Investigating the Effectiveness of an Advanced Adaptive Mechanism for Considering Learning Styles in Learning Management Systems *

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***Abstract*—Blended and online learning becomes more and more popular and learning management systems (LMSs) are used by many educational institutions to host such blended or online courses. However, such LMS typically do not adapt to students' individual characteristics and provide each student with the same content and presentation. Such one-size-fits-all approach does not fit most students particularly well and can lead to low student performance and satisfaction. In this paper, we present a study to evaluate an advanced adaptive mechanism that extends LMSs with adaptive functionality to automatically provide students with courses that fit their learning styles. The results of this study showed two significant benefits of the adaptive mechanism for students: receiving higher grades on adaptive lessons than on non-adaptive ones while spending a similar amount of time on both, and spending less time on adaptive lessons than on non-adaptive ones while receiving on average the same grades. Based on these results, the proposed adaptive mechanism can be seen as an effective extension to LMSs in order to support students in learning.**

Keywords—Adaptivity; Learning Styles; Learning Management Systems;

I. INTRODUCTION

Learning management systems (LMSs) such as Moodle [1], Blackboard [2] and Sakai [3] become more and more used by educational institutions to offer blended or fully online courses. While these LMSs provide teachers with a great variety of easy to use features to create, administrate, and hold online courses, they do not consider individual differences of students and provide every student with the same structure and content, independent of his/her individual needs and characteristics. On the other hand, adaptive learning systems focus on considering individual students' needs and characteristics by providing students with personalized courses that are automatically tailored to individual students. However, typically, such adaptive learning systems are prototype systems that do not offer the same variety of features as LMSs to create, administrate and hold online courses and moreover, require significant additional effort from teachers to set up courses and/or adaptive rules so that these courses can then be provided to students in an adaptive manner.

In this research, we aim at combining the advantages of LMSs and adaptive learning systems by extending LMSs with adaptive functionality. The proposed advanced adaptive mechanism enables LMSs to automatically create courses that fit students' learning styles.

There exist several adaptive and intelligent learning systems that consider students' learning styles (e.g., [4, 5, 6, 7]) and evaluations of such systems showed benefits such as better performance, less time for learning and higher learner satisfaction. Our proposed adaptive mechanism is different from other systems that consider learning styles in at least one of two ways: First, the proposed adaptive mechanism extends LMSs and therefore allows teachers to continue using the LMS they are familiar with and where they enjoy plenty of easy to use features. Second, the proposed adaptive mechanism focuses on making it as easy as possible for teachers to use it in any courses they teach. Therefore, the mechanism is flexible with respect to existing course designs/structures and requires only very little additional effort from teachers to be used in their courses.

In our previous work, we developed, implemented and successfully evaluated a mechanism that also provided adaptivity based on students' learning styles in LMSs [8, 9]. However, the adaptive mechanism proposed in this paper extends our previous work significantly in three ways: First, instead of having only six types of LOs which are required in each section of the course, the proposed adaptive mechanism is flexible and extendable with respect to the course structure and the types of LOs used, supporting 12 types of learning objects which can but do not have to be included in each section of the course. This extension makes the proposed adaptive mechanism generally applicable for different types of courses in any domain (e.g., theory-based courses, courses with practical focus, etc.). Second, the adaptive framework has been extended to use adaptive annotations and adaptive sorting instead of only changing the sequence and number of types of LOs. Third, while the previous version only supported three out of four learning style dimensions of the learning style model, this advanced adaptive mechanism supports all four dimensions. While the previous version has been successfully evaluated, showing that students who were presented with adaptive courses spent significantly less time

* The authors acknowledge the support of NSERC, iCORE, Xerox, and the research related gift funding by Mr. A. Markin. Furthermore, the authors acknowledge the support of the Federal Ministry for Education and Research (BMBF) of the Federal Republic of Germany, the Ministry for Science and Culture of Lower Saxony, the Ministry of Infrastructure and Agriculture of Brandenburg and the Ministry for Science, Research and Art of Bavaria.

978-1-4799-4038-7/14 $31.00 © 2014 IEEE
DOI 10.1109/ICALT.2014.41

in the course but got on average similar grades, the aim of this paper is to evaluate the proposed advanced adaptive mechanism and investigate whether and how learners benefit from adaptive courses based on this advanced approach.

