Learning Styles and Navigation Patterns in Web-Based Education

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Abstract. Researchers agree that it is possible to diagnose student's learning style and that learners with a dominant preference for certain learning style may have difficulties in knowledge acquisition in conditions where teaching strategy is not compatible with it. This paper presents an experimental work conducted in order to determine if students with different learning styles have different navigational needs while using web-based learning environment. Correlations between learning styles and students' learning performance are also observed and discussed. A group of 102 graduate and postgraduate students were involved in the study. Learning styles according to Felder-Silverman learning style model have been explored in the context of an e-learning course delivered through a Learning Management System. The main results show that the course supports global learners to some extent. The methods for meeting the needs of sequential learners are proposed.

Keywords: learning styles, learning behaviour, navigation patterns, web based environment, empirical study.

1 Introduction

Learning is a process that engages perceptual and cognitive capabilities of students in various ways. Students perceive, process and represent learning material differently; they have different preferences for types, number and order of learning resources. Generally, a set of attitudes and behaviours which determine an individual's preferred way of learning is considered as a learning style [1]. While there is a number of learning style theories, researchers agree that it is possible to diagnose student's learning style and that learners with a dominant preference for certain learning style may have difficulties in knowledge acquisition in condition where it is not compatible with the teaching strategy [2]. The thesis that incorporation of learning styles in learning environment enables more pleasant learning experience and higher performance of students has inspired development of many adaptive educational systems such as CS388 [3], INSPIRE [4], eTeacher [5], INDeLER [6].

This paper presents an experimental work conducted in order to determine if students with different learning styles have different navigational needs while using a Learning Management System (LMS). Correlations between learning styles and students' learning performance are also observed and discussed.

C. Stephanidis (Ed.): Universal Access in HCI, Part IV, HCII 2011, LNCS 6768, pp. 587–596, 2011.

The paper is structured as follows. Background section briefly introduces the theories of learning styles with an emphasis on Felder-Silverman learning style model [2] and stresses the efficiency issues of adaptation to learning styles in web-based education. Main part of the paper brings detailed experimental procedure along with obtained results. Discussion offers interpretation of findings and critical review of the methodology. The last section summarizes the results and outlines future work.

2 Background and Motivation

2.1 Learning Styles

Exploration of learning process has emerged a variety of models of learning styles, each relying on diverse concepts and proposing distinctive descriptions and classifications of learners' tendencies. Kolb [7] propose that learners can be distinguished into *convergent learners*, *divergent learners*, *assimilators*, and *accommodators.* Honey and Mumford [1] offer another interpretation of Kolb's theory of experiential learning [7] and classify learners into four types: *activists*, *pragmatists*, *reflectors* and *theorists*. This learning style model is frequently implemented in existing adaptive systems, for example INSPIRE [4]. However, one of the most popular models of learning styles in adaptive education is Felder-Silverman learning style model, FSLSM [2], implemented for example in CS388 [3], SAVER [8], eTeacher [5], INDeLER [6], as well as an add-on for the LMS Moodle [9]. FSLSM places student's learning tendencies along discrete scales on four dimensions: *sensing/intuitive*, *visual/verbal, active/reflective* and *sequential/global*. This model provides very precise quantitative estimation of learner preference for each dimension. To date, FSLSM is considered as the most suitable learning style theory for application in adaptive systems design and development [10; 11].

The sensing/intuitive dimension of FSLSM 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 theories and principles. Visual/verbal dimension reflects students' preferred perceptual tendencies: visual learners like to see pictures and graphs; verbal learners learn better what they hear and the best what they hear and discus out loud. Verbal learners also deal better with written representation of data than visual learners. 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. Finally, sequential/global dimension describes the way students make progress towards comprehension of subject: sequential learners proceed through the material in a logical order, usually in the manner the material is presented. Opposite to them, global learners prefer to glance through the whole material and then select the topics to grasp more deeply. They usually master the material by jumping to more complex issues, filling the gaps after.

