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Adapting Learning Contents to Mobile Devices and Context to Improve Students' Learning Performance: A Case Study

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Abstract: E-learning has been a revolution in recent years in training field. This, combined with the increased use of mobile devices has caused the emergence of m-learning. Hence new problems have appeared in the training field, such as displaying correctly learning contents in a mobile device that has restricted features or taking into account the learner's context in the learning process, who could be anywhere. For this reason the adaptation concept is used, in order to personalize or adapt the learning contents to each student. This paper presents a case study in a real course using a multi-agent system for adapting the learning contents to the learner's context and to his/her mobile device. The results of the experiment show that the students who used the adaptive system (experimental group) obtained better grades than the students who did not (control group).

Keywords: Mobile device adaptation, Case study, Experimental design, Context-aware, Learning performance
Categories: G.3, I.2.6, K.3.2

1 Introduction

M-learning is defined as the acquisition of any knowledge and skills through the use of mobile technology anywhere and anytime [Liu, 10] and is usually observed as an evolution of e-learning based on the use of mobile devices. According to [Becker, 07] [Zhang, 05], most people have a mobile device at almost any time, and thus the use of mobile devices eliminates the identified weakness of the use of laptops. Additionally, there is a technological revolution with the emergence and use of these devices, as people have incorporated them as one more tool in their daily lives [Liu, 10]. Mobile devices are not only used as a tool for social communication, but also for leisure and work tasks and finally, in the learning process as well.

However, despite a huge potential, there are many challenges to the adoption of m-learning. The results of research performed by [Attewell, 05] show that a significant proportion of observed students did not show any preference for future use of m-learning. This research was performed in 2005, but more lately the shift was slightly positive. For instance, the main factors driving the adoption of m-learning recognized by Liu et al. [Liu, 10] are personal innovativeness and perceived near/long term usefulness. Thus, Liu et al. conclude that offering students the m-learning content with long term usefulness will be the key reason to persuade students to use their unproductive time for learning process.

From this point of view, the learner now may use different devices for learning, with different features and limitations. These devices can be used anytime and anywhere, so the context of the learner also varies and is dependent on learning location. Therefore, some approaches and systems are proposed by different authors for adapting the learning process or content taking into account the context [Martín, 06] and the mobile devices [Gómez, 10] [Gómez, 09]. We approached to this problem from different perspective: we have carried out an experiment with students using a multi-agent system for adapting the learning content to their competences, contexts and mobile devices.

This paper reports the results of a case study trying to identify whether or not there are significant differences in grades when students use an adaptive system instead of a traditional e-learning system. Two groups of students are analysed, one of them uses the adaptive system and the other one uses a common e-learning platform.

Thus, the paper is organized as follows. Section 2 shows the background and related work to the research topics. Section 3 describes the adaptive system used for the experiment and Section 4 describes the plan of the experiment. Section 5 shows the analysed results and finally in Section 6 conclusions are discussed.

2 Prior research

Mobile learning (m-learning) is an e-learning extension, in which mobile devices and wireless technologies are used to perform the learning process. M-learning lets to further extend the e-learning paradigm, i.e., the ubiquity of learning for being able to learn anytime and anywhere [Pu, 11]. Due to the wide variety of existing mobile devices and their different technical characteristics, the application of m-learning is complicated and limited. Most of e-learning systems developed to date have rarely taken into account the differences [Zhao, 08], and e-learning systems should be modified when new devices with different characteristics appear, for being able to continue using them with the new devices.

A framework for m-learning development was established in [Motiwalla, 07], which states that personalization and adaptation of content is one of the fundamental aspects for developing m-learning activities. According to [Pu, 11], it is important for students to have the information and educational resources in an adaptive way based on their characteristics and needs.

In computing, another term related to context is also used: ‘context-aware computing’. [Dey, 01] indicates that a system or an application is ‘context-aware’ if “it uses context to provide relevant information and/or services to the user, where relevancy depends on the user’s task.”