In this paper, we first provide a brief introduction on the proposed adaptive mechanism (section 2) and then present an evaluation of the adaptive mechanism with 23 students (section 3). Section 4 concludes the paper and discusses future works.

II. ADAPTIVE MECHANISM

In this section, a description of the proposed adaptive mechanism is provided. While this section explains the most important aspects of this mechanism, a detailed description of the adaptive mechanism and how courses are adapted to each learning style is provided by Graf, Kinshuk and Ives [10]

The proposed adaptive mechanism provides adaptivity based on the Felder-Silverman learning style model (FSLSM) [11]. FSLSM describes learning styles in very much detail and is therefore highly appropriate for providing adaptivity based on learning styles. Furthermore, the FSLSM is based on the concept of tendencies, allowing handling of exceptional behaviour by considering learning styles as a main tendency rather than as an obligatory type. Moreover, FSLSM is widely used in adaptive learning systems focusing on learning styles and some researchers even argue that it is the most appropriate model for the use in adaptive learning systems [12, 13]. According to FSLSM, each learner has a preference for each of its four dimensions: active/reflective, sensing/intuitive, visual/verbal, sequential/global. All four dimensions of learning styles are supported in the proposed adaptive mechanism.

As mentioned before, one major goal of the adaptive mechanism is to be easy to use for teachers and requiring them to have as little as possible additional effort when using it in their courses. Therefore, there are only three requirements that have to be fulfilled in order to use the adaptive mechanism in a course. The first requirement is that the course needs to consist of several sections which can then be adapted by the proposed mechanism. Sections can (but do not have to) be grouped into units so that the course consists of several units which in turn include several sections. Each section can then include learning objects (LOs). The second requirement is that each section should have at least one content object which presents the learning material of this section. Furthermore, teachers can add a variety of other types of learning objects, including commentaries (or outlines), reflection quizzes, self-assessment tests, discussion forum activities, additional reading materials, animations, exercises, examples, real-life applications, conclusions, and assignments. Other types of learning objects can be included in the course too but would not be considered by the adaptive mechanism at this time. One or more instances of the types of LOs described above can (but do not have to) be included in each section to enrich the learning experience of students. The more LOs are available in each section, the richer the students' learning experience will be and the better sections can be adapted to learners' learning styles. The third requirement is that teachers are asked to provide the type of a learning object as meta-data. To facilitate teachers in this process, an add-on is used in the authoring interface of learning objects, where teachers can simply click on a checkbox to indicate what type the respective learning object is (e.g., reflection quiz, self-assessment test, additional reading material, etc.).

In order to adapt courses to students' learning styles, two techniques are used: adaptive annotation and adaptive sorting. With respect to adaptive annotation, two different annotations for LOs are used: recommended and standard. Recommended means that a LO is suggested to be visited, either because it is an essential element of the course such as commentaries, content objects, and conclusions, or because the LO fits well to the student's learning style. LOs that do not support students' learning styles are annotated as standard. Whether a LO is annotated as recommended or standard is determined based on the students' learning style, the type of LO, and how many LOs of the same type are included in the section. Therefore, the system can recommend the learner which types of LOs he/she should visit and how many of these types of LOs he/she should visit.

Furthermore, through adaptive sorting, the sequence of the LOs within the section is determined. The position of LOs is based on the general structure of the section. In this general structure, the commentary is the only LO that has a fixed position, always at the beginning of the section. After the commentary, there is an area where a few LOs can be presented in order to motivate students and raise their interest in the respective topic. Subsequently, the content objects are presented, followed by an area after the content objects where the remaining types of LOs are presented. Self-assessment tests, animations, exercises, examples, and real-life applications can be presented either between commentary and content objects or after the content objects. The area after the content objects can also include additional reading material, reflection quizzes, and forum activities. For both areas, the types of LOs that shall be presented within these areas are ranked based on how strongly they support the student's learning style and are presented in the respective order within the area. For the area before the content, maximum two different types of LOs are presented in order to avoid overloading the students with activities before they even start to read the actual learning material, in terms of content objects. Only two types of LOs are not considered in these two areas: assignments are either only presented at the very end of a section or additionally in the beginning of the course, and conclusions are either presented right after the content or at the end of the section before the assignments.

It should be mentioned at this point that the adaptive mechanism just provides recommendations to students. Students have always the possibility to see all available LOs and visit them in any sequence they prefer.

