Exploring the Adaptation to Learning Styles: The Case of *AdaptiveLesson* Module for Moodle

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Abstract. Understanding learners and acknowledging diversities in their learning behavior is the key to design effective e-learning systems. This paper presents an innovative solution focused on adaptation to learning styles in the context of the learning management system Moodle. A new activity module named *AdaptiveLesson* has been developed as an extension of the *Lesson* module. It simplifies the interface for teachers who are creating lesson content while on the other hand provides students with individually adapted on-line courses in respect to their learning styles. Modifications in adaptive lessons with respect to regular lesson are described and the mechanism for adaptation to learning styles is presented. In order to evaluate the effectiveness of the proposed solution, a pilot evaluation of an on-line course developed by the *AdaptiveLesson* module has been conducted. The experiment is based on the comparison of an adaptive and an equivalent regular course. Results are discussed and guidelines for further research are established.

Keywords: e-learning systems, Moodle lessons, learning styles, adaptive course.

1 Introduction

Research in the academic community confirms that understanding learners and acknowledging diversities in their learning behavior is the key to design effective e-learning systems [3; 12]. The handicap of insufficient presence or even absence of the teacher in modern class needs to be compensated by the capabilities of e-learning systems. A respectable teacher senses the class, knows the capabilities of her/his students and recognizes their current motivational state. Thus she/he can change the approach and adapt the lecture to all these factors trying to engage the most of the students to catch the best of the lecture. A vast number of e-learning systems are developed with the intention to do the same, with more or less success. Among the most widely used systems are Virtual Learning Environments (VLEs) also well known as Learning Management System (LMSs) which support a number of activities for course creation, administration and delivering as well as facilities for

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communication between participants and sharing information on a course. Besides commercial environments such as Blackboard [1] and Sakai [25], there is a number of open-source systems, for example Moodle [21], Ilias [15], Claroline [6] and others.

It appears that Moodle is one of the most commonly deployed systems as up to February 2013 it has over 66 million of registered users, both teachers and students in 229 countries, using more than 7 million courses [21]. Moodle courses are intended to be learner-centered resources rather than just repositories of documents previously used for face-to-face learning and additionally enriched with on-line tests and communication tools. In addition to existing core facilities (some of them yet poorly exploited, such as the Lesson activity) there is a possibility to develop plugins for supporting a variety of additional resources and activities. For example, a teacher can use the Lesson module to create lessons in form of series of HTML pages which is already a step ahead of the commonly used courses consisting of documents developed elsewhere and imported into Moodle. Another step towards a highly learner-centered course is to enable developing of a new kind of lessons that will be adapted by the LMS to individual characteristics of the students, such as background knowledge, preferences, cognitive abilities, learning styles, preferences, and so on. In this paper one such initiative focused on adaptivity to learning styles is presented along with the first evaluation of an adaptive on-line course.

The paper is structured as follows. The next subsections discuss learning styles definition and description with special attention to the Felder-Silverman learning style model. Section 2 deals with on-line courses in Moodle. Regular lessons designed through the *Lesson* module are introduced followed by the description of the new *AdaptiveLesson* module and lessons that are adapted to learning styles of the students. Modifications in adaptive lessons with respect to regular lessons are described, and the mechanisms for adaptation to learning styles are explained. Section 3 presents the pilot study on effectiveness of the *AdaptiveLesson* module through the first adaptive on-line course implementation. Results are interpreted and discussed in light of related research.

1.1 Learning Styles

A set of attitudes and behaviors which determine an individual's preferred way of learning is considered as a learning style [13]. While there is a number of learning style theories, researchers agree that it is possible to diagnose a student's learning style and that learners with a dominant preference for certain learning style may have difficulties in knowledge acquisition in conditions where their learning styles is not compatible with the teaching strategy [7]. The thesis that incorporation of learning styles in learning environments enables more pleasant learning experience and higher performance of students has inspired development of a number of adaptive educational systems. These implementations employ different learning style models relying on diverse concepts, each proposing distinctive descriptions and classifications of learning types. One of the most popular models of learning styles in adaptive education is Felder-Silverman learning style model, FSLSM [7], implemented for example in CS383 [4], eTeacher [26], INDeLER [16], as well as an add-on for the LMS Moodle [9].

1.2 Felder-Silverman Learning Style Model

FSLSM places student's learning tendencies along four dimensions: sensing/intuitive, visual/verbal, active/reflective and sequential/global.

The sensing/intuitive dimension classifies learners according to the type of information they preferentially perceive: sensing learners prefer concrete information with lots of facts and examples, while intuitive learners learn better from abstract learning material such as theories and principles. As described in Graf *et al.* [11], sensing learners are usually more practically oriented and more patient with details. On the other hand, intuitive learners tend to see relationships between concepts and to discover additional possibilities.

