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EMPIRICAL EVALUATION OF AN ADAPTIVE E-LEARNING SYSTEM AND THE EFFECTS OF KNOWLEDGE, LEARNING STYLE AND MULTIMEDIA MODE ON STUDENT ACHIEVEMENT

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ABSTRACT

This paper presents an empirical evaluation of an adaptive e-learning system (AES). The system was evaluated in an experimental research. During the 9 weeks of experimentation, the students studied the learning material in two randomly allocated groups, an experimental group using the AES and a control group using the non-AES. Research findings are described as follows. Students who learned using the AES performed better significantly than those who learned using the non-AES. The implementation of test repetition as a function of knowledge adaptation in the AES increased student achievement significantly. When the effect of test repetition was removed, the implementation of learning style and multimedia mode adaptation in the AES was still found to have significant effect upon student performance. Students whose learning style and multimedia preferences were matched with the system achieved better results.

1. INTRODUCTION

Empirical studies have shown that individual one-on-one tutoring is the most effective mode of teaching. Individual tutoring allows learning to be highly individualized and consistently yields better outcomes than other methods of teaching (Hock, Pulvers, Deshler, & Schumaker, 2001). Because individual tutoring logistically and financially is impossible for all students in a traditional classroom situation, numerous kinds of computer programs have been developed for teaching.

The advances of web technologies have boosted development of new learning experiences for students. One of the first types of web application for delivering instruction via the Internet was web-based instruction or e-learning. Benefits of e-learning are both classroom and platform independence. In many current web-based courses, the course material is still implicitly oriented for a traditional on-campus audience consisting of homogeneous, well prepared and well motivated students.

Normally web-based courses are used by a much wider variety of learners than any campus-based courses. These learners may have very different goals, backgrounds, knowledge levels and learning capabilities. A web-based course designed for a specific group of users, like a traditional course, may not fit other users. Therefore the course material needs to be flexible so that different students may get different materials and an order of presentation that depends upon their own characteristics. Adaptive e-learning systems try to solve these problems by altering the presentation of material to suit each individual student.

This paper focuses on the evaluation of an adaptive e-learning system (AES) through an experimental research. The system was developed by incorporating three distinct characteristics such as *knowledge*, *learning style*, and *multimedia mode*. A separate non adaptive e-learning system (non-AES), identical to the adaptive system except for the absence of adaptation to individuals, was developed in parallel as a control.

2. ADAPTIVE E-LEARNING

Adaptive e-learning is a recently established area of research integrating technologies of CAI, ITS and hypermedia systems (Pilar da Silva, Van Durm, Duval, & Olivié, 1998). There are at least two reasons driving the advances of adaptive e-learning. First, e-learning applications are typically used by much more heterogeneous users than any standalone computer-based learning application. Any web-based learning system that is designed for a specific group of users may not suit other users. Second, generally the user of web based courses is working without any assistance from teachers, as would be the case in a traditional classroom situation.

The term *adaptive* is often confused with *adaptable*. Systems that adapt to the users automatically based on the system's assumptions about user needs are called *adaptive*. Systems that allow the user to change certain system parameters and adapt their behaviour accordingly are called *adaptable* (Oppermann, Rashev, & Kinshuk, 1997). An important characteristic of adaptive systems, identified by Jameson (2001), is that the systems adapt their behaviour to each individual user on the basis of non-trivial inferences

from information about that user. The adaptivity is limited by non-trivial inferences to exclude straightforward trivial adaptations that are usually adopted by all kinds of systems.

The systems that have only these trivial adaptations are called adaptable and not adaptive. Adaptable systems are not based on intelligent algorithms that infer how to adapt on their own. They just offer a flexibility to change the interface or the behaviour manually according to user needs or preferences. According to Cristea and De Bra (2002), the lowest level of intelligence for web-based instruction is to have some adaptable features, i.e. the user has some options that will determine some alterations to the aspect, contents or functionality of the web material. These static adaptable features are classified as adaptability.

On the other hand, compared to adaptability, *adaptivity* represents a more advanced step towards artificial intelligence. The actual capability of adaptive systems is to adapt automatically to the new conditions that are usually deduced from the user model (Cristea & De Bra, 2002). In comparing adaptable and adaptive systems, Totterdell and Rautenbach (1990) define an adaptable system as a system that provides users a capability to make an explicit change to the system, and an adaptive system as a system that monitors user interactions, stores user profile and presents information based on user progress and understanding. According to Papanikolaou et al. (2003), in designing an AES, it is important to implement both adaptivity and adaptability.