III. EVALUATION

In this section, the evaluation of the proposed adaptive mechanism is described. In order to evaluate the proposed

mechanism, it has been implemented into the learning management system Moodle. In the following subsections, the materials, experiment design, method of statistical data analysis as well as results and discussion are presented.

A. Materials

The investigated online course is a project in the WeGA Horticulture Research Network to ensure the transfer of current research results into different postsecondary education curricula in Germany. The course is about quality management, evaluation and certification for bachelor students. Present data come from the second course year (2012/2013), where the described adaptive mechanism was used. In this online course, 23 students from three postsecondary educational institutions have participated. All of them were in the third study year (semester 5) in a Bachelor of Horticulture Science program. The participating postsecondary educational institutions were two universities of applied science (15 students) and one research university (8 students).

The course contains seven online lessons in Moodle with a diverse range of learning objects in each lesson, four 60-90 minutes video conferences in special transmission sites at the different postsecondary educational institutions and a weekend workshop, where students from all participating postsecondary educational institutions met each other face-to-face. While learning materials were brought to students mainly in the Moodle online lessons, the weekend workshop served primarily for practicing the learned subjects and to get additional information from quality management experts.

For assessment, students had to perform an online test for each lesson and had to write a paper exam at the end of the course.

B. Experiment Design

All 23 students were randomly assigned into two groups upon registration by the adaptive mechanism. Accordingly, there were 11 students assigned to Group 1 and 12 students assigned to Group 2. Within the registration process, each student took the Index of Learning Styles questionnaire [14], a widely used and well-investigated 44-item questionnaire that determines a student's learning styles based on the FSLSM. This information enables the adaptive mechanism to adjust the course to fit the learning styles of each individual student. The seven lessons in the course were presented either in adaptive or non-adaptive mode to students. For a lesson presented in adaptive mode, the adaptive mechanism was used to make the lesson fit to a student's individual learning styles. A lesson presented in non-adaptive mode is presented in a standard way, which is the same for each student. For both groups, the first lesson was presented in non-adaptive mode. For students in Group 1, lessons 2, 3, and 4 were presented in adaptive mode and lessons 5, 6, and 7 were presented in non-adaptive mode. On the other hand, for students in Group 2, lessons 2, 3, and 4 were presented in non-adaptive mode and lessons 5, 6, and 7 were presented in adaptive mode.

C. Method of Statistical Data Analysis

The aim of this evaluation was to investigate whether and how students benefit from adaptive lessons compared to non-adaptive lessons. In particular, two variables have been investigated: performance and time spent on the lessons in the course. For analyzing differences between the two modes (adaptive and non-adaptive) for both groups (Group 1 and Group 2), paired t-tests were applied for each group, comparing the students' performance in adaptive and non-adaptive lessons as well as the time students spent on adaptive and non-adaptive lessons.

Regarding the performance, the grades on the online tests for each lesson were used. Grades on each online test ranged from 0 to 20 points and were transferred to values from 0 to 1 for calculations. In Group 1, the average grade on online tests in lessons 2, 3, and 4 represent the performance in adaptive mode and the average grade on online tests in lessons 5, 6, and 7 represent the performance in non-adaptive mode. In Group 2, the average grade on online tests in lessons 2, 3, and 4 represent the performance in non-adaptive mode and the average grade on online tests in lessons 5, 6, and 7 represent the performance in adaptive mode. Since lesson 1 was presented in non-adaptive mode for all students, the online test in lesson 1 was not considered.

Furthermore, the time students spent on each particular lesson was calculated and considered, including only learning activities in each lesson. Therefore, general activities such as a student making modifications to his/her user profile or changing his/her password were not seen as learning activities and were therefore not considered. Furthermore, we filtered out activities where a student spent very short time (e.g., because he/she clicked on the wrong link or is searching through pages until he/she finds the page that he/she actually wants to read). In addition, learning breaks and the end of learning sessions were identified and respective durations were filtered out. Once the time a student spent per lesson was known, the average time spent on adaptive lessons and non-adaptive lessons was calculated, using a similar approach as described above for the performance. Accordingly, for students in Group 1, time spent on lessons 2, 3, and 4 counted towards the time spent in adaptive mode and time spent on lessons 5, 6, and 7 counted towards time spent in non-adaptive mode. Similarly, for students in Group 2, time spent on lessons 2, 3, and 4 counted towards the time spent in non-adaptive mode and time spent on lessons 5, 6, and 7 counted towards time spent in adaptive mode.