The visual/verbal dimension reflects students' preferred perceptual tendencies: visual learners like to see pictures and graphs while verbal learners learn better what they hear and discuss out loud. Verbal learners also deal better with textual representation of data than visual learners.

The active/reflective dimension considers students' way of processing information, i.e. converting it into knowledge: active learners prefer to be engaged in physical activity, collaborative discussion or any kind of experimentation, while reflective learners benefit from introspection and quiet observation. Active learners learn best by doing any kind of exercise with the learning material, while reflective learners prefer to observe and reflect on the material. Unlike reflective learners who like to learn alone, active learners prefer communication with peers, especially if it includes group work and active discussion.

The sequential/global dimension describes the way learners make progress towards comprehension of the subject: sequential learners proceed through the material in a logical order, usually in the manner the material is presented, while global learners prefer to glance through the whole material and then select the topics to grasp more deeply. Global learners usually master the material by jumping to more complex issues, filling the gaps afterwards. In problem-solving activities, sequential learners usually follow logical steps to find a solution. On the other hand, global learners can solve complex problems using original approaches but they often cannot explain the way they did it.

To assess students' learning style according to FSLSM, the Index of Learning Styles (ILS) is generally used [8]. It contains 44 two choice questions distributed along the four learning style dimensions, where one choice increments and the other decrements the score of the particular dimension. The resulting index of preference for each dimension is expressed by an odd integer, ranging [-11, +11] since 11 questions are posed for each dimensions. The ILS questionnaire provides a very precise quantitative estimation of a learner's preference for each dimension of FSLSM.

Reliability and validity of the ILS questionnaire were confirmed in several studies, as reported in Graf, Liu and Kinshuk [10]. Test-retest reliability studies showed moderate to strong reliability with correlation coefficients between 0.505 and 0.683 for eight-month interval [33] and between 0.60 to 0.78 for a seven-month interval [19].

Regarding internal consistency reliability, literature suggests that Cronbach's alpha coefficient of 0.5 or higher is an acceptable value for attitude-assessing instruments [29]. Several studies showed that the ILS questionnaire met this limit for all dimensions, with Cronbach's alpha values between 0.51 and 0.76 [19; 30; 33], except of one result which showed an alpha value of 0.41 for the sequential/global dimension [30]. Findings of our previous study [23] are in line with those results. Cronbach's alpha coefficient for sequential/global dimension was 0.45. When the weakest item of the instrument is removed, as suggested in Litzinger *et al.* [18] alpha scores 0.48, and after removing two items the alpha value is 0.51. These results confirm that ILS questionnaire can be considered as reliable for sequential/global dimension as well.

Graf, Liu and Kinshuk [10] also reported several studies that support construct validity of the ILS questionnaire and concluded that the ILS questionnaire may be considered as reliable, valid and suitable instrument for measuring learning styles according to FSLSM.

These features of the ILS questionnaire probably led to the fact that FSLSM is one of the most widely used learning style models in adaptive education. Research suggests FSLSM as one of the most appropriate learning style models for application in e-learning systems [4; 17]. In addition to that, Graf *et al.* [11] stressed the advantages of FSLSM over other learning style models. The fact that the model distinguishes between strong and weak preferences for a particular learning style makes it a very suitable theory for application in adaptive systems design and development.

2 Adaptive On-Line Course Design

The Learning Management System (LMS) Moodle enables teachers to create a lesson in form of a series of HTML pages. Lessons are created through the *Lesson* module and consist of content pages and question pages. There are several types of questions available via the *Lesson* module: true/false, multiple choice, numerical, pair matching, short answer, essay, and so on. Teacher can provide a response to a learner's answer and decide what page the learner will see next in case of correct answer, and in case of incorrect answer. After submitting an answer to a question, a student gets appropriate response and follows the path predefined by the teacher.

On the other hand, the content pages can be equipped with several navigation buttons which enable students to choose what page they want to read next. Figure 1 shows a typical content page of a lesson in Moodle. The page content covers the central part of a page; buttons are in beneath of the content, while the map of the lesson is placed on the left. The lesson map contains captions of all content pages as hyperlinks. The question pages are not visible in the map. The teacher decides how many buttons will be on each content page and for each button what is the target page ("jump to"). The "Next page" button allows direct guidance of a student, i.e. he/she will follow the default path determined by the teacher. The other buttons along with map of the lesson allow the students to create their own path through the lesson.

