lab. It allows students to explore the behavior of programming exceptions. They drag one of the program statements in the pile underneath the editor window on the left into a code frame provided in the editor window. Then, they push the button "Übersetzen" to compile the resulting code and run it if the compiler succeeds (in which case the button on the right is highlighted). 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 "vorzeitig abgebrochen" (aborted) and "regulär beendet" (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. A player has to find a treasure by moving strategically in this area. 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.

The online course was delivered through the learning management system Moodle [12]. It was supervised and tutored 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 [13][14]. This repository enabled the online students to share and collaboratively work on their contributions in a protected space. The repository functionality allowed them to control which access rights to their personal workspace they wanted to grant to selected peers.

IV. Quantitative Study Design

To acquire data about the students' perception of the new online learning environment and their competence gain on the subject of this course, two online questionnaires were developed.

Our first experimental study was conducted during the summer semester 2012 [1]. It consisted of a:

- Pre- and post-test to determine the students' competence gain in core topics of the course.
- Learning behavior analysis of a subgroup of online students based on various log data.
- Technology assessment of the online student group.
- Analysis of homework submissions.
- Written examination at the end of the semester covering all learning objectives for the course.

Unfortunately, a disappointingly low number of students participated in the post-test performed in July 2012. As a consequence, we were unable to determine the competence gain of the anonymized subjects. In addition, we observed hardly any overlap between students who participated in the competence tests and in the final examination. This fact prevented us from correlating competence gains and examination scores. For similar reasons, a statistically valid comparison of the final grades of online and offline students was impossible.

These weak results encouraged us to repeat the study in the winter semester 2013/14. To reduce the problems of the first study, we adapted some study parameters that had caused problems before. These modifications are discussed in Section C.

A. Learner Satisfaction Analysis

Besides acquiring a detailed insight into the students' online behavior, we also wanted to collect their satisfaction with the online course material and the learning environment provided.

Based on Davis' technology acceptance model (TAM) [15], Venkatesh's extension TAM2 [16], and Brooke's System Usability Scale (SUS) [17], we developed a technology acceptance questionnaire tailored to our specific learning environment. Both TAM and SUS have been successfully used in the study of e-learning environments [18][19]. We also considered the most recent model TAM3 [20] but did not find extensions like "Perceptions of External Control", "Computer Anxiety", "Perceived Enjoyment" and others relevant for our learning analysis purpose. The online questionnaire we gave our students includes 28 Likert-scaled items and covers the following analytical dimensions:

- Preferred computer equipment.
- Individual experiences with e-learning.
- Usability of the online course and tool environment.
- Subjective evaluation of prior knowledge on the course topics.
- Communication and cooperation competencies gained in the online course.
- Comparison of the effectiveness of the study process with traditional distance learning textbooks and the online study material, respectively.

At the end of the semester, the questionnaire was delivered online via LimeSurvey [21]. Those students who attended the online-course and also agreed to participate in the behavior analysis were asked to work on it.

B. Competence Measurement

For the competence analysis, a new competence measurement instrument was applied. The instrument was developed in several steps in the project "Measurement Procedure for Informatics in Secondary Education (MoKoM)" by researchers in the fields of didactics of informatics and psychology. The German Research Foundation (DFG) funded the MoKoM project. The goal of the project was the development of an empirically sound competence model and corresponding measurement instrument for the domains of informatics modeling and system comprehension.

In the first step, several relevant national and international curricula and syllabi like the ACM/IEEE Computing Curriculum 2011 [22] and the ACM Model Curriculum for K-12 Computer Science [23] were analyzed and used to derive a theory based competence framework. It consisted of three cognitive and one non-cognitive competence dimension.

To refine this framework, the Critical Incident Technique was used to conduct 30 expert interviews with experienced persons in the field of computer science education. Each interviewee was presented four problem scenarios and was asked how (s)he would solve the given task [24]. The scenarios were derived from the theoretical competence framework. The transcribed interviews were analyzed by means of the qualitative content analysis [25]. The results were used to refine and restructure the competence framework. This process led to an empirically refined competence model with six dimensions: K1 System Application, K2 System Comprehension, K3 System Development, K4 dealing with system complexity and K5 Non-Cognitive Skills [26].

In the next step, for each competence a test item was developed to compile a measurement instrument for the considered domains. The items were developed following the principals of Situational Judgment Tests and the experiences made in other competence measurement studies like TIMMS and PISA [27]. Based on detailed competence descriptions, tasks for every single competence item were created. To ensure an objective and coherent evaluation, a comprehensive grading manual was created alongside the test items. Due to the resulting large amount of test items, the instrument was split into six blocks and then compiled into six booklets with three blocks each. Additionally, each booklet contained a block for the non-cognitive dimensions of the competence model. These booklets could be completed in 90 minutes and were used in a test with 800 students in upper secondary education computer science classes.

To use the instrument in the study at hand, all items were transformed into respective online versions. The resulting questionnaire was delivered through the online survey system LimeSurvey. Due to the nature of the questions, some items could not be transformed properly, e.g., the drawing of diagram. For each of these items, a decision had to be made whether the associated competence was appropriate for the field of OOP. If the answer was positive, a new item had to be developed. As we wanted to exploit the breadth of the competence model and expected a high number of participants in the test, the partition into six booklets was kept for the first online survey conducted in 2012.