D. Results and Discussion

The results of the performed t-tests in Group 1 and Group 2 are shown in Table I and Table II respectively. As can be seen from the results, for Group 1, a significant difference was found with respect to the performance in adaptive and non-adaptive mode and no significant difference was found with respect to time. Accordingly, students in Group 1 received significantly higher grades on online tests in adaptive lessons than on online tests in non-adaptive lessons, and spent on average the same amount of time on adaptive and non-adaptive lessons.

For Group 2, a significant difference was found with respect to the time spent in adaptive and non-adaptive mode, and no significant difference was found with respect to performance. Accordingly, students in Group 2 spent significantly less time on adaptive lessons than on non-adaptive lessons but received on average the same grades on adaptive and non-adaptive lessons.

Therefore, based on the results, we found two different benefits for students using adaptive lessons: (1) receiving higher grades while spending on average the same amount of time and (2) spending less time while receiving on average the same grades. In order to find out why the two groups benefited in different ways from adaptive lessons, further investigations were conducted. Our hypothesis for this result is that students from both groups experienced both benefits but, due to the small sample size, only one benefit was significant in one group and the other benefit was significant in the other group.

TABLE I. RESULTS FOR GROUP 1

	Adaptive		***Non-Adaptive***		***t***	***df***
	Mean	*SD*	*Mean*	*SD*		
Performance	0.92	0.05	0.85	0.05	5.206***	10
Time (in min.)	161.61	55.10	143.88	54.78	1.826	10

*** = p≤ .001

TABLE II. RESULTS FOR GROUP 2

	Adaptive		***Non-Adaptive***		***t***	***df***
	Mean	*SD*	*Mean*	*SD*		
Performance	0.86	0.05	0.89	0.07	-1.141	11
Time (in min.)	108.03	35.85	146.04	36.74	-4.172**	11

** = p≤ .01

In order to verify this hypothesis, further investigations were done on the raw data. In particular, these further investigations aimed at finding out how often a certain benefit was experienced in each group.

To find the first benefit, we looked into whether a student received higher grades on online tests in adaptive lessons in comparison to grades on online tests in non-adaptive lessons and whether a student spent a similar amount of time in adaptive and non-adaptive lessons. To calculate whether a student received higher grades on online tests in adaptive lessons, we measured the relative grade $rGrade_{adapt}$, which represents the distance between a student's average grade on online tests in adaptive lessons and the average grade of all students on online tests of adaptive lessons in the respective group. Furthermore, we calculated the relative grade $rGrade_{nonadapt}$, which represents the distance between a student's average grade on online tests of non-adaptive lessons and the average grade of all students on online tests of non-adaptive lessons in the respective group. Then, the difference *dG* was calculated through formula 1, representing the difference between a student's relative grades on online tests in adaptive lessons and online tests in non-adaptive lessons:

$$dG = rGrade_{adapt} - rGrade_{nonadapt}) \quad (1)$$

If *dG* is greater than 0, it means that the student achieved a higher grade on online tests in adaptive lessons than on online tests in non-adaptive lesson. If *dG* is smaller than 0, it means that the student achieved a lower grade on online tests in adaptive lessons than on online tests in non-adaptive lesson.

To calculate whether a student spent a similar amount of time on adaptive and non-adaptive lessons, we measured the relative time $rTime_{adapt}$, which represents the distance between a student's average time spent on adaptive lessons and the average time spent on adaptive lessons of all students in the respective group. Furthermore, we calculated the relative time $rTime_{nonadapt}$, which represents the distance between a student's average time spent on non-adaptive lessons and the average time spent on non-adaptive lessons of all students in the respective group. Then, the difference *dT* was calculated through formula 2, representing the difference between a student's relative time spent on adaptive lessons and relative time spent on non-adaptive lessons:

$$dT = rTime_{adapt} - rTime_{nonadapt}) \quad (2)$$

In order to determine whether a student spent a similar amount of time on adaptive and non-adaptive lessons, the range of half a standard deviation from the average values of time spent on adaptive and non-adaptive lessons from all students of the respective group was considered as a threshold t_{time}. If the absolute value of *dT* is smaller than t_{time}, a student is considered to have spent a similar amount of time on adaptive and non-adaptive lessons. Otherwise, the student is considered to have spent significantly more time on adaptive or non-adaptive lessons.