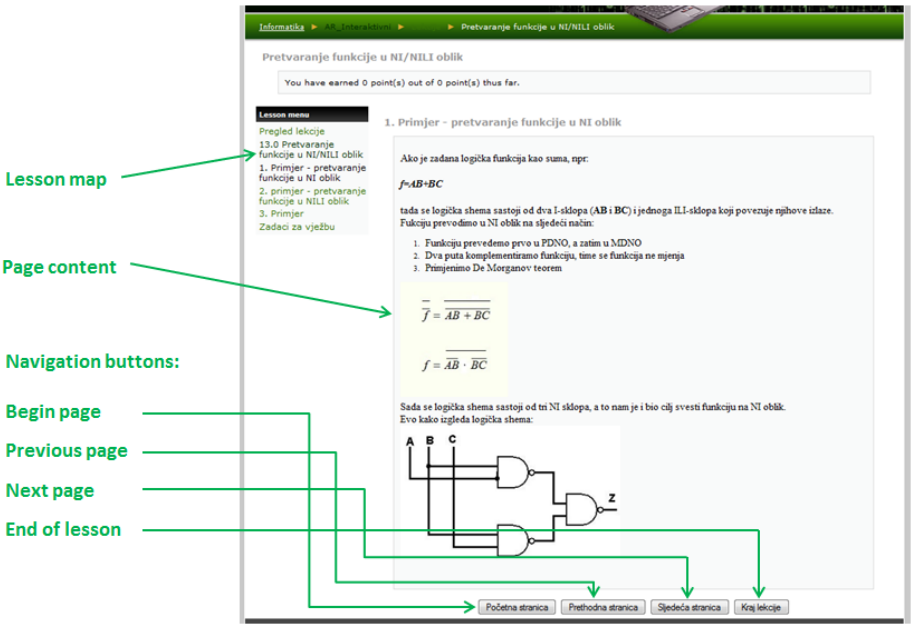

Fig. 1. Interface of a typical content page created by the *Lesson* module

As it allows the students to create a self-directed path through the lesson, the *Lesson* module is often claimed as adaptive [22]. However, in such contexts it could be argued about the claimed "adaptive ability" since this type of adaptivity is quite restricted to learners' knowledge. In order to enable this type of adaptivity teachers are required to do a lot of additional work, besides creating the lesson content, as they have to write captions and target pages for each button on each page and for each question.

The interaction of the teacher and the student with the *Lesson* module is shown in Figure 2a.

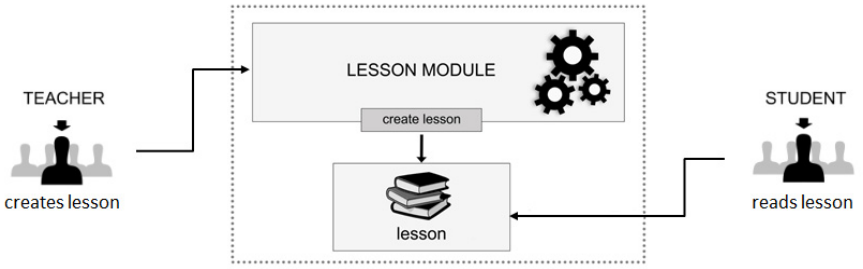

Fig. 2a. Teacher's and student's interaction with the *Lesson* module

To provide advanced adaptive behavior, we have developed a new module called *AdaptiveLesson*, which enables the creation of lessons adapted to the learning styles of students according to FSLSM. Adaptive lessons have several advantages over the regular lessons as the module implements a number of techniques to provide content adaptation as well as adaptive navigation support [2]. At the same time the effort of teachers creating adaptive lessons is reduced in regards to regular lessons. The next subsections bring the *AdaptiveLesson* module description followed by in-depth report on modifications of teacher's and students' interface.

2.1 *AdaptiveLesson* Module Description

The *AdaptiveLesson* module of the LMS Moodle is developed as an extension of the *Lesson* module. In addition, ILS questionnaire, i.e. its translation into Croatian, is integrated in the *AdaptiveLesson* module. A student is required to fill out the questionnaire at his/her first attempt to read an adapted lesson. Once a student fills out the ILS questionnaire, her/his learning style is detected and discrete values of every learning style dimension are stored in the *AdaptiveLesson* module database. Once students have filled out the ILS questionnaire, they can read all the lessons of any adaptive on-line course each time logged in.

Teacher and students have a specific interaction with the module, as shown in Figure 2b. The teacher creates lessons and triggers adaptation. The students fill out the ILS questionnaire, get information about their learning styles and read adaptive lessons.