An empirical study was done by Kim et al. [Kim, 02], whose main aim was to identify the most relevant contexts used in mobile Internet. Regarding m-learning, the context is the set of possible environment states and adjustments based on the established roles between learners and tutors. The definition of the contexts is important to improve the system's adaptive ability. To achieve this objective, the key is to provide the mobile device with a context-content service, whose function is to provide an intelligent, dependent on the situation and personalized information for mobile devices based on heterogeneous educational resources [Pu, 11]. Adaptability and personalization in m-learning systems mainly refers to the system adjustment process to the situation and needs of the learners [Wu, 08]. Current research on adaptability and personalization in m-learning systems acknowledges the importance on pedagogical aspect and that it may be as important as the system design factor [Kinshuk, 12]. According to [Gómez, 12], several works have tried to model the context, as well as to describe the elements that might be part of the user's interaction with the learning system. A commonly used definition of contextual information in e-learning by defining the learning context is "the current situation of a person related to a learning activity" [Luckin, 10].

Based on the limited capabilities of an adaptation in a client-side and the opportunities that the distributed systems offer for content adaptation in the server-side, Gómez et al. [Gómez, 10] proposed an adaptation process. This process is subdivided into two processes: (1) adaptation process at design-time and (2) adaptation process at run-time. In order to detect the learner’s mobile device capabilities the specification WURFL (Wireless Universal Resource FiLe) [WURFL, 08] was used. WURFL is a based-XML repository of capabilities for mobile devices that contains information about more than 7000 different mobile devices.

Heretofore, few experiments and studies with real students have been presented about adaptation and personalization based on the m-learning contexts. In [Gómez, 13] a context-aware adaptive and personalized system is proposed, and is also presented an evaluation of its use and effectiveness about delivering adaptive and context aware content based on the learners' feedback through a questionnaire. In [Martín, 09] an adaptive system is presented, which adapts the contents to the m-learning environments by proposing collaborative activities in different contexts. Furthermore, it presents the outcomes of two case studies carried out with students based on the results and feedback obtained from students.

In the experiment we carried out not only the learners' feedback about the use of the system has been analysed, but also a statistical analysis has been presented about the influence of the adaptive system proposed about the results obtained by the learners who used it. This may provide a more solid basis to this research field. The following sections explain the details of the experiment performed.

3 Adaptive system used

The adaptive system used for the experiment is a multi-agent system (Figure 1) (based on the proposal of [García, 13]). It is able to adapt a learning content to the learner’s context, to his/her mobile device and to his/her competences. The system has four elements as inputs: competences, characteristics of the mobile device, current context and the syllabus of the subject or course. The output is a course (a set of learning contents) adapted to these parameters. Five different agents are used to carry out this task: Logical Sequencing Agent, Federated Search Agent, Device Agent, Context Agent and Manage Agent.