Adaptive e-learning technology is actually a combination of two distinctive technologies of hypermedia and adaptive systems. According to Brusilovsky (1996) adaptive e-learning can be defined as all hypertext and hypermedia systems that accommodate some user characteristics into the user model and apply this model to adapt various visible aspects of the system to the user. Three key components of adaptive e-learning are hypertext/hypermedia, user model and ability to adapt the hypermedia using the user model.

3. RESEARCH METHOD

The developed AES was evaluated in an experimental research involving 67 undergraduate engineering students in the Department of Electronics at Yogyakarta State University. The learning material of Analogue Electronics was implemented into both the AES and non-AES under seven chapter headings. The experimental design was based on a randomized pretest-posttest control group design. A random assignment technique was used to assign every student into either group in order to equalize the comparison groups. Employing this design minimized possible threats to internal validity such as history, maturation, instrumentation, regression, and selection.

During the 9 weeks of experimentation, the students studied the learning material in two randomly allocated groups, an experimental group using the AES and a control group using the non-AES. A pre-test was administered to measure initial student knowledge. The student achievement was measured at the end of each chapter of material using a chapter test and at the end of the experimentation as a whole using a post-test. Basic statistical analysis of t-test and Mann-Whitney U were conducted to investigate any difference of student achievement between the two groups. A further detailed analysis using multilevel modeling was conducted to investigate any possible effects of the adaptive parameters on the student achievement. A total of 7 hypotheses were tested during data analysis.

4. EVALUATION RESULTS

4.1. Main effect

The main effect of the independent variable manipulation on the student achievement was evaluated through the Hypothesis #1. The rejection of the null Hypothesis #1 concluded that students who learn the learning material of Analogue Electronics in the AES achieve higher post-test scores than those who learn the same material in the non-AES.

De Bra (2000) criticized that non adaptive systems were often generated from adaptive ones by simply disabling all adaptive features leading to a crippled version of applications and thus to unfair comparison because the non-adaptive version is not well designed and puts the student at a disadvantage from the start. This study addresses this issue by developing both the AES and non-AES separately from the beginning. The non-AES was not automatically generated from its counterpart, but was designed in accordance to the same instructional principle as the adaptive system was. The content material, exercises and tests are exactly the same in the two systems.

The basic analysis was only able to show the main effect of the experimental treatment on the students' post-test scores and it did not identify the contributing factors that influenced this effect. A further analysis using multilevel modeling was therefore undertaken to investigate the effects of *knowledge*, *learning style* and *multimedia mode* on the student's achievement. Instead of measuring students achievement at the beginning and the end of learning process for the main effect analysis, data for the multilevel analysis was collected every week of the experimental period over seven consecutive weeks where within each chapter (week) individual students may repeat the test several times.

4.2. Knowledge adaptation

Presentation of the learning material in the AES was adapted to the student knowledge. At the first learning

session when the level of student knowledge is assumed to be low, the system presents the Chapter 1 material and does not allow the student to access any further chapters. The system then tests the student knowledge after the student has learned at least 80 % of the material in Chapter 1. If the student obtains a satisfactory test result form the current chapter, then the student is allowed to access the next chapter. Otherwise, the system presents recommendation links that are suitable for the level of attained knowledge. The student needs to either repeat the learning material or redo the test until s/he exceeds the minimum scores required for that chapter. When the student exits the session and re-enters at a later time, the system will recommend that the student access Chapter 2 if the student has mastered Chapter 1.

Effectiveness of the *knowledge* adaptation to increase the student scores was evaluated using Hypothesis #2. The multilevel modeling was started by building the first model and moving forward until the optimum model was obtained. In order to eliminate the influence of *learning style* and *multimedia mode*, the variables of these aspects were not included. The hypothesis testing showed that there is enough empirical data to reject the null hypothesis at the significance level of $p = 0.05$. Therefore, it is concluded that students who study using the AES have higher test score significantly at $p = 0.05$ than students using the non-AES because the adaptive e-learning system adapts to knowledge as implemented by test repetition.

4.3. Learning Style and Multimedia adaptation

The AES presents the learning material either globally (*global mode*) or sequentially (*sequential mode*), depending on the student's learning style tendency. In the *global mode*, the student can jump to any page of the learning material within the chapter currently being studied. In the *sequential mode*, the student can only move one page forward and backward by clicking the appropriate navigation button. The system provides additional multimedia features depending on the student's tendency toward visual or verbal learning. For a student who has a greater tendency towards visual learning, the multimedia features will be enabled. On the other hand, for a student who has a greater tendency towards verbal learning, the multimedia features will be disabled.