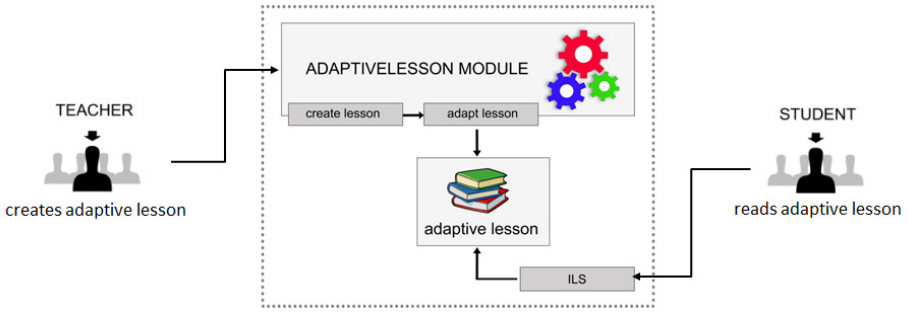

Fig. 2b. Teacher's and student's interaction with *AdaptiveLesson* module

2.2 Modifications for Teachers

In order to unify the interface of all pages, as well as to reduce the effort of teachers, the *AdaptiveLesson* module includes several changes in default settings compared to the *Lesson* module. The number of buttons for each page is set to four, and the text for buttons captions and target pages are filled in by default.

The mechanism for content adaptation is based on different content types. In order to use this mechanism, teachers/course creators are required to annotate a page type as one of the following: example, exercise, outline and theory.

While designing a lesson, the teacher usually determines several examples and exercises that are fundamental for understanding the basics of the lesson. For students who want to learn more, the teacher can prepare a few extra examples as well as additional exercises to be done as a single or group assignment. According to FSLSM, some students prefer more examples while other students prefer more problem-solving activities [7]. Those extra pages are considered for adaptation to learning styles. With that purpose, the teacher's interface for creating a content page is supplied with a checkbox for annotation of a content page as optional. The checkbox is enabled for examples and exercises, but disabled for outline and theory. Figure 3 shows the new items on teacher's interface for creating or editing a content page.

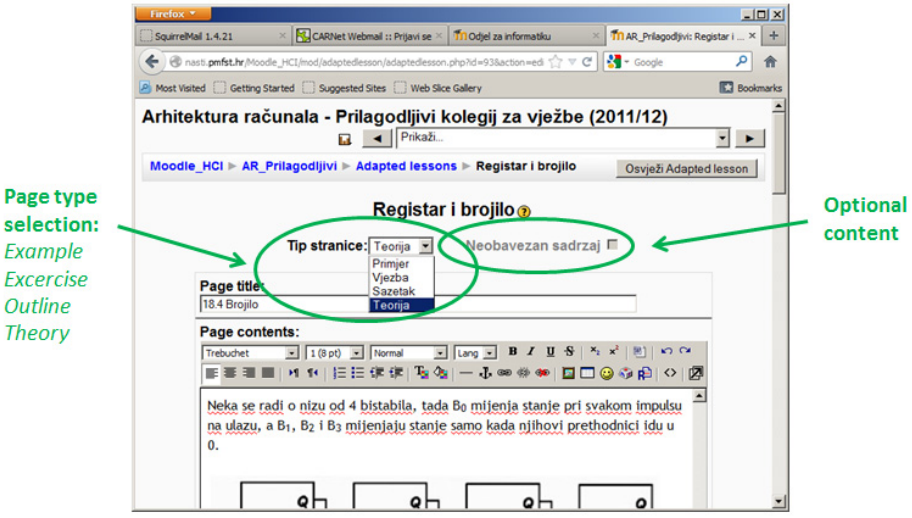

Fig. 3. Interface for creating or editing a content page of an adaptive lesson

The question pages are used occasionally throughout the lesson in order to provide self-assessment for students. In the *AdaptiveLesson* module no changes have been conducted in the interface for creating question pages.

Upon creation of all pages of the lesson, both the content pages and the question pages, the teacher triggers the adaptation algorithm. Figure 4 shows a new "Adapt lesson" tab with a button for triggering the adaptation of the lesson. Adaptation algorithm performs several techniques for adaptive presentation and adaptive navigation support [2] thus creating an adapted course as described in the next subsection.

