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ABSTRACT

Multimedia technology is increasingly being used as a complementary way of delivering instruction. To find out whether the use of a multimedia-interactive system is able to help the students to better learn complex issues such as Data Structures, this article describes an exploratory study comparing the effect of using three different teaching approaches, such as traditional teacher-led instruction, Web pages and a multimedia-interactive system. Descriptive statistics and ANOVA test results show that there are significant differences in students' performance using multimedia. It is concluded that multimedia can effectively be used to help students learn data structures specifically binary trees.

INTRODUCTION

Learning data structures is a complex issue for many students (Hartmann & Hopcroft, 1971; Martí, Ortega, & Verdejo, 2003; Peña, 2005). Complexity is defined as a problem that can has several solutions (Rodriguez, 2000). Some complex problems in the computational area are: teaching programming (Wiedenbeck & Kain, 2004), algorithms (Jain, 2005) and data structures (Brookshear, 1993), among others. The major problem in teaching data structures has been the difficulty of capturing the dynamic nature of the material (Karavirta, Korhonen, & Stalnacke, 2004).

Previous studies of teaching data structures are classified based on their interactivity such as tutorials with hypertext (Martí & Palomino, 2005; Warendorf, 1997), websites or Web pages (Del Puerto & Ruiz, 2002; Pita & Del Vado, 2007) and interactive systems (Karavirta et al., 2004; Park & Hannafin, 1993).

Interactive multimedia has the potential to revolutionize the way we work, learn and communicate (Stemler, 1997). Although interactive multimedia is related to traditional and computer-aided learning systems, many of its aspects are arguably different from sequential media and computer-based instruction, as well as from hypertext (Park & Hannafin, 1993). There is evidence in previous studies (Bagui, 1998) showing that, in some cases, computer-based multimedia can help people assimilate information better than traditional classroom lectures.

Even though the subject of learning data structures has been studied under different situations, not many multimedia-interactive systems are specifically designed to teach binary trees, so the goal of this exploratory study was to statistically prove the effects of learning using a multimedia-interactive system, specifically in the topic of binary trees (data structures), and find whether students exposed to this technology (in a limited time frame) show better academic performance. Thus, our hypothesis is as follows: "Multimedia technology is a better teaching approach to teach complex subjects compared to a traditional and Web page approaches".

METHODOLOGY

We conducted an exploratory study using three groups in the Autonomous University of Aguascalientes (UAA), México. Each group was formed by thirty students: one, using traditional instruction methods (TG), other using Web pages (WG), and the other using a multimedia-interactive system (MIG). Ninety undergraduate Computer Science students taking the Data Structures course were invited to participate in the study. At the moment of the study, all students had passed the basics in programming languages (sequence, decisions, loops, pointers and dynamic memory) and the basics in data structures (arrays and structures). Participants were randomly assigned to the groups. The content was focused on the subject of binary trees. This subject was selected because it coincided with the literature as a topic that is difficult to students learn (Martí et al., 2003; Peña, 2005) and the failure rates that students have from the University.

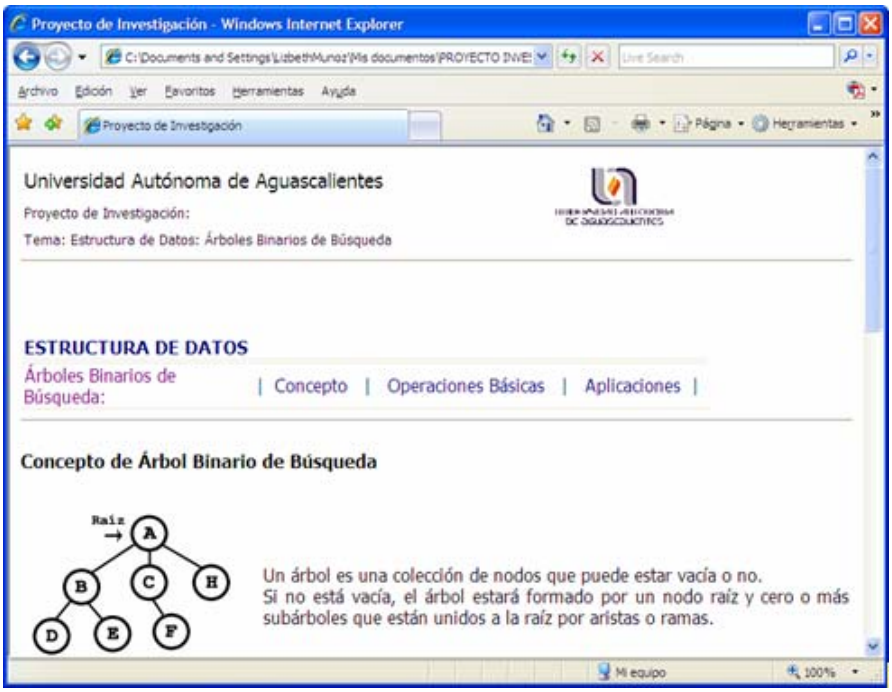
In order to control teaching styles differences, all groups were taught by the same professor. Participants received the same lecture, examples and exercises so that teaching materials differences were controlled. In addition, participants had feedback from the instructor. In order to measure whether participants learn about the subject, the same test was applied before and after the lecture.