Students in the AES group have the advantage of access to four different combinations of *learning style* and *multimedia mode*, i.e. global with multimedia, global with non-multimedia, sequential with multimedia and sequential with non-multimedia. The combination of learning style and multimedia mode is here called *learning mode*. Since the *learning mode* in the non-AES is fixed, students using this system are presented the learning material sequentially with no multimedia. However, in order to make a fair comparison between systems, Hypothesis #3 was proposed to examine the effect of knowledge adaptation by equalizing the setting of learning mode for both groups. Having performed the multilevel analysis, it was concluded that the null hypothesis should be rejected at the significance level of $p = 0.05$. Even though students in both groups learnt the material using the same learning mode, the AES students performed better than the non-AES students. Therefore, the knowledge adaptation itself contributed to the improved performance of the AES students.

Hypothesis #4 was proposed to examine the effect of learning mode adaptation without considering the influence of knowledge adaptation i.e. by analyzing test scores of the first try only. When students in the AES group were doing the test for the first time, they had not benefited from using material modified from knowledge adaptation. From the hypothesis testing, it can be concluded that students who learn using the AES will have higher test scores than students using the non-AES even though no test repetition is considered in both systems. Therefore, the learning mode adaptation itself contributed to the improved performance of the AES students.

4.4. Learning Style and Multimedia Suitability

It is known that a mismatch between student learning styles and the way the material is presented can lead to poor student performance. Students whose learning styles and multimedia preferences are not suited to the system's learning mode may therefore have learning difficulties leading to low test scores.

Hypothesis #5, which states that "Students who study the learning material in the non-AES in which their actual learning mode preferences are suited will achieve higher test scores than those who study the same material in the same system in which their preferences are not suited", was proposed to examine this assumption. The multilevel modelling results suggest that there is enough empirical data to reject the null hypothesis at the significance level of $p = 0.05$. Therefore, students who learn using the non-AES in which their actual learning mode preferences are suited will have higher test scores than students using the same system in which their preferences are not suited.

In the AES, the learning mode can be adapted to the students' learning preferences. Students needed to fill out questionnaires in order for the system to acquire knowledge of their learning mode preferences; the system then presents the learning material accordingly based on the preferences. However, not all students originally filled out the questionnaires. As a consequence, the learning mode of the AES may not match their preferences. Hypothesis #6 was therefore proposed. This states that "Students who study the learning material in the AES in which their actual learning mode preferences are suited will achieve higher test scores

than those who study the same material in the same system in which their preferences are not suited." The analysis results concluded that the null hypothesis was rejected at the significance level of $p = 0.05$.

A number of researchers have investigated the improved performance of students whose learning styles matched the presentation mode. Ford and Chen (2001) have found a significant difference in performance on conceptual knowledge for students learning in matched and mismatched conditions. Performance in matched conditions was significantly higher than that in mismatched conditions. Bajraktarevic et al. (2003) has suggested that significantly higher results were obtained for the matched session compared with the mismatched session.

Hypothesis #7 was proposed to determine whether or not the match between student preference and the system learning mode is important regardless of the adaptation features of the system. This states that "Students who study the learning material in the non-AES in which their actual learning mode preferences are suited will achieve equal test scores to those who study the same material in the AES in which their preferences are suited." The analysis results show that the students in the non-AES group in which their actual learning mode preferences are suited have equal test scores to students in the AES group in which their preferences are suited. In other words, students with preferences matched in either system performed equally well.

In terms of the relative merit of each contributing factor toward a student's achievement, the order of the effects was found to be (1) knowledge, (2) multimedia, and (3) learning style. Whilst repeated knowledge testing is an established cause of improved performance, the positive effects on student performance of using multimedia artifacts over choice of learning style is a new finding.

5. SUMMARY

Results of the empirical evaluation can be summarized as follows:

1. Students in the AES group have significantly higher post-test scores than those in non-AES group.
2. The increased performance is due to knowledge adaptation as implemented in test repetition when the effects of *learning style* and *multimedia mode* are removed.
3. The implementation of *learning style* and *multimedia mode* adaptation in the AES has significant effects on the student's performance. Even though the effect of the test repetition is removed, the AES still performs better.
4. Within either AES or non-AES group, students whose preferred *learning style* and *multimedia mode* match the system presentation perform better than those whose preferred *learning style* and *multimedia mode* mismatch the system. This indicates that regardless of the systems, students have better achievement when their *learning style* and *multimedia mode* preferences are matched with the system settings.
5. Relative merit of each contributing factor toward the student's achievement can be ordered as follows: (1) knowledge level, (2) multimedia mode, (3) learning style.

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