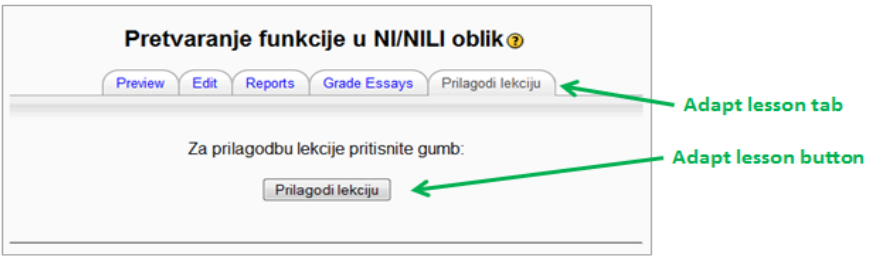

Fig. 4. Interface for triggering the adaptation algorithm

2.3 Modifications for Students

Two types of modifications have been done for the students' interface in the *AdaptiveLesson* module. First, modifications were done in order to provide students with adaptive courses that fit their learning styles, as described in more detail in the next subsection. Second, a few modifications were done for students regardless of their learning styles. Those modifications of students' interface are designed upon results of our previous study on navigation behavior of students while learning from regular Moodle lessons [23]. Those lessons were supplied by several navigation tools, but the study showed that the "Next" button is the most frequently used navigation tool for students, independent of their learning styles. This supports the decision to enlarge the "Next" button on all pages, for each learning style, as shown in Figure 5a. This feature prevents accidentally clicking on other buttons and improves students' navigation through the lesson.

Another improvement of students' interface is made in the *AdaptiveLesson* module. In contrast to the *Lesson* module, all question pages are shown in a lesson map, which improves students' orientation through the lesson, regardless of their learning styles. Visibility of the question pages enables students to reach any question any time they want, thus supporting navigational possibilities. Position of the questions inside the lesson structure depends on students' learning styles, so the next page a student will see after the correct answer is determined by the adaptive path of the lesson for each student.

Adaptivity Mechanisms. This subsection describes the modifications of the students' interface in order to provide them with courses that fit their learning styles. According to the ILS results, students are classified into several categories. For example, for active/reflective dimension, we refer learners who scored from -11 to -5 as active, those who scored from -3 to 3 as balanced between active and reflective, and those who scored from 5 to 11 as reflective learners. In the same way, the learners are categorized along sequential/global dimension as sequential, balanced and global learners.

Adaptation to visual/verbal dimension implies the existence of two different modes of presentation for the same content. Thus we do not consider any learner as balanced between visual and verbal, but classify learners as visual (scored from -11 to -7 on ILS) and moderately visual (from -5 to -1) on one hand, as well as verbal learners (from 7 to 11) and moderately verbal learners (from 1 to 5) on the other hand. Table 1 presents the distribution of ILS scores into learning styles categories as described.

Table 1. The distribution of ILS scores into learning styles categories

active -11 -9 -7 -5 -3	balanced between active and reflective -3 -1 1 3		reflective 5 7 9 11
visual -11 -9 -7	moderately visual -5 -3 -1	moderately verbal 1 3 5	verbal 7 9 11
sequential -11 -9 -7 -5	balanced between sequential and global -3 -1 1 3		global 5 7 9 11

The module does not have any adaptive features for sensing/intuitive dimension. Such adaptation would have additional requirements for teachers creating a lesson (for example to annotate the percentage of facts and concrete data in the page content). We assumed it would be very difficult for teachers and their motivation to make adaptive content could decrease to a great extent if this dimension would be added.

Adaptation to active/reflective dimension. The adaptation algorithm implements adaptive selection of pages for active and reflective learners and ensures pages to display in a corresponding order according to a certain type of learner. These techniques are known as adaptive content selection and adaptive sorting of pages, and they are widely applied in adaptive hypermedia [2; 3].

According to Felder and Silverman (1988), active learners are comfortable with problem-solving activities and group discussions, they prefer answering questions and doing exercises but less theory and examples. In contrary, reflective learners learn by reflecting on the matter and thinking things through. Thus, they are introduced with the theory pages first and examples afterwards. Exercises are following, but the number of exercises is limited and only obligatory exercises are recommended for reflective learners. If there are any optional exercises in the lesson, reflective students will see them at the bottom of the lesson map and annotated as additional pages. Those pages are adaptively annotated by different link color thus improving students' orientation through the lesson. Page layout for an active student is shown on Figure 5a, and for a reflective student on Figure 5b. The differences in page layout for active and reflective learners are shown in terms of selection of recommended pages and page ordering.

A student whose learning style is balanced between active and reflective see the lesson pages in default order as determined by the teacher.

Adaptation to visual/verbal dimension. Content adaptation is enabled by using two different modes of presentation wherever possible, namely text and graphics for the same learning concept. Visual students are presented with parallel modes of presentation, having graphics shown by default while accompanying text is hidden. Students can "stretch out" or "stretch in" the textual explanation by clicking on the link. Visual learners cannot hide graphics. The page layout for visual learning style is shown on Figure 5b. Moderately visual learners have an additional link to hide/show graphics. They can hide graphics if they have too much items on a page after stretching out a lot of text. This option seems to be very convenient for pages rich with content.