In empirical study that will be presented in the paper, learning styles have been studied in the context of the e-learning material developed as Moodle lessons for learning basics of human-computer interaction (HCI). The material offers

fundamentals and principles of the domain; it is rather theoretical, accompanied with relatively small number of illustrations and few examples. Along these lines we believe that such lessons are already adjusted to intuitive, verbal and reflective students, so the experiment deals only with the sequential/global dimension of the FLSLM.

2.2 Efficiency of Adaptation to Sequential and Global Learners

Despite an increasing number of existing adaptive and adaptable learning systems which consider learning styles, empirical studies on an efficiency of the developed systems are rarely conducted. Furthermore, results of such studies, even only in respect to the sequential/global dimension, are rather inconsistent. For example, Bajraktarević et al. [12] found significantly higher learning outcomes for students learning in conditions that matched their learning styles. Similar results were found in several studies regarding other models of leaning styles comparable to the sequential/global dimension [13; 14]. On the other hand, there are studies that have not found any differences concerning learning outcomes between matched and mismatched group. For example, Graf and Kinshuk [9] found that adaptation is effective only in terms of time students spent on learning activities and of the number of requests for additional learning objects, but not in terms of learning outcomes. Furthermore, Brown et al. [15] found no correlations of sequential/global dimension and learning performance in any of relevant aspects. Their study has imposed further investigation of potential educational benefits of adaptation to sequential and global learners.

Taking into account related work and the fact that user performance considerably depends on a particular system, we have studied learning styles in the context of the e-learning material developed at the University of Split, Croatia. If an outcome of the study suggests that the learning process would benefit from the lessons adapted to sequential and global learners, once created learning material could be easily restructured in terms of learning objects sequences and their availability for students with different learning preferences.

3 Empirical Study

The paper presents an experimental work aimed at finding out more about learning styles, particularly sequential/global dimension and the relationship to students' navigation patterns when learning in the web-based environment. An empirical study was carried out in order to identify and validate individual sequential/global dimension, as well as to detect its correlations with the results of selected objective variables. Learning outcome and learning behaviour in the chosen web-based learning environment have been measured and defined as objective variables.

3.1 Research Questions

This empirical study attempted to provide answers to the following questions: do learners with different learning styles employ different navigation patterns when

using the web-based e-learning system; does it affect their learning performance and if does, in what way? Consequently, we have postulated the following:

H_0: There is no difference in the learning performance, i.e. the sequential/global learning does not affect learning outcomes and learning behaviour if the students are provided with enough time to pursue the whole learning material.

H_1: Learners classified into one learning style according to the sequential/global dimension accomplish higher learning outcomes.

H_2: Differences related to the sequential/global dimension result in different navigation behaviour of learners, i.e. sequential learners prefer system controlled navigation, while global learners use a number of various navigational tools which enable learner controlled navigation.

3.2 Instruments and Measures

In order to identify learning styles, particularly the sequential/global dimension, the Index of Learning Styles questionnaire (ILS) [16] was used, which aims at assessing learning styles based on the FSLSM. The ILS questionnaire is commonly used instrument which contains 44 questions distributed along four dimensions. FSLSM determines learning preference for each dimension by values ranged from 11 to -11. For the purpose of the study, 11 questions related to the global/sequential dimension have been extracted.

E-learning material developed as Moodle lessons and used in several HCI courses at University of Split was involved in the study. Each learning page is accompanied with a set of navigation tools to support various learning behaviour of students. Figure 1 illustrates the layout of a typical page: learning content is placed in the centre of the screen along with navigation buttons located below, while lesson menu map is positioned on the left side of the screen, offering chapter headings as links.