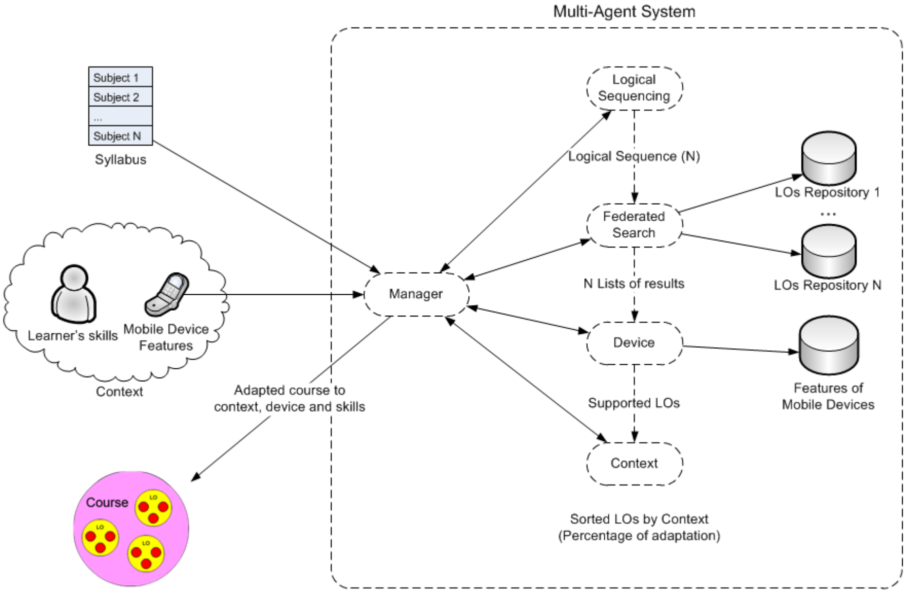

Figure 1: Designed multi-agent system

Logical Sequencing Agent establishes a sequence of topics or subjects that the learner has in his/her syllabus. Federated Search Agent performs a federated search in different repositories of learning objects (LOs) using each element of the logical sequence. The objective of Device Agent is filtering the learning objects that the learner's mobile device does not support, e.g., if a mobile device does not support Flash format, all learning objects in Flash format are removed from the list. When all LOs can be shown by the learner's mobile device, these learning objects are sorted by context.

Finally, the purpose of Manager Agent is to manage the other agents, since they are not aware of each other's presence. Also, this agent aims to interact with the learner and it is also responsible of calling a specific agent if any parameter changes, e.g., if the learner changes his/her mobile device or context.

4 Experimental design

The experiment aims to check how the adaptive system (described in the previous section) behaves in a real learning environment, with different learners and mobile devices.

The main goal of this study is to check whether students using this system improve their grades when compared to those using a traditional e-learning system. An experimental group has been created in Usability and Accessibility course of Master in Software Engineering for the Web in our institution. This course has 6 ECTS and it is a blended learning course (online + lecture). Assessment of learners is composed of one Intermediate assignment (30%), one Final assignment (50%) and one Evaluation Test (20%).

The course students in the academic year 2011-2012 were divided into two groups: an experimental group (using the adaptive system) and a control group (using a common e-learning system, Blackboard LMS). The students voluntarily chose the group they wanted to belong. The aim was to measure the grades obtained by learners in each of the groups in order to compare them later.

The hypotheses of this experiment are two: (1) learning performance (measured by grades obtained) will be higher when using the adaptive system than when using the traditional e-learning system; and (2) learning performance of students who use the adaptive system will be higher in students who use a mobile device than students who use other devices.

The results obtained in the experiment have been analysed from three points of view:

1. Learning performance: the grades of both groups are compared for checking the learning performance in each of them.

2. Learning performance using mobile devices: it checks whether the students who used their mobile phones for accessing to the system got better grades than students who did not.

3. Attitudinal survey: for knowing the students' attitude towards the tool, an attitudinal survey has been carried out in the experimental group.

5 Results

The experiment was performed during Spring semester 2012. Experimental data was gathered and results are presented in the following sections.

5.1 Learning performance

The data taken into account for this analysis are the grades obtained in the assessments (intermediate assignment (30%), final assignment (50%) and test (20%)) and the overall grade for each student.

Firstly, a normality test has been done, for selecting the suitable statistic method for analysing the results. According to the results, Evaluation Test does not pass the normality test ($p < 0.05$), while Intermediate assignment, Final assignment and Overall grade pass the test ($p > 0.05$). Therefore Kruskal-Wallis (non-parametric method) is selected for analysing the results of Evaluation Test and ANOVA method for the other cases (Intermediate assignment, Final assignment and Overall grade).

For the first case, Evaluation Test, Kruskal-Wallis method returns $p = 0.255$ ($p > 0.05$, $H(1)=1.30$) so there is no statistical difference between the experimental and control groups. This means that the type of e-learning system (adaptive or not adaptive) does not influence the grades of the Evaluation Test.

Regarding to the data of Intermediate assignment grades, ANOVA method is applied and shows a *p*-value of $p = 0.096$, so there is statistical significance with a confidence interval of 90% ($p < 0.1$). In this case, there is a difference between using the proposed adaptive system and the traditional e-learning system.

ANOVA analysis (for the grades obtained in the Final assignment) returns $p = 0.025$, so there is statistical significance with a confidence interval of 95% ($p < 0.05$). In this case, it can be affirmed that the learners who used the adaptive system had better grades than learners of the control group.