Adaptation for verbal and moderately verbal learners works in a similar way. Graphics are hidden by default, while textual explanation is stretched out. Verbal learners see the textual explanation all the time (Figure 5a), while moderately verbal learners have an option to stretch the text in.

Adaptation to sequential/global dimension. According to FSLSM, sequential learners tend to learn in small incremental steps, mastering the learning content in the presented order. They might have difficulties in learning if using learner control tools frequently, as also confirmed in [23]. As the findings of the study suggest, sequential learners who jumped a lot through the lesson achieved lower learning outcomes compared to sequential learners who followed the linear path through the lesson.

To restrict navigation possibilities for sequential learners, the left menu is hidden by default but available via hyperlink on the left side on the lesson page. Once stretched out, the left menu can be hidden again. For students balanced between sequential and global, the left menu is always visible, i.e. without option to be hidden, thus enabling students to browse all the pages of the lesson (Figure 5b). Finally, adaptation for global learners is accomplished by vertically displaying left menus of all lessons of a course theme on each page (Figure 5a). Thus global learners get the "big picture" of the subject and can randomly jump from one lesson to another inside a theme representing a chapter of the course. For global learners all the left menus are always visible.

In addition to that, the enlarged "Next" button is expected to be beneficial to sequential learners. This feature is accepted to encourage sequential learners to follow the path that the *AdaptiveLesson* module has recommended for them with respect to other dimensions of their learning styles.

Flexibility for Students. The module implements soft adaptivity, meaning that all adaptivity features are very flexible. The students can easily ignore some of the features recommended for their learning styles and activate them later. There are two reasons supporting this decision. First, FSLSM is based on tendencies, indicating that even learners with a high preference for a certain behavior can act sometimes differently, enabling the learning style model to consider exceptional behavior. Second, the ILS questionnaire is very sensitive and one wrong answer can classify a student to a different category of a learning style dimension or even to a different learning style (e.g. moderately verbal instead of moderately visual). It is possible that a student

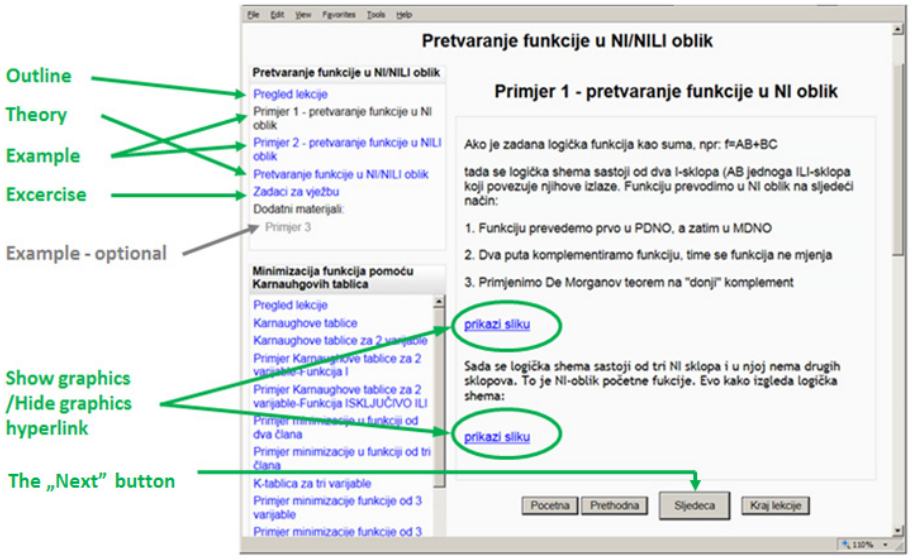

Fig. 5a. Page layout for student with active, verbal and global learning style

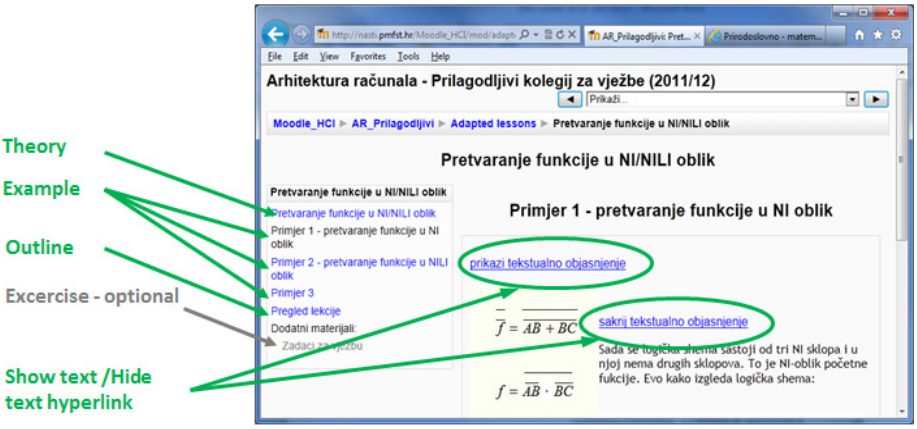

Fig. 5b. Page layout for student with reflective and visual learning style. A student has balanced learning style between sequential and global.