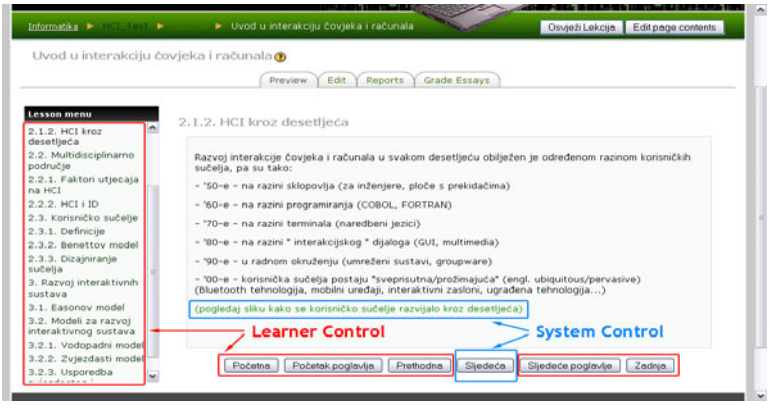

Fig. 1. Screenshot of the e-learning material with navigation tools

Analysis of the conducted learning sessions enabled us to identify student's learning behaviour thus providing measures for a number of variables: navigation steps and usage of system control versus learner control tools, together with navigation paths of each student.

Navigation steps are represented by two variables called *Next* (relative number of system control tools used by students, i.e. the ratio of system control tools number and total number of clicks) and *Map* (relative number of clicks on the lesson menu map). Navigation path was determined through the total number of clicks (variable *Clicks*), the relative number of *Jumps* (usage of learner control buttons) and the number of *Passes* through the whole learning material which students used in their learning session.

Learning outcomes, expressed as variable *Quiz,* are calculated from scores on a post-test which concludes learning session. The post-test is structured as an on-line quiz via Moodle with 20 multiple choice questions. The experimental design of the conducted empirical study is illustrated in Figure 2.

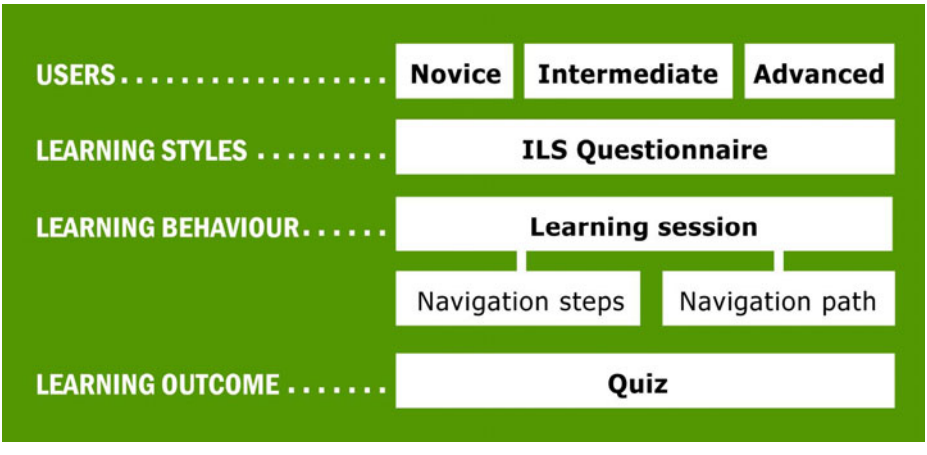

Fig. 2. Design of the experiment

3.3 Participants and Procedure

A group of 102 participants from two faculties was involved in the study. They were all computer science students, sharing nearly equal experience in web-based learning. Experimental procedure comprised three major steps. In the first step a pilot study with ten participants was performed in order to test learning material adopted for the experimental session, duration of the session and post-test quiz, as well as to determine quantitative parameters for the measurement of the student's learning behaviour.

Remaining 92 participants joined the study in the second and the third step. They have been allocated to two experimental groups: 61 participants to the "learners" group and 31 to the "assistants" group. Learners were selected from three different university courses and have been classified according to their background knowledge related to the chosen subject matter into novice, intermediate and advanced learners. In the second step all learners completed ILS questionnaire. A twenty minutes learning session followed by the on-line post-testing, as the third step of the experiment, concluded the procedure. The group consisted of 31 assistants was randomly chosen to help in observing and recording learners' work.

