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Interactive Multimedia-Based E-Learning: A Study of Effectiveness

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The author conducted two experiments to assess effectiveness of interactive e-learning. Students in a fully interactive multimedia-based e-learning environment achieved better performance and higher levels of satisfaction than those in a traditional classroom and those in a less interactive e-learning environment.

A major limitation of some multimedia-based e-learning systems is that they do not support sufficient learner–content interaction and flexible learning process control (Zhang et al. 2004). Lack of sufficient control over instructional content can diminish potential learning benefits. Some systems simply post multimedia instructions without any processing or organization. They do not allow random content access. In such cases, e-learning is less likely to hold learners (Hammond et al. 1995; Hiltz and Wellman 1997). A key challenge is to provide learners with easy, intuitive, and fast access to the content.

Learning Theories and Interactivity

Leidner and Jarvenpaa (1995) categorize learning models into several categories: objectivism, constructivism, collaborative learning, cognitive information processing, and socioculturism. Among them, the constructivist learning model, which calls for learner-centered instruction, is the most commonly adopted in e-learning. Learning is an active process in which a learner uses sensory input and constructs meaning out of it, not a passive acceptance of knowledge that already exists. Constructivism em-

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phasizes active participation and reflection by learners, who should control the pace of instruction and construct knowledge by themselves. Constructivist learning always begins from a learner's point of view (Jonassen et al. 1995; Shang, Shi, and Chen 2001).

In a learner-centered environment, knowledge is constructed through highly interactive tasks. Interactivity is not simply a function of computer-based transaction but a fundamental success factor for teaching and learning in an online environment as well (Sims, Dobbs, and Hand 2002).

Moore (1989) defined three types of interaction in learning: learner–instructor, learner–learner, and learner–content. Learner–instructor interaction is a major factor accounting for cognitive learning (Bloom 1981). Learner–learner interaction fosters collaborative learning. In this article, learner–content interaction refers to any interactive activities between the learner and instructional content in an online learning environment. A growing body of literature has shown that interaction is a critical factor for learner satisfaction, higher levels of academic achievement, higher learner engagement, and a positive attitude toward distance education (Chapman, Selvarajah, and Webster 1999; Fredericksen et al. 2000; Fulford and Zhang 1993). Online learners should be able to control what content should be skipped or emphasized based on their own needs.

Although it is believed that high-level interaction is desirable and can positively affect learning (Berge 2002), research has focused mainly on learner–instructor and learner–learner interaction. It remains unproven that learner–content interaction improves the quality of multimedia-based e-learning. Therefore, this study concentrated on learner–content interaction. To the author's knowledge, there have been few empirical studies that investigate the effect of learner–content interaction on learning effectiveness in multimedia-based e-learning environments.

Development of Hypotheses

The major objective of emphasizing learner–content interaction in e-learning is to increase learner engagement and enhance learner control over the content and process. The higher interactivity an e-learning environment provides, the better learning performance students may achieve (Northrup 2001). The lectures designed and used in the study were prepared in exactly the same way for traditional classroom instruction and online learning. The Learning By Asking (LBA) system, a learner-centered and highly interactive learning environment, was used in this study. It presents integrated multimedia instruction and provides rich learner–content interaction, including media format selection and random access to multimedia instruction. According to previous research findings that (1) higher levels of interactivity are hypothesized to generate higher student performance (Merrill 1994), and (2) multimedia instruction can help maximize learners' ability to retain information and learner engagement (Chapman, Selvarajah, and Webster 1999; Syed 2001), the first hypothesis is as follows:

> H1: Given the same amount of learning time, students in an interactive multimedia-based e-learning environment can achieve higher test scores than those in a traditional classroom.

It is also common to assess learners' satisfaction levels with regard to their knowledge construction in learning environments (Alavi 1994). Therefore, it is important to assess students' satisfaction with such e-learning environments. Previous studies have reported mixed results. Some found that students were satisfied with e-learning (Amir, Iqbal, and Yasin 1999), whereas others revealed that students were less satisfied (Rivera and McAlister 2001). Previous research has shown that both multimedia instruction and high levels of interaction can lead to increased learner satisfaction (Piotrow et al. 2000). Interactive multimedia-based e-learning environments such as LBA (1) present multimedia instruction equivalent to what students can get in a traditional classroom, except immediate feedback from the instructor; (2) allow students to learn at their own pace and to proactively skip or repeat any specific portions of material; and (3) provide an easy-to-use and straightforward user interface, which tends to lead to positive responses. Therefore, the second hypothesis is as follows:

> H2: Students in an interactive multimedia-based e-learning environment will report higher levels of satisfaction than those in a traditional classroom.

Some e-learning systems are less interactive than others. For example, they do not provide learners with random content access and an ability to select a preferred content presentation format. Based on earlier discussion, it is believed that for an interactive e-learning environment, the capability of providing random access to learning material and selection of content presentation format are critical for getting students engaged, thus improving learning effectiveness. It can help students access the content of their interest in a much more effective way and be more comfortable with content presentation, which may also lead to better learner engagement. Therefore, the third and fourth hypotheses are generated as follows:

H3: Given the same amount of learning time, students in a multimedia-based e-learning environment that involves more learner–content interaction can achieve higher test scores than those in a less interactive multimedia-based e-learning environment.

H4: Students in a multimedia-based e-learning environment that involves more learner–content interaction will report higher levels of satisfaction than those in a less interactive multimedia-based e-learning environment.

The LBA System

LBA was developed with the aim of supporting just-in-time, multimedia-integrated, and interactive e-learning (Zhang and Nunamaker 2004). It integrates and synchronizes multimedia content, including instructional videos, PowerPoint slides, and lecture notes and provides all three types of interaction to learners. The LBA system works in the following way. Lectures are videotaped, and the instructional videos are logically, not physically, segmented into a number of individual video clips (i.e., a stream of contiguous frames uniquely identified by starting and ending time) based on their content, so that each clip focuses on a single subtopic. Videos, as well as other multimedia instructional material, are stored in a Web knowledge repository that can be accessed via the Internet. LBA provides participants with interaction and process flexibility. The learner's computer needs only a Web browser, a video player, and a sound card.

The *interactive e-classroom* in the LBA system was used in this study. In the experiments, the participants involved in an interactive e-learning group could see a video of the instructor, hear what he says, and read associated slides and lecture notes. Instructions in different media are synchronized. In other words, while an instructional video is playing, the LBA system automatically presents corresponding slides and notes. Video logic segmentation can be manipulated at different granularities. In this study, each clip was identified as a portion of the instructional video that explained an individual slide. If a participant did not do anything during the lecture session, the whole lecture would automatically "flow" from the beginning to the end. However, participants could perform various operations at any time to control their learning pace and content by pressing control buttons on top of that interface. For example, participants could click the "Next" button to skip the current video clip/slide/note, or press the "Prev" button to return to the previous subtopic. When a participant moved the mouse over the "Content" button, a pull-down menu would appear and display a hierarchical content index of this lecture. A participant could directly jump to any particular clip/slide/note by clicking a subtopic (i.e., random access to content).

Research Design

Two separate lab experiments were employed using the interactive e-Classroom subsystem in LBA as the e-learning environment to test the hypotheses. Because there has been extensive research on cooperative learning (Alavi 1994), the author concentrated on individual learning performance in this study. As a result, participants were not allowed to use e-mail or an online discussion forum to communicate with each other in