accidentally provides a wrong answer, but on the other hand it is true that some students do not feel like properly fill-out the questionnaire. They simply do not provide answers that are describing them in the best, thus their resulting learning styles are not reliable.

For these reasons, we have offered to the students the freedom not to follow recommended content. This is the option they can use occasionally in some situations or constantly through the whole course.

3 Evaluation of an Adaptive On-Line Course: A Pilot Study

The first evaluation of *AdaptiveLesson* module effectiveness was conducted in the spring semester 2011/12 at University in Split, Croatia, Faculty of Science. The study was carried out in the Computer Architecture class which is supported by two on-line courses developed and delivered via Moodle: a regular course consisted of lessons built by *Lesson* module, and an adaptive course consisted of lessons built by *AdaptiveLesson* module. The study examines the hypothesis that learning in an environment that matches students' learning styles results in higher learning outcomes than learning in an environment that does not match learning styles of the students.

3.1 Experimental Procedure

The class had total enrollment of 83 undergraduate second-year students and 67 of them have taken the class for the first time. These students have been considered as participants of the study and were assigned to one of three groups, controlled by background knowledge calculated from students' grades on five previously passed exams on Computer Science during the first year of their study. Because of the small number of participants, to eliminate the influence of background knowledge to learning outcomes, all of the students were first categorized into three groups according to their background knowledge: novice, intermediate and experts. After that the students from each group were randomly assigned to one of the three groups for the experiment. One group of students was enrolled in the regular course, referred to as standard group, while two groups were enrolled in the adaptive course as follows. The first group of students was enrolled using their actual learning styles (referred to as matched group) and the second group was enrolled using the opposite learning style categories for all dimensions of learning styles (referred to as mismatched group). For example, a student classified as active, visual and global learner was provided with a course for reflective, verbal and sequential learners. The students were not aware of belonging to a particular group while the experiment was carried out.

Participants were learning introductory concepts on both on-line Computer Architecture courses on Moodle, the regular and the adaptive course. The first three out of twenty lessons of the courses were considered as part of the pilot experiment. The content of all respective lessons of two different courses was exactly the same, and this content was not presented to students in any other way or from any other resources outside these courses.

The students' scores from mid-term and final exams were taken as the measures for learning outcomes. Only the answers to the first and the second question of these

exams are taken into account since only those questions dealt with content taught in the experiment. The criterion variables were (i) the scores on the first and the second question in mid-term exam and (ii) the scores on the first and the second question in final exam.

3.2 Data Set

Since some of the students did not attend the mid-term and/or the final exam, a total of 61 datasets were completed and analyzed. Data analysis was performed using SPSS 16.0 software statistical package. The number and percentage of students in each category of learning styles is shown in Table 2.

Table 2. The frequencies of learning styles in the sample

active	balanced between active and reflective		reflective
10	47		4
16.4%	77.0%		6.6%
visual	moderately visual	moderately verbal	verbal
21	23	15	2
34.4%	37.7%	24.6%	3.3%
sequential	balanced between sequential and global		global
6	55		0
9.8%	90.2%		0.0%

There were 23 male (38%) and 38 female (62%) students in the sample. The standard group consisted of 18 students, matched group of 23 and mismatched group of 20 students.

3.3 Results

One-way ANOVA is used to compare the means of standard, matched and mismatched group. The significance level of 0.05 was adopted for the study. The results are shown in Table 3.

Analysis showed no statistically significant difference between groups in respect to background knowledge, confirming that the influence of background knowledge to criteria variables is eliminated.

Criteria variables q11 and q12 represents the scores on question 1 and question 2 on mid-term exam, while q21 and q22 represents the scores on question 1 and question 2 on final exam. Sums are calculated as follows: Sum1=q11+q12, Sum2=q21+q22, thus Sum1 is related to mid-term exam as the first students' attempt to answer the questions, and Sum2 refers to final exam as the second attempt to answer related questions. Data analysis has shown no statistically significant differences between standard, matched and mismatched group in respect to all criteria variables.