In the end, 53 participants have successfully completed procedure of the main study. The group was consisted of 27 male (51%) and 26 female (49%) students. The

age of all participants varied from 18 to 23 years, with a median value of 22. The distribution of gender, age and study group is presented in Table 1.

Table 1. The distribution of age, gender and study group in the sample

Participants	Study group	Gender			Age	
		Male	Female	Total	< 22	> 22
Novice	5. sem. graduate	9	13	22	21	1
Intermediate	1. sem. postgraduate	13	7	20	14	6
Advanced	3. sem. postgraduate	5	6	11	0	11
Total		27	26	53	35	18

3.4 Results

With the aim of testing our hypotheses, data analysis was performed using SPSS 16.0 software statistical package.

Descriptive statistics for all measured variables, along with the overall number of participants (N), the minimum and the maximum scores, arithmetic means (Mean) and standard deviations are presented in Table 2.

Table 2. Descriptive statistics of the measured variables

Variables	N	Minimum	Maximum	Mean	Standard Deviation
Quiz	53	3,13	7,93	5,92	1,170
Clicks	53	8	116	36,68	17,414
Passes	53	1	2	1,55	0,503
Next	53	0,13	1	0,73	0,204
Map	53	0	0,74	0,11	0,179
Jumps	53	0	0,64	0,10	0,131

Table 3 shows descriptive statistics of measured variables for the participants divided into two groups of learners according to their ILS score. The number of participants per group (Ng), arithmetic means (Mean) and standard deviations are presented.

Table 3. Descriptive statistics of the measured variables for participants divided into two groups of learners

Variables	ILS	Ng	Mean	Standard Deviation
Quiz	sequential	25	5.64	1.244
	global	28	6.18	1.060
Clicks	sequential	25	3540	15.610
	global	28	37.82	19.094
Passes	sequential	25	1.56	0.507
	global	28	1.54	0.508
Next	sequential	25	0.69	0.219
	global	28	0.66	0.191
Map	sequential	25	0.12	0.197
	global	28	0.11	0.165
Jumps	sequential	25	0.12	0.148
	global	28	0.08	0.113

Factors that could have an influence on web-based learning were identified from the acquired results of measured variables. Learning outcomes and perceived navigation of users were explored with the analysis of differences of arithmetic means and by the correlation analysis. Statistically significant difference in the results of measured variables for the two groups of learners was tested with a number of t-tests for independent samples. T-test scores (t) along with degrees of freedom (df) and levels of significance (p) are shown in Table 4.

Table 4. Findings on testing differences in results of measured variables for the two groups of learners

Variables	t	df	p
Quiz	-1.70	51	0.096
Clicks	-0.50	51	0.618
Passes	0.17	51	0.863
Next	0.67	51	0.507
Map	0.09	51	0.927
Jumps	1.21	51	0.230

Bivariate correlation method was carried out. Pearson's correlation coefficients for participants' results in the relevant variables are shown in Table 5.

Table 5. Pearson's correlation coefficients of measured variables
* significant correlation at level of $p < 0.1$
** significant correlation at level of $p < 0.01$

Correlation of results	r
Quiz - Jumps	-0.23*
Next - Map	-0.89**
Next - Jumps	-0.42**
Map - Jumps	0.60**

4 Discussion

Statistically significant difference in the *Quiz* scores ($t = -1.70$; $df = 51$; $p < 0.1$) between the two groups of learners indicates distinction in learning outcome in favour of global learners. Furthermore, analysis of results shows no significant differences in the measures for navigation behaviour of learners. For that reason H_0 hypothesis is only partially supported, while H_1 hypothesis is fully accepted.

The finding that supports H_1 hypothesis could be a result of the structure of the learning material: the lessons are presented first, and students take quiz after they have learned all the lessons related to the subject matter. Although not created with an intention to support any learning preference, it seems that such structure supports global learners, the result which is in line with suggestions from the literature, e.g. [11].