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-tests without revealing the students' identities.

To assess the competence 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 group had access to one of the six test booklets provided in LimeSurvey.

C. Revision of the Competence Analysis Questionnaire

The underwhelming results of the first survey (see Table V and Section V.A) led us to redesign the test instrument for a second survey that was carried out during the winter semester 2013/14. To get more students to finish the test, the target was to enable its completion within 60 minutes. For this reason, instead of testing the complete range of competences of the MoKoM model, a subset of items especially tailored to the requirements of the course at hand was selected. To choose the appropriate test items, we matched the learning objectives of the course with the competence descriptions of the MoKoM model. This way, we could accumulate a proper selection of relevant test items and combine them into a custom-designed competence test. This tailoring also eliminated the need for several test booklets and let us assume that more students than before would now work on the same set of items.

D. Study Groups in the First Study

Before the course started in summer semester 2012, we invited all 693 students enrolled to evaluate the online competence test. To raise their interest in the study, we announced to give away three books in a raffle based on voluntarily provided email addresses. 146 students followed this request and worked on the test with different degrees of completion. They formed the *competence study group*.

Then we asked for students who would be willing to study the online course unit and allow us to track their online behavior. We found 12 volunteers who formed the *online student group*. This group was also invited to participate in a technology assessment survey conducted after the online course module was passed.

At the end of the course, we asked the whole student population again to evaluate the competence (post-) test and mark it with the same code the students had used in the pre-test.

Finally, we wanted to differentiate the test scores of final examination participants among online and offline (textbook) students to search for significant differences between both groups. The written examination test typically consists of 6 or 7 problems addressing a) major levels of Bloom's cognitive taxonomy and b) core course topics. A typical test includes:

1. A block of 5-7 questions testing the understanding of core OOP concepts and their relationships.
2. One or two problems for which the meaning of a given program must be interpreted.
3. Four constructive tasks including the design of a class structure and the implementation of selected methods, the design of an iterative and a recursive algorithm for a given computational problem, and the design of simple data structures and algorithms operating on them.

The test lasts two hours and is conducted simultaneously in more than 10 different locations throughout Germany, Switzerland, and Austria (usually in lecture halls of universities) under the supervision of FernUniversität academic personnel.

E. Study Groups in the Second Study

980 students were enrolled in the course OOP in the winter semester 2013/14. Following the communication process of the first study, all students were informed about the study before the course started. Simultaneously, they were asked to work on the competency pre-test and volunteer as online students and thereby allow us to track their online behavior.

To inspire the participation in these studies and balance out the extra workload, we offered all students 5 bonus point if they completely answered both competence tests and up to 5 bonus points for online students, depending on their degree of online learning activity.

165 students volunteered for the online study. As we considered these students as particularly motivated, we decided to accept only 98 subjects as *online students* and form a control group of motivated students, called *offline students*, from the other 67 volunteers.

At the end of the course, all students enrolled were asked to work on the post-test using the same personal code they had used in the pre-test. The online students were asked to evaluate their subjective impression of the learning environment by answering the TAM questionnaire. The students who had registered for the final examination were requested to provide their personal code on the examination paper and thus allow us to correlate competence test results with the examination test scores.

V. RESULTS OF THE COMPETENCE ANALYSES

We separate our discussion of the analysis results into two subsections, one for each study.

A. First Study performed 2012

Unfortunately, the participation in the survey performed during the summer semester 2012 was disappointing. Of the 693 students registered for the course, only 57 started their pre-test booklet and just 19 students in total finished more than 75% of all items. These numbers got even worse for the post-test with 30 subjects who started to work on the booklets

and only 5 finished it. IN both tests intervals around 150 users visited the survey page but only one third and one fifth, respectively, started to answer the first item at all. Since the participants who finished their booklet were spread across the six booklet variants, the useable data for each test item was too small to get any meaningful results regarding the competence gains of the students. Only one student completed both tests. 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 Fig. 2). The eighth item was completed by only 50%.

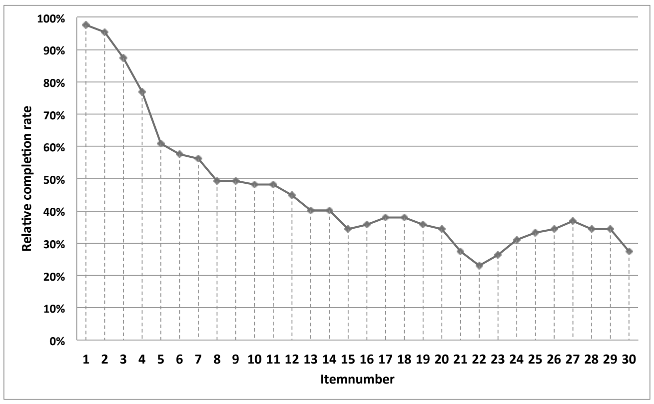

Figure 2. Relative completion rate of survey items.