We will focus on the Overall grade obtained by students because it represents a general value of learning performance in the subject. Figure 2 (left) shows the boxplot with the results in Overall grade. The average and median of the experimental group are higher than in control group. The grades of the experimental group are higher with respect to the grades of the control group, which are in lower values.

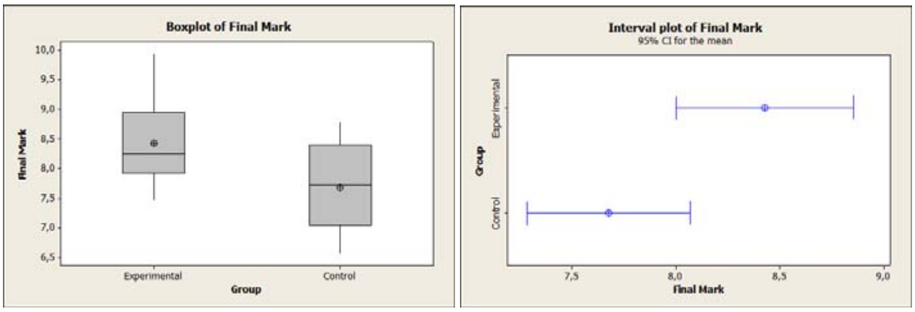

Figure 2: Boxplot and Interval plot of Overall grade

Figure 2 (right) shows the interval plot for both groups. ANOVA analysis shows $p = 0.010$, so there is statistical significance with a confidence interval of 95% ($p < 0.05$). In this case, similar to previous analyses, the learning method (adaptive system or traditional e-learning) influences the marks of the learners.

Table 1 shows a summary of the results of ANOVA and Kruskal-Wallis analyses. Overall grade is composed of grades obtained in other assessments so we could determinate that there is a general statistical significance between experimental and control group (grades of students in experimental group were higher than those in the control group in at least three of the four evaluations).

Table 1 shows that the average is higher in the experimental group than in the control group in all cases, but there is statistical significance in the cases of Intermediate and Final assignment, and Overall grade. In the case of Evaluation test there is not statistical significance, which means that we are not able to say that the type of e-learning system (adaptive or not adaptive) influences the grades of theoretical content.

Finally, in conclusion of this first analysis, we could determine that the results are partially positive because despite of there is not statistical significance in the results of the evaluation test; there is statistical significance in the rest of results. Therefore, it means the method used (adaptive or not adaptive) influences the grades obtained by students.

	Experimental Group			Control Group			Significance
Assessment	**Avg**	**SD**	**Std err**	**Avg**	**SD**	**Std err**	***p***
Evaluation Test	9.035	0.664	0.177	8.500	1.197	0.299	0.255
Intermediate	8.143	1.216	0.325	7.273	1.508	0.377	0.096
Final	8.357	0.735	0.196	7.593	0.987	0.247	0.025
Overall grade	8.428	0.736	0.197	7.678	0.736	0.184	0.010

Table 1: General results of Kruskal-Wallis and ANOVA between experimental and control group

5.2 Learning performance using mobile devices

Some students in the experimental group (who used the adaptive system) used their mobile devices to access the system, and some did not. For the following analysis, the experimental group is divided into two groups: users who used their mobile device and those who did not. Only 4 of the 14 students in the experimental group used their mobile device to access the system. Because this number of subjects is very low, the results presented should be carefully taken.

The same method as explained in the previous section is followed, analyzing the data of the three evaluations (Evaluation test, Intermediate and Final assignment) and the final mark (Overall Grade). The statistical methods applied were Kruskal-Wallis and ANOVA, and the results obtained are showed in Table 2.

	Experimental Group: Non Mobile Devices			Experimental Group: Mobile Devices			Significance
Assessment	**Avg**	**SD**	**Std err**	**Avg**	**SD**	**Std err**	***p***
Evaluation Test	8.950	0.550	0.174	9.250	0.957	0.479	0.413
Intermediate	7.875	1.069	0.338	8.813	1.463	0.732	0.204
Final	8.125	0.586	0.185	8.938	0.826	0.413	0.058
Overall grade	8.215	0.525	0.166	8.962	0.994	0.497	0.085

Table 2: General results of Kruskal-Wallis and ANOVA in experimental group using mobile devices

The grades average of students who used their mobile device are higher in the three evaluations and in the final mark than those of students who did not use their mobile device. However, there is not statistical significance in none of the cases, so we cannot say that using a mobile device influences the obtained grades.