A statistically significant correlation ($r = -0.23$; $p < 0.1$) was obtained between variables *Quiz* and *Jumps*. Negative correlation implies that in post-testing users with higher usage of learner control tools score slightly lower result. No difference was found in the relative number of jumps which have been made by our two groups of

users in their learning session. Our findings suggest that both sequential and global learners had jumped to the similar extent. While free browsing is, according to FSLSM, typical behaviour of global learners, sequential learners usually follow navigation path controlled by the system. For that reason, previous result suggests that sequential learners who have made a lot of jumps, scored lower in post testing. It seems that the structure of the learning material with no navigational restrictions in a way "discriminates" sequential learners.

Considering navigation patterns for the two groups of learners categorized by the ILS, there were no statistically significant differences found to support hypothesis H_2, thus H_2 is rejected. However, analysis of the results has shown clear distinction between users who prefer the system control over the learner control. High negative correlation between variables *Next* and *Map* ($r = -0.89$; $p < 0.01$) in addition to correlation between *Next* and *Jumps* ($r = -0.42$; $p < 0.01$) reveals strong differences in learners' navigation behaviour; regular users of system control tools rarely used learner control tools. Positive correlation between *Map* and *Jumps* ($r = 0.60$; $p < 0.01$) is also in line with our findings, supporting the structure of the learning material and offered navigation tools.

Obviously, there is a vast distinction among learners in their navigation behaviour, but it seems that the ILS questionnaire as an instrument does not offer sophisticated way of their distinction. To investigate this hypothesis, we have tested internal consistency reliability of the ILS. Cronbach's alpha coefficient for the sequential/global dimension was 0.45, while literature suggests that an acceptable value for attitude-assessing instruments is at least 0.5 [17]. Research shows that the scores for the reliability of the instrument could be improved if the weakest item of the instrument is removed [18]. In our study, such elimination resulted only in a minor increment of the alpha coefficient, that is 0.48. Although a majority of studies reported slightly higher values of the internal consistency reliability of the ILS, as reviewed for example in [19], researches agree that ILS reliability is generally weak and that there is a need for its refinement.

Besides using insufficiently reliable measuring instrument, another possible limitation of the conducted experiment should be mentioned. There were a number of "assistants" involved in the empirical study, i.e. 31 students were engaged for observing and recording user's navigation patterns. Although they have been precisely instructed, still the data for 8 of the total of 61 users have been dismissed due to the irregularities in the observation of their learning behaviour. Therefore, in similar experiments the usage of log files or adequate software for screen monitoring would be much more appropriated.

On the other hand, a strong feature of the conducted empirical study comes from careful operationalization of learning behaviour which has resulted in the definition of the precise metric for learners' navigation patterns. Defined variables for measuring navigation steps and navigation path are conformed to the structure and layout of the learning material, and at the same time applicable for the identification of navigation patterns in comparable learning environments.

5 Conclusion

Summarizing the results of the conducted experiment we conclude that the structure of the learning material for the selected course to some extent supports global learners. This result indicates that sequential learners could benefit when knowledge testing is more frequently provided (best at the end of each chapter) and from the partial restriction of available navigation tools, thus enabling more strict system control. The additional finding of the study is related to the analysis of the learners' navigational patterns and their possible connections with the learning outcomes. However, such relationship along with learning styles implications on the web-based learning requires additional thoughtful research. Currently, the opinions about possibilities of an employment of the learning styles in adaptive systems are rather controversial [20; 21]. Thus our future work will also encompass investigation of other factors that could contribute to the better learning performance in the web-based environment, in accordance with the framework for user individual differences proposed in [22].

Acknowledgments. This work has been carried out within project 177-0361994-1998 *Usability and Adaptivity of Interfaces for Intelligent Authoring Shells* funded by the Ministry of Science and Technology of the Republic of Croatia.

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