A reason for these results might have been the length of the competence test. Tailored to be conducted in a German classroom setting, where two successive lessons equals 90 minutes, it seems the time a distance-learning 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 [28]. This ideal timeframe is, however, too short for a competence test. As discussed in Section IV.C, the average workload for the revised competence test was reduced to 60 minutes.

B. Second Study Conducted 2013/14

This time, the pre-test was called 162 times. After cleanup of duplicates and removal of data sets not completely answered, 126 evaluable records remained. The post-test was edited only by half as many students and just produced 49 complete data sets. Based on the personal code used on both tests, 40 data sets could be paired with each other to compare the results on an individual though anonymous basis.

In each test, a maximum of 77 points could be obtained from 21 tasks. The blue bars in Fig. 3 depict the points students achieved in the pre-test, while the red bars on top indicate the gain in points in the post-test. Four students even showed a negative gain ranging between -3 and -28 points less in the second test.

In the pre-test, an average of 43.54 (57%) points was achieved, in the post-test 55.15 (72%). Based on the personal code, 40 data sets of both tests could be paired to see the competence gain of individual students (see Fig. 3).

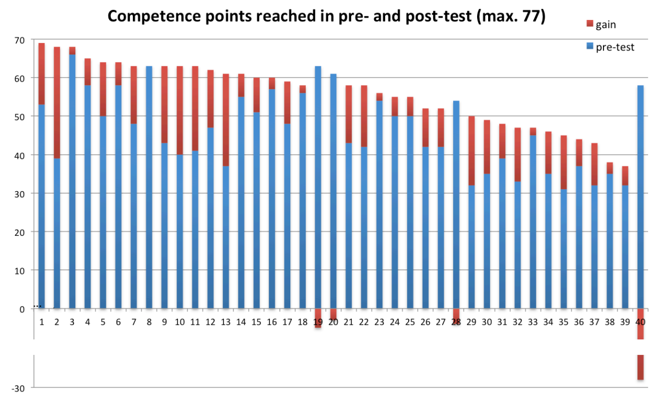

Figure 3. Competence gain of anonymized students.

Based on this reduced sample, the mean value increases in the pre-test to 46.38 points (60%), while it nearly stagnates in the post-test with 55.25 points (72%). This result represents a significant improvement in skills ($t(39) = 5.68$, $p < 0.001$). The boxplot in Fig. 4 visualizes the distribution of points.

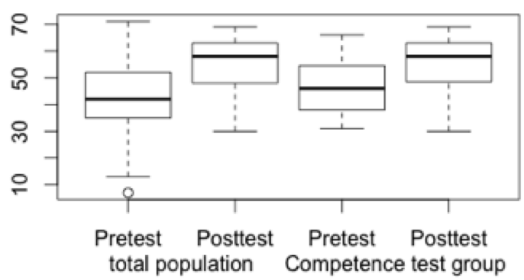

Figure 4. Boxplot of the competence points achieved.

Out of the 40 pairs of competence analysis sets, 16 were delivered from online students and 24 from students in the control group (offline students). With regard to the total number of points, both groups indicate significant increases. However, the online group improved by an average of 10.7 points compared with 7.6 in the control group (see Fig. 5).

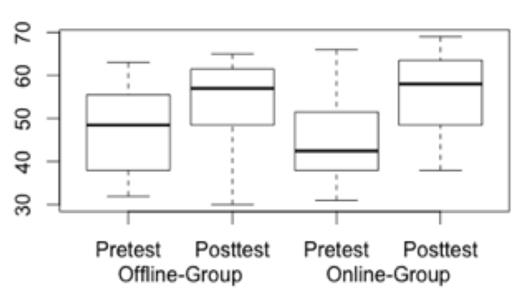

Figure 5. Boxplot of the competence points achieved.

But this difference turns out to be insignificant. At the item level, the post-test reveals significant differences in two tasks: The online group explains the concept "inheritance" more reliably and can better explain the function of a stack. Fig. 6 depicts the increase of competences on the topic "ordering of test sequences" as a bar chart.

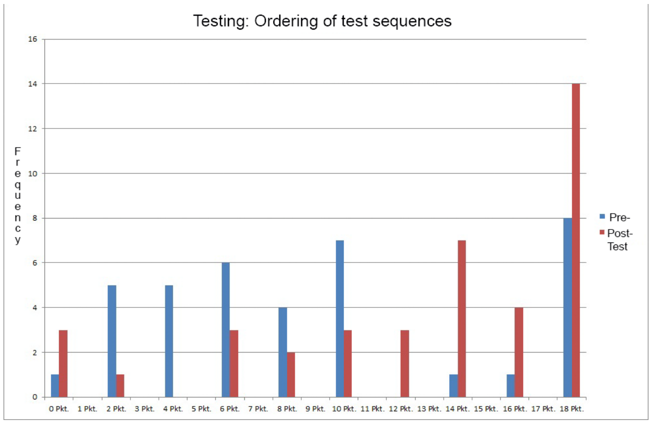

Figure 6. Pre- and post-test results of competence test for topic "ordering of test sequences.

The shift from lesser to more points from the first to the second test is obvious.