Description of the Learning Material

For our study, the material was adapted to a Spanish speaking audience. For the traditional instruction group the learning material consisted on a simple text with some images as examples; the material was presented in PDF format. The Web pages interface (see Figure 1) consisted primarily of text to show information about the topic, some images as examples and hyperlinks for navigation to go forward and backward through the material (Shiavi, Brodersen, Bourne, & Pingree, 2000). An important issue of this Web page was the absence of multimedia elements (Boyle, 1997; Najjar, 1996). The multimedia-interactive system (see Figure 2) kept the same content of the Web page and it included examples and interactive exercises.

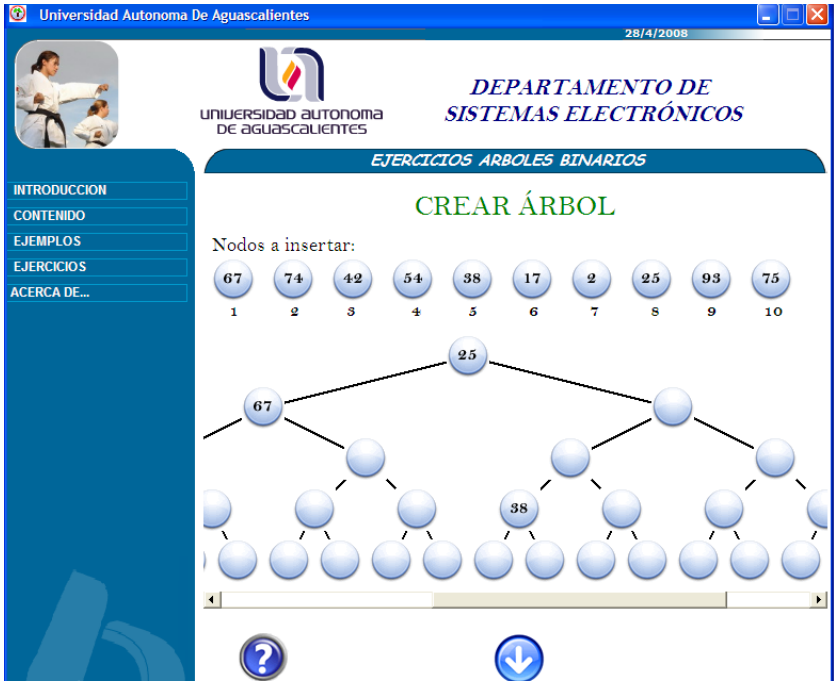
A more detailed description of the material used in the study is required. The Figure 1 shows the Web page used in the study. It shows general information such as name of the University, menu options and topic. The Web page contains hyperlinks to navigate through the information and examples (Shiavi et al., 2000). The information is shown by text and images. There is no animation and interactivity in the Web page (Fowler, 1980), in this case the instructor has to check and evaluate the students' exercises.

Figure 1: Web page to teach binary trees.



The multimedia-interactive system (see Figure 2) kept the same content of the Web page: text and images that shows the general information about the topic. There are some interaction differences: animation and sounds as explanatory sections of each topic (insertion, deletion and searching nodes) (Fulton, Glenn, & Valdez, 2004). Also, this system includes interactivity where students had the ability to answer interactive exercises by moving data and images (Bosco, 1986; Fletcher, 1990). Finally, an output section to show the exercises results to students is included (Almeida, Blanco, & Moreno, 2003; Karavirta et al., 2004). In this case the instructor does not check and evaluate the students' exercises, the system does this activity.

Figure 2: Multimedia-Interactive System to teach binary trees.



Description of the Test Results

In order to avoid the effect of stress and anxiety, students were asked to answer a written test. In both cases (before and after the study) the test consisted of two sections:

Section I. This section had four multiple choice questions to evaluate theoretical concepts. Each question had value of one point. This section was formed by the following questions:

- Concept of binary tree
- Concept of depth
- Concept of degree
- Type of operations that can be performed with binary trees

Section II. This section had three exercises to demonstrate the knowledge acquired about node insertion, node deletion, and searching for data into a binary tree. Each exercise had value of two points. The scoring criteria for this section had the following aspects:

- To insert nodes (in an empty binary tree, in a binary tree with nodes).
- To delete nodes from a binary tree.
- To search a node (pre-order, in-order and post-order)

The complete test was to sum up a total maximum score of 10 points (4 points in Section I and 6 points in Section II).

Conditions for All Study Groups

In order to control technological differences, all groups received the lecture in the same computer laboratory classroom. Each group received the same lecture about binary trees topic, same examples and exercises, all groups had individual free time to study/use the corresponding learning materials, and had time to make questions and receive feedback from the instructor. Finally each group had to answer a written test. Times were recorded for each section: Instruction from the teacher (lecture): 20 min, examples and exercises: 30 min, individual free time for students: 15 min, time for doubts and feedback: 15 min, and time to answer the test: 60 min.