Table 3. One-way ANOVA by learning styles categories

		Sum of Squares	df	Mean Square	F	Sig.
Background	Between Groups	53,411	2	26,705	,857	,430
	Within Groups	1807,901	58	31,171		
	Total	1861,311	60			
q11	Between Groups	196,332	2	98,166	2,499	,091
	Within Groups	2278,685	58	39,288		
	Total	2475,016	60			
q12	Between Groups	9,663	2	4,832	,098	,906
	Within Groups	2845,189	58	49,055		
	Total	2854,852	60			
q21	Between Groups	27,287	2	13,644	,287	,752
	Within Groups	2756,352	58	47,523		
	Total	2783,639	60			
q22	Between Groups	1,815	2	,908	,017	,983
	Within Groups	3147,267	58	54,263		
	Total	3149,082	60			
Sum1	Between Groups	177,674	2	88,837	,692	,504
	Within Groups	7441,113	58	128,295		
	Total	7618,787	60			
Sum2	Between Groups	38,859	2	19,429	,128	,880
	Within Groups	8778,387	58	151,352		
	Total	8817,246	60			

4 Discussion and Concluding Remarks

There are two limitations of presented research that have to be acknowledged. The limitations are caused by uncontrollable factors of the study which could have affected the obtained results. First, the *AdaptiveLesson* module enables students to not follow recommended content. This flexibility allows the students not to behave as expected according to their ILS scores. Although FSLSM indicates that students can act sometimes differently from their primary tendencies, we can assume that some students have used this possibility more often than the others: first, the students who did not carefully and accurately fill out the ILS questionnaire, and second, the students who have been assigned to mismatched group.

The second limitation of the study is the fact that students' learning achievements on the studied lessons were measured with a significant delay in respect to time of learning. The mid-term exam was four weeks and the final exam ten weeks after the learning sessions included in the study. This additional time enabled students to

consult other resources besides the on-line resources that were recommended for them in the course.

Limitations of the study can be addressed as follows. Monitoring student's behavior is suggested to dynamically check the use of adaptivity features and update students' learning styles according to their learning behavior. The flexibility of the system is a desirable feature and should be preserved in order to provide a high level of learner control. Moreover, to support students' learning styles better, the system should be able to recognize the navigation and behavior patterns that are in line with particular learning styles and dynamically compute the new values of learning styles. To address the second limitation, learning outcomes have to be measured immediately after the learning session. A pre-test should also be involved in the study to enable more accurate measuring of learning outcomes on particular lessons. In addition to that, inclusion of the time limit for learning session would probably decrease the influence of flexibility of the system to learning outcomes. If all the students have equal time for learning, we can conclude that students in standard group and even more in mismatched group would spend some time to find the resources that fit to their learning styles. Consequently, these students would have less time for reading those resources which could affect their learning outcomes. We conclude that the *AdaptiveLesson* module enables teachers to easily create on-line courses that adapt to learning styles of the students. Compared to the *Lesson* module, the effort of teachers creating adaptive lessons is reduced. The teachers can create adaptive lessons without any knowledge about learning styles definition or identification methods. Once the lesson is finished, teacher triggers the adaptation algorithm and the *AdaptiveLesson* module automatically adapts the content presentation as well as navigation options to learning styles according to FSLSM.

Although the adaptation mechanism strictly follows the theory of FSLSM, the pilot evaluation has shown no evidence of higher effectiveness of adaptive over regular Moodle lessons. The findings are in-line with related research where objective standard criteria such as learning outcomes usually fail to find a difference between adaptive and non-adaptive versions of a system [32]. Compared to studies with a similar design such as Graf and Kinshuk [9] we conclude that the lack of significant difference in learning outcomes occurred due to the fact that students had the flexibility to use all resources of the adaptive course in the way that suits for them the best. There is a high probability that students were quite aware of how they prefer to learn and they were using the flexibility that we provided them with. Research on improvements of criteria to find the valid indicators of interaction quality or adaptivity success is on-going and the new criteria are proposed [27; 28]. Acknowledging also a number of subjective criteria, e.g. user perception, motivation and satisfaction, complementary approaches to evaluation of adaptive systems are emerging suggesting the using of usability evaluation methods such as usability testing and heuristic evaluation [20; 24].

The advantage of presented research compared to similar studies is that the comparison of adaptive and non-adaptive lessons is grounded on fair basis as required in literature [14; 31]. The study contributes to the body of knowledge on adaptive education, as well as on methods of evaluation of adaptive systems.

Further research needs to be conducted in controlled conditions that address the lessons learned from the limitations of pilot experiment. A number of qualitative criteria regarding user motivation and satisfaction should be included in future studies.

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