VI. Behavior Analysis of Online Students

The number of online students involved in the first study (12) is too small to provide statistically valid results. Moreover, as only 6 of the online students took the examination test at the end of the semester, these figures are not sufficient to compare the outcomes of online and offline students. Therefore, we focus our discussion about the online behavior of distance students enrolled in the course OOP on the results of the second study. Here, 57 of the 98 volunteer online students we had accepted were finally active in the learning environment. But first, we sketch the data sources and analysis techniques employed.

A. Data Sources and Analysis Techniques

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 see how successful a student was in the interaction with a learning object, which errors he or she made, and how often a student tried to solve a given task implemented by an object.

All log data were time-stamped. These time-stamps helped 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 [29]. 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-assessment 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. Particular indexes of the network analysis are the weighted in- and out-degrees of course elements, which indicate the frequencies of visits.

Usage mining provides useful descriptive statistics. This includes:

- Information about the number of page visits.
- Retention time, i.e., the cumulative elapsed time between page views; an average value was assumed for exit pages.
- Typical entry and exit pages.

B. Results of the Second Behavior Study

Among the 98 students who had been admitted to the online study group, a total of 55 subjects logged-in at least once in Moodle. 52 students accessed at least once the online content. Of these 52, twelve students spent less than 15 minutes online, 19 were less than an hour online. As these overly short online times seem unreasonable, we chose a retention time of one hour as the lower threshold for the data analysis. This decision left 33 online students to evaluate.

The study conditions with remote subjects who learn autonomously render it impossible to know whether a student's online time was fully dedicated study time. However, the retention times neither vary conspicuously by clock time, nor did we detect meaningless values. A realistic workload for the online learning module should, however, be much higher than the measured average retention time. It is therefore likely that some online students had also used other study materials for learning, e.g., the course textbook.

The number of pages viewed varies from 25 to 696 with an average of 169 and a median of 142 page views. The average time spent on a text page varies from1:00 to 4:51 minutes (median: 02:21 minutes). The maximum time spent on a page varies between 8:32 and 107:38 minutes (median: 58:41 minutes). Although we cannot be sure whether students spent this time on effective learning, the high values appear plausible, since they were observed for self-assessment pages. The highest values occurred for pages with solutions to self-assessment tests on the topics "exceptions" and "testing". A quiz on topic "program documentation" had also very high page view figures.

TABLE I. Retention Times Shared of Page Types

Chapter	Documentation	Exceptions	Testing	Error handling
Reading & Understanding	51.68%	54,64%	55,52%	75,34%
Self-assessment	30.11%	42,99%	32,46%	18,98%
Forum	18.21%	2,37%	12,02%	5,68%

Table 1 shows the retention times students spent on the average per chapter on the different page types. We distinguish between knowledge acquisition, practice, and forum activities. The former occur when students need to read into and understand new course topics. In the online course, information pages are intertwined with self-assessment pages. On the latter, students find interactive learning objects and programming tasks to test their understanding and give them hands-on experience with smaller programs. Each chapter has its own forum, which takes a prominent place at the beginning of each chapter.

Students spent between 52% and 75% of the time on reading and understanding new topics, 20-43% for self-assessment tests, and 6-18% in the forum. The differences may be explained by the fact that Chapter Error Handling includes only one self-assessment exercise, while Chapter Documentation provides 6, Chapter Exceptions 9, and Chapter Testing 13. Although students visited the forums quite frequently, only a few students contributed by posing and answering questions or exhibiting an own problem solution. The largest proportion of practice time was spent on the topic Exceptions. The corresponding chapter offers a few challenging programming tasks and interactive learning objects for self-assessment.

The usage data collected through the learning objects record very detailed observations. They show that about half the online students interacted with them quite intensively, whereas the other online students largely ignored them. In the discussion of the examination scores in Section VIII we will fall back on these observations.

Interestingly, 30% of the volunteers for online study were female students although their share among the students enrolled in the course is only 25%.

C. *Reading into the Log Data of Interactive Learning Objects and Programming Tasks*

The log data captured from the students' interactions with Flash objects and a built-in compiler back-end to compile and run own solutions to programming tasks provide some interesting insights. In the following discussion we focus on learning activities related to Chapter Exceptions because this theme was particularly tested in the written examination.

For instance, 17 online students worked with the learning object Crash Lab depicted in Fig. 1. Together they spent 2:40 hours working with this object. 16 students placed all 6 statements properly, 9 students created 1-3 own statements. Only five students evaluated the predicted behavior of the test programs, which was correct in four cases. Students #7, #27, #40 and #44 were successful in the first attempt. We explicitly indicate anonymous student identities here because we will refer to them later in the discussion of grades in Section VIII.

Another learning object tests the students' ability to understand the passing of exceptions. It is composed of 4 sub-tests in which the last sub-test can be varied and explored several times. 13 students interacted with this learning object, summing up 3:11 hours total interaction time. 11 students successfully solved the first sub-test and 9 students also completed the second sub-test. Finally, 5 students worked successfully on the other two sub-tests as well, including students #14, #27, #40, and #44. We observe a decreased activity rate with each sub-test, which supports the author's intention to increase the difficulty of the sub-tests step by step.

An investigation of the log data of a learning object in which students had to write code reveals that one student performed significantly worse than his or her peers who worked on the same object. This behavior seems to exhibit a trial-and-error strategy as opposed to the structured progress of the other students.

VII. Technology Acceptance

In the second study, 34 online students completed the TAM questionnaire. The results show that the majority of students has at least two devices in the selection "notebook, tablet, smartphone, or desktop" to access the online study material. Only 16% of all respondents used the services of the learning environment less than once per week, 61% used it two or three times, or more. In particular, the self-assessment tasks and reading materials were retrieved and used frequently.

The online students exhibit a high degree of technical affinity: 85% work frequently with web applications and 67% are online most of the day. Most students found the ergonomics of the e-learning environment convincing (see Fig. 7). It consists of the online course and the learning tools Moodle, edu-sharing, news, forum, and chat.

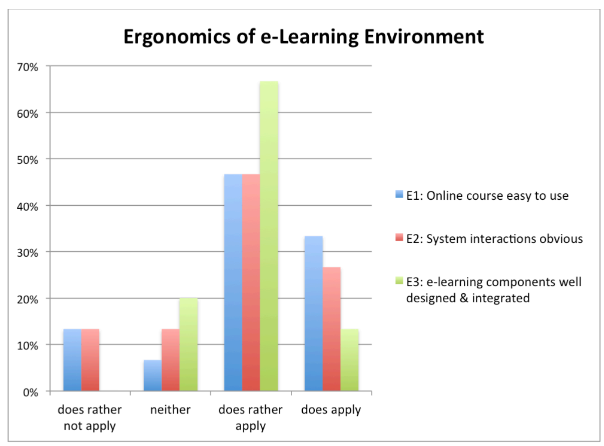

Figure 7. Student perception of the e-learning environment

Fig. 8 illustrates the students' evaluation of the value of the online course module to mediate methodological knowledge about program documentation. The high values of positive answers (84% and 78%, respectively) to the items:

- Q1: The online module helped me to understand the importance of program documentation and quality assurance.
- Q5: I'm able to produce a program documentation using Javadoc.

confirm that only a minority of online students was unable to assess the learning support function of the online version of the course positively.

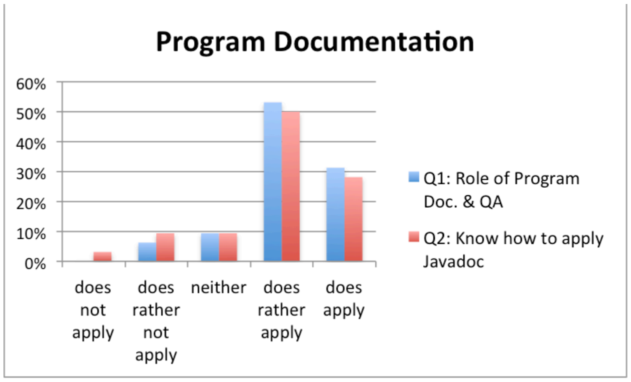

Figure 8. Mediation of methodlogical knowledge on program documentation. Q1: The online module helped me to understand the importance of program documentation and quality assurance. Q5: I'm able to produce a program documentation using Javadoc.

Similar questions were raised for the other key topics of this course module, including program testing, exception handling, and error recovery. Table II summarizes the students' perception of the e-learning environment's ability to convey methodological knowledge on program testing. Again, the positive answers predominate with the exception of constructive knowledge and practical skills needed to work with JUnit. Note that such skills were also lower rated in the domain program testing.

TABLE II. IMPARTING OF METHODOLOGICAL KNOWLEDGE ABOUT

QUESTION	RATHER APPLIES	APPLIES
Q6: I understand the possibilities and limits of testing	53%	25%
Q7: I know about test levels and test methods	67%	15%
Q8: I know how to identify and apply test cases	48%	12%
Q9: I'm able to implement test cases in JUnit	24%	18%

Fig. 9 shows again a high confidence in factual and conceptual but a weaker result in procedural knowledge about exception handling.

Most respondents also certify that the online learning environment exhibits a slightly higher motivating factor. This increased motivation does, however, not carry over to cooperative tasks. The vast majority (82%) did not feel encouraged to interact with other students and to solve team tasks cooperatively. An aversion to synchronous person-to-person interaction over a distance is also reflected in the preference of asynchronous communication methods such as email and forums over synchronous forms such as instant messaging and Skype. This trend towards independent study habits is confirmed by the low interest in cooperative problem solving reported in Section VI.B and previous experience of the course tutors. The main reason quoted for the low interest in cooperation with peer students is a job-related lack of time. A few respondents also saw no reason to contact other students to help them get over hurdle because they had solved their study problems themselves, e.g., by researching the Internet.

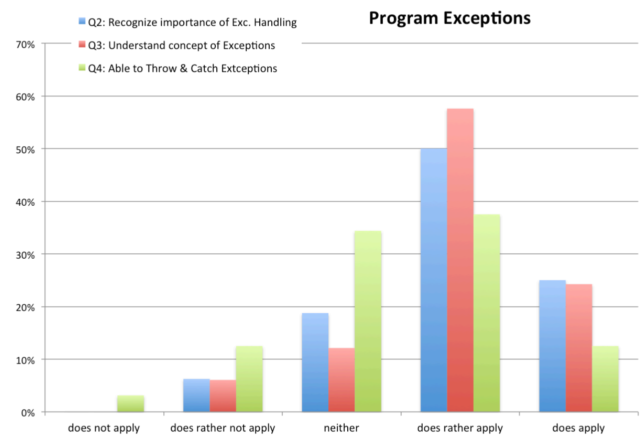

Figure 9. Mediation of methodological knowledge on exception handling. Q2: This course module animated me to reflect on exception handling during program development. Q3: Now, I understand the concept of exceptions. Q4: I'm able to throw and catch exceptions in Java

At the beginning of the semester, the students had not much prior experience with program testing and exception handling. Only about a quarter was knowledgeable in these areas. This changed after completion of the course unit addressing these topics. About 60% of respondents now believed to be able to identify proper test cases and test levels. More than 70% were convinced to know the possibilities and limits of testing. This self-evaluation is also confirmed by the competence test (see Section V.B). Here, the tasks related to testing showed the statistically most significant improvements in competences.

Several items in the TAM questionnaire addressed a comparison of the classical correspondence material and the online version of the course module. Table III summarizes the students' judgment.

TABLE III. STUDENT PREFERENCES: ONLINE VS. DISTANCE STUDY TEXTBOOK

QUESTION	NA	RNA	NN	RA	A
The online module illustrates complicated facts better than the traditional textbook	0%	16%	25%	47%	13%
Due to the online module I feel easier to work on a typical problem from the topic area than with the traditional textbook.	7%	13%	40%	33%	7%
I prefer the online course to the classical textbook	0%	27%	33%	20%	20%
I prefer to study with the textbook	9%	25%	19%	34%	13%
I would like to see more course content be offered in a similar online version	0%	7%	20%	47%	27%
I totally dislike e-learning	64%	6%	18%	9%	3%

NA: does Not Apply; RNA: does Rather Not Apply; NN: Neither; RA: Rather Applies; A: Applies

The responses to these questions suggest that the students are rather indifferent towards the use of the online course material compared to the traditional textbook. Though most students are open-minded regarding the new learning opportunities (74% would like more courses to offer online material) and a majority of 60% acknowledge, that the online version can help to illustrate complicated matter in better ways, only 40% of the students actually prefer the online course to the classical textbook and 47% prefer to study with the classical version exclusively. These answers suggest, that the students think of the online course as a supplement to the traditional textbooks. An explanation might be the new experience the online material offers and the lack of experience with it. Thus, the students don't want to rely on an e-learning approach alone. When online courses become more common, the willingness to utilize them might increase.

VIII. Examination Results Put in Context

The maximum test score students can reach in the final examination of this course is 100 points. At least 50 points are needed to pass the test. The grade acquired for the course is derived from a student's score in the final examination. Table IV illustrates the mapping of test scores to grades. Grade 5.0 means failed.

TABLE IV. Scores mapped to Grades

Score Points	Grade
100 - 95	1.0
94 - 90	1.3
89 - 84	1.7
83 - 80	2.0
75 - 79	2.3
74 - 69	2.7
68 - 65	3.0
64 - 60	3.3
55 - 59	3.7
50 - 54	4.0
49 - 0	5.0

A. Examination in August 2012

Out of the 693 students who were enrolled in the course during the first study 199 took the final examination in September 2012. This group included 6 of the 12 online students. 142 students passed, including 4 online students, and 57 failed, including 2 online students.

B. Examination in February 2014

141 students participated in the final examination test conducted in February 2014. (In our experience, the relative number of examination participants is lower in the February than in the August examination test. For instance, in the summer semester 2014 only 636 students were enrolled in the course OOP but 250 took the examination test.)

89 students passed, producing a typical success rate in the range 60-67%. The examination group included 22 students from the online and 28 from the control group. Fig. 10 shows the distribution of scores for the group of online students (N = 22) and the control group (N = 31) for the examination element program exceptions. The distribution curves are very similar. Slight differences can be seen only in the failure rates (grade 5.0 or score points < 50). They were: 45.5% in the online and 51.6% in the control group. In both groups, seven students achieved a grade than better 2.3. Given this small number of subjects, no effect of the study material, online course unit versus textbook, can be reliably derived from these variances.

The failure rate of the whole examination test, which included four additional problems, was only 39.6% (N=141). 9 students in the online group and 7 students in the control group, who would have failed on test element "exceptions", finally passed the examination test because they scored better on other test problems. This can be explained by the fact that other test problems have a higher success rate over the whole examination group. Test element "exceptions", which ranges at level "Analysis" in Bloom's cognitive taxonomy [10], achieved a rate of 49,5%, while two other test problems ended up with 67.9 and 72.1. In Bloom's taxonomy they range on levels "Comprehension" and "Application", respectively. This observation about the difficulty level of test problems coincides with remarks that students communicated to the tutors independently of the study: They found the examination topic "exceptions" very difficult because it has not yet been tested this intensively in previous examinations. (Note here that examination problems and master solutions are made available after a test has been concluded to help future students to prepare for their own examination.)

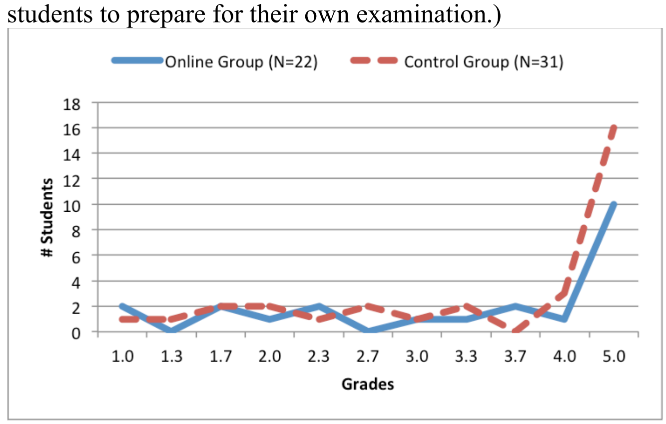

Figure 10. Distribution of examination grades among students in online and offline group.

When overlaying the examination scores of the online students for the test element "exceptions" (line diagram) and their retention times spent on information and exercise pages of this chapter, the result in Fig. 11 emerges. If we would draw a trend line, it would slightly fall from left to right. But let us discuss a few more striking issues of the bar charts and score line in Fig. 11.

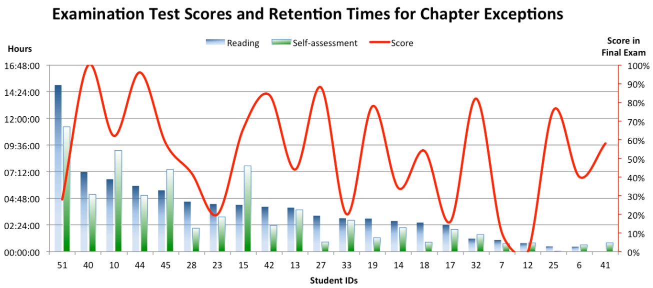

Figure 11. Retention times and examination results of individual students for test item “exceptions”.

In the discussion of Fig. 11, we also consider both the log data collected from within the online learning environment (see Section VI.C) and the online exercise system for homework assignments, which was mentioned in Section III.A, and the competence tests.

Let us pick a few extreme examples, starting with the positive ones. Students #40 and #44 achieved 100 and 96% of the maximum sore. Both accessed the information pages between 7 and 5 hours and worked on the exercise pages roughly 5 hours. We also know from Section VI.C that both were higly active and successful with the self-assessment elements of this course unit. In their homework, they acquired 100 and 95%, respectively. Student #40 also achieved the highest score in the competence post-test (69 score point out of 77) with a gain of 16 points. Student #44 scored a bit worse with a final score of 62 points and a gain of 15 points.

With 82%, student #32 scored relatively close to these two students but spent only 2.5 hours in total on exception topics, and a bit more on assessment than reading activities. (S)he ranges second in the competence post-test with 68 points and showed the higehst gain with 29 points. Student #25 exhibits the lowest time period spent on Chapter Exceptions but still ended up with a score of 76% in exception problems. All these students worked quickly on the excercises and largely error-free. Most likely, some of them acquired the necessary topic knowledge from other sources than the online course.

On the other hand, the student with the longest retention time both on reading and exercise pages (#51) missed the 50% mark necessary to pass the examination. This student achieved 95% of possible scores in the homework but did not access any of the self-assessment elements on topic exception. The latter is also true for Student #23 who also failed in the examination. Student #51 had a competence score of 59 and a gain of 11 points, while #23 collected 60 in the pre-test and gained 9 points compared to the pre-test.

The result of the correlation of examination scores and retention times indicates that we have no evidence to draw any conclusion on examination success from retention times in the online learning system. However, the targeted use of interactive learning objects and self-assessment programming tasks seems to have a positive impact on the examination test scores.

IX. Verbal Student Feedback

After all survey and log data had been evaluated, we felt the need to add a qualitative data analysis to clarify some results of the quantitative research. Questions of interest include:

- How do online students learn?
- Had the online students used other sources than just the online materials provided?
- What motivated them to volunteer for online study?
- Were their expectations satisfied?
- Did they find the online materials sufficient for reaching the learning objectives?
- How do they compare learning with traditional correspondence materials and online media?

The plan was to perform semi-structured telephone interviews with a representative sample of online students and analyze the interview content to find possible answers to these questions and detect unexpected relationships between them.

An interview guideline with 32 questions was designed, and in July 2014 a request to volunteer for a telephone interview was sent to all online students of the winter semester 2013/14 course. Unfortunately, only two students were able to take an interview. Many respondents regretted not to be able to follow the request because they were preparing for the September 2014 examination in other courses. Some students did not react at all. For reliable qualitative research, this number of subjects is by far too small. Nevertheless, we decided to organize at least the two interviews offered in search of authentic responses that would support or question our assumptions about online learner behavior.