5.3 Attitudinal survey

The students of the experimental group were asked by a satisfaction questionnaire with the questions of Table 3. All questions were answered with values from 1 to 5 (Likert scale), indicating the level of agreement with each question (1 = Do not agree, 5 = Completely agree). This instrument has previously been used by other authors in different surveys [Garrido, 08][de-Marcos, 10]

Question	Average	Std. Dev.	Std. Err.
Q1: The learning content has been showed with efficiency.	4.250	0.965	0.279
Q2: I have learned about the subject.	4.250	0.622	0.179
Q3: I have enjoyed the experience.	3.583	0.793	0.229
Q4: Using the tool has been easy.	4.417	0.996	0.288
Q5: The practical exercises proposed have been easy.	4.333	0.651	0.188
Q6: The amount of proposed exercises has been enough.	3.583	0.996	0.288
Q7: Time for doing the exercises has been enough.	3.750	1.055	0.305
Q8: I have been involved.	3.9167	0.2887	0.0833
Q9: I would like to learn more about the subject.	4.167	0.718	0.207
Q10: I liked the learning experience.	4.167	0.937	0.271

Table 3: Descriptive statistics results of the satisfaction questionnaire

Table 3 shows the descriptive statistics results of the satisfaction questionnaire. The average for each question is above 3.5 (between 3 “Undecided” and 4 “Agree”). Questions Q3 and Q6 have the lowest average and Q4 the highest average. The system used for the experiment was a prototype with a no very polished interface, so it may explain the result in Q3. With respect to Q6, in future courses the amount of practical exercises should be increased. On the other hand, despite the prototype used the students considered the system was easy to use, explaining the result of Q4.

A multivariable analysis returns a Cronbach’s Alpha = 0.6257 (<0.7) so, although it is lower than 0.7, the degree of internal reliability (of the questionnaire) is high, suggesting that all questions measure the same.

6 Conclusions

The experimental group (students that used the adaptive system) obtained better grades than control group (students who used a traditional system) in three out of four evaluations performed (intermediate assignment (p = 0.096), final assignment (p = 0.025) and overall grade (p = 0.010)). Students in the experimental group did not have statistically better grades in the evaluation test (p = 0.255 (>0.1)), suggesting that this kind of systems are not good for learning theoretical contents. Focusing on overall grade, which is composed of grades obtained in the other evaluations, we have analyzed that in this case there is statistical significance (p = 0.010), so we could conclude that, in general, the method used (adaptive or not adaptive) influences the grades obtained.

Therefore, the first hypothesis proposed (learning performance will be higher when using the adaptive system than when using the traditional e-learning system) is partially accepted, depending on the evaluation we are talking about.

Regarding the second case analyzed (students who used their mobile devices), we cannot say that using a mobile device in an adaptive system provides higher marks than using other type of device because there is not statistical significance ($p < 0.05$) between the cases studied. However, the average of grades obtained by students who used a mobile device was higher than students who used other devices. Maybe it would be interesting to repeat this study with a greater number of students, because it might be that these results are not statistically significant because only 4 users in the experimental group used their mobile device to access the system.

The second hypothesis (learning performance will be higher in students who use a mobile device than students who use other devices) cannot be accepted with the results obtained in the experiment carried out.

Finally, the attitudinal survey showed an average of 4.250 (value between 4 "Agree" and 5 "Completely agree"), so in conclusion the experience was gratifying for students who participated in the study, despite being a prototype.

In future we plan to carry out new experiments and case studies in other subjects and courses on different levels of education (secondary school, undergraduate courses, postgraduate courses, etc.) in order to determine whether adaptive systems and the mechanism of adaptation contribute to improve the grades of the students.

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