Accordingly, the first benefit is found if *dG* is greater than 0 and the absolute value of *dT* is smaller than t_{time}.

To find the second benefit, we looked into whether a student spent less time on adaptive lessons than on non-adaptive lessons and received on average the same grades on online tests of adaptive and non-adaptive lessons. To calculate whether a student spent less time on adaptive lessons than on non-adaptive lessons, *dT* was calculated as described in formula 2. If *dT* is smaller than 0, a student spent less time on adaptive lessons than on non-adaptive lessons. If *dT* is greater than 0, the student spent more time on adaptive lessons than on non-adaptive lessons.

To calculate whether a student received similar grades on online tests of adaptive and non-adaptive lessons, *dG* was calculated as described in formula 1. Furthermore, a threshold t_{grade} was considered, which was calculated as half a standard deviation from the average values of the grades received on online tests in adaptive and non-adaptive lessons of all students in the respective group. If the absolute value of *dG* is smaller than t_{grade}, a student is considered to have received similar grades on online tests of adaptive and non-adaptive lessons. Otherwise, the student is considered to have received significantly higher grades on online tests in adaptive or non-adaptive lessons.

Accordingly, the second benefit is found if *dT* is smaller than 0 and the absolute value of *dG* is smaller than t_{grade}.

Besides these two benefits, a third benefit has also been investigated. This third benefit combines the first and second

one, meaning that a student spent less time on adaptive lessons than on non-adaptive lessons and receives higher grades on online tests of adaptive lessons, in comparison to online tests of non-adaptive lessons. This benefit is found if *dT* is smaller than 0 and *dG* is greater than 0.

When looking at the raw data of Group 1, we found one student who benefited from adaptive lessons through the first benefit (higher grades and similar time), two students who benefited from adaptive lessons through the second benefit (less time and similar grades), and four students who benefited from adaptive lessons through the third benefit (higher grades and less time). When looking at Group 2, we found two students benefiting from adaptive lessons through the first benefit (higher grade and similar time), one student benefiting from adaptive lessons through the second benefit (less time and similar grades), and two students benefiting from adaptive lessons through the third benefit (higher grades and less time). It should be noted here that we did not investigate other variants of benefits of adaptive lessons (e.g., receiving much higher grades and spending little bit more time, etc.) since the aim of this investigation was to explain why the first benefit was found to be significant in Group 1 and the second benefit was found to be significant in Group 2.

From this investigation, our hypothesis was confirmed, indicating that students from both groups experienced both benefits and sometimes even benefit from a combination of them. The results of this investigation confirm the results of the t-tests, namely that the adaptive mechanism has significant benefits for students, including receiving higher grades while spending a similar amount of time and spending less time but receiving on average the same grades.

IV. Conclusions and Future Work

This paper introduced an advanced and flexible adaptive mechanism that extends learning management systems with adaptive functionality to automatically provide students with adaptive courses that are tailored to their learning styles. The adaptive mechanism has been evaluated with 23 students. Results of this evaluation showed that students benefited from adaptive lessons significantly in two ways: (1) by receiving higher grades in adaptive lessons than in non-adaptive ones while spending on average the same amount of time, and (2) by spending less time on adaptive lessons than on non-adaptive ones while receiving on average the same grades.

While this study is based only on a relatively small sample size, it already provides a clear indication for the effectiveness of the adaptive mechanism to support students in learning. The proposed adaptive mechanism allows teachers to make their existing courses (hosted in a learning management system) adaptive to students' learning styles with very little additional effort for the teacher. It provides teachers with an easy way to keep all the features that they currently use in learning management systems and additionally offer their students adaptive functionality that can improve their grades and/or reduce their learning time.

Future work will deal with a large-scale evaluation of the adaptive mechanism, where we plan to investigate in further detail for which learners the adaptive mechanism is particularly useful (e.g., depending on learning styles, performance, etc.). Furthermore, in order to make the adaptive mechanism even more flexible and extensible, future work will deal with developing a tool that allows teachers to add whatever type of LOs they want the adaptive mechanism to consider, making the adaptive mechanism adaptable to teachers' needs.

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