The typical method of learning of both students is to read the course material cursorily first to judge the learning effort. Then, in a second run, they study the content in detail and thereby take notes, mark and annotate the text, perform self-assessment tests, and solve homework assignments. Some students seem to produce their own summary of course topics; our two interview partners did not. Shortly before the examination test takes place, they go through previous examination tests to get a better feel for what a typical examination test looks like and how they operate under time constraints. In addition, they re-evaluate homework assignments. To overcome understanding problems or acquire more detailed information on a topic, both students preferably use a search engine to find resources in the web that help clarify their questions. Depending on the given subject, they also buy additional textbooks recommended in the reading list. Both students felt no need to contact peer students or tutors to discuss unclear course topics. They also did not work on the collaborative tasks because they consider it difficult to synchronize with peers. This confirms our earlier experiences that distance students largely learn autonomously, mostly due to time problems.

Both interview partners state that their performances in this course match those of other courses or are slightly better. They believe that this course has a difficulty level comparable to other courses they have been enrolled in. Both students felt that they learned a lot. One student was inspired to apply and extend his/her programming skills by adding dynamic web pages to his/her web presence using PHP [30].

The motivation to volunteer for online studies were: a) a general interest in e-education paired with e-learning experiences in the work context; b) a personal interest in the question whether online learning is advantageous over the study with classical distance learning textbooks. One student said that his expectations were partly satisfied. On one side, the interactive learning objects and programming tasks were considered helpful in assessing the learning progress. The lack of possibilities to highlight and annotate passages in the online materials was seen negative. In summary (s)he felt that "Basic knowledge about object-oriented programming concepts and basic programming skills definitely came across." The other student said: "I liked the general layout, the content, and the mix of reading and exercise pages of the online course. I would like to have more of this." Both students solved all online tasks but the collaborate task completely.

Asked whether the students perceived a difference in learning effort for both media types, one student thought that the learning objectives could be achieved faster with the online version. The other student was undecided.

Both students stated that they also studied the textbook version after having studied the online version to be on the safe side because they had noticed that both versions differ in structure and presentation. This may explain why the online times of most students were relatively short and largely dedicated to the examination of online tests. When comparing both versions, one student replied: "Studying the online material was full of variety, while the textbook is drier to go through". The other said that (s)he is better motivated by working with the online material, while studying the course text on paper leads earlier to a loss of concentration. The students did not feel exhausted when learning for a longer time in front of a computer or tablet screen. Both students said that the communication means offered were useful. In particular the topic-specific online forum is considered more effective than the course newsgroup, which requires special newsreader and addresses all course topics.

In an independent student evaluation, which is carried out every semester for every course of the curriculum, this course typically receives a rating above average. This is also true for the evaluation performed at the end of the winter semester 2013/14 (1.6 on a scale 1-3). The students also find the workload in the usual range. Some were asking for additional learning video and interactive online media. Many students consider the supervised forum essential for an effective learning process.

X. Conclusion and Lessons Learned

With this study we wanted to learn more about the influence of e-learning elements in higher distance education. To this end, we used an introductory programming module in the undergraduate degree program on Business Informatics as a case to compare learning attitudes and outcomes of students using the classical correspondence study material with students learning along an interactive online version of a selected learning module. The study was performed twice in two different years on the same course but with different student populations because the first run produced statistically unreliable results. Table V depicts relevant figures of the two investigations undertaken. The questionnaires used in the second study and the raw data collected thereby are accessible online [31].

In summary, the research questions we started from can be answered as follows:

1. The competence analysis shows that the students achieved significant growth in competence, particularly on the course topics "testing" and "program exceptions". However, no significant difference can be observed between online students and the control group (see Fig. 5).
2. Even if we chose the students' final grades acquired in a written examination that took place at the end of the course, no significant difference in learning outcomes can be seen (see Fig. 10).
3. The retention times in the online environment are no useful indicator for test success or failure, a result that has been confirmed before in a workload study [32].
4. The behavior analysis depicts a correlation between high and targeted use of interactive learning objects.
5. The results of the technology acceptance analysis and the online behavior analysis suggest that the students appreciate technology-supported learning. At the same time, both studies clearly show that students, on the one hand, have little tendency to adopt cooperative learning and, on the other hand, do not feel capable because time constraints.

TABLE V. TEST PARAMETERS FOR BOTH STUDIES

Activity	SS2012	WS 2013/14
Students enrolled in course	693	980
Competence pre-test	57	162
Pre-test: complete sets	19	126
Competence post-test	12	78
Post-test: clean sets	5	49
Post-test paired with pre-test	1	40
Online study volunteers*	12	186
Volunteers selected	12	98
Volunteers actively studying	10	45
Technology acceptance test		34
Final examination	141	200
Participating online students	6	21

*Online students have experience with traditional correspondence materials from other course units and courses

As a result of this investigation, we decided to enrich other topics of the course OOP with further interactive learning objects for self-assessment and practice. For the near future, we will keep the textbook version as the main learning medium for our students.

To support the autonomous preparation for an examination test, we plan to produce short video clips explaining how to understand a given problem and constructively approach its solution.

In general, we find that technology-assisted learning elements for distance students increasingly arouse interest, to the extent that they are efficient and supportive for the learning process. We believe that e-learning still offers many degrees of freedom for pedagogic innovations of distance learning, while the pedagogy of the traditional correspondence-based distance education model is largely exhausted. Research in the field of online distance education is, however, still largely disconnected and disparate. In their new book, for the first time, Olaf Zawacki-Richter and Terry Anderson have tried to integrate major research trends in online distance education into a systematic research agenda [33].

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