Before the experimental sessions, a test was applied to each group *(TG, WG, MIG)*, as a reference about previous knowledge of the subject. This test had a 60 minutes limited.

Conditions for Each Study Group

For the traditional group (TG) the instructor gave the lecture using a projector and a PDF file as a learning media, in this case participants had to solve written exercises. In the Web page group (WG) the instructor gave the lecture using a projector and a Web page as learning media, in this case participants had to solve written exercises. For the multimedia-interactive group (MIG) the instructor gave the lecture using a projector and a multimedia-interactive system as learning media, in this case participants did not to solve written exercises.

RESULTS

As mentioned earlier, one test was applied to participants (before and after). Table 1 shows descriptive statistics obtained from test results. Tests were graded using from 0 to 10 scales. TG mean increased an overall 20%. WG mean increased an overall 10%. MIG mean increased an overall 23%. Based on these results, it can be argued that any teaching approach contributed to the overall knowledge. In all groups a reduction in standard deviation can be observed, which means results were less dispersed.

Table 1: Descriptive statistics of the study.

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	BEFORE_TG	4.679	30	3.1041	.5667
	AFTER_TG	6.583	30	1.4025	.2561
Pair 2	BEFORE_WG	5.666	30	2.6238	.4790
	AFTER WG	6.533	30	1.5365	.2805
Pair 3	BEFORE MIG	5.001	30	2.7015	.4932
	AFTER_MIG	7.353	30	1.0925	.1995

In order to test whether groups were similar in knowledge acquired in previous courses, a standard ANOVA test was applied to the pre-lecture test (see Table 2). Results show that there are not significant differences (0.338), which mean that the three groups have similar knowledge and that participants' previous knowledge does not impact our study outcomes.

Table 2: Pre-lecture ANOVA test.

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	15.210	2	7.605	.958	.388
Within Groups	690.719	87	7.939		
Total	705.929	89			

In order to test whether teaching approach has an effect in performance, a standard ANOVA test was applied to results from the post-lecture test (see Table 3). Results show that there is a significant difference (p=.036) in the performance of the three groups.

Table 3: Post-lecture ANOVA test.

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	12.678	2	6.339	3.444	.036
Within Groups	160.123	87	1.840		
Total	172.801	89			

In order to identify which group has better performance, multiple comparisons tests were calculated (LSD and Dunett tests). Table 4 shows results obtained. In all cases MIG has the highest difference compared to TG and WG (e.g., LSD test: TG vs. MIG, sig=.031). These results support our hypothesis that multimedia technology is a better option in teaching complex subjects such as binary trees.

Table 4: Multiple comparisons after the study.

	(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
LSD	Traditional group (TG).	Web page group (WG).	.0500	.3503	.887	-.646	.746
		Multimedia-Interactive group (MIG).	-.7700*	.3503	.031	-1.466	-.074
	Web page group (WG).	Traditional group (TG).	-.0500	.3503	.887	-.746	.646
		Multimedia-Interactive group (MIG).	-.8200*	.3503	.022	-1.516	-.124
	Multimedia-Interactive group (MIG).	Traditional group (TG).	.7700*	.3503	.031	.074	1.466
		Web page group (WG).	.8200*	.3503	.022	.124	1.516
Dunnett t (2-sided)[a]	Traditional group (TG).	Multimedia-Interactive group (MIG).	-.7700	.3503	.056	-1.558	.018
	Web page group (WG).	Multimedia-Interactive group (MIG).	-.8200*	.3503	.040	-1.608	-.032

*The mean difference is significant at the .05 level

a. Dunnett t-test treta one group as control, and compare all other groups against it.

DISCUSSION AND FUTURE STUDIES

In this exploratory study three approaches to teach data structures specifically the topic of binary trees were chosen: traditional instruction (Najjar, 1996), Web pages (Almeida et al., 2003; Del Puerto & Ruiz, 2002; Pita & Del Vado, 2007; Shiavi et al., 2000) and a multimedia-interactive system (Stemler, 1997). Variables such as content, teaching style, written tests and time of exposure were controlled. One difference was that traditional group and Web page group made exercises in a written form while multimedia group made exercises through the system. The results of this exploratory study seem to indicate that the traditional group and Web page group did not show any significant differences in the performance of the participants. However, a multimedia group did show significant differences due to the combination of multimedia and interaction under specific conditions mentioned previously.

The field of multimedia-interactive systems can be benefited with more experimental studies measuring achievement, students' attitudes and completion time to give instructors a clearer vision as to under which circumstances this kind of systems can be more effective to academic performance.

For future studies we propose to develop and empirically test a multimedia-interactive system based on design principles (Najjar, 1996) with an emphasis on usability, and with an easy to use, fun and stimulating interface (Uden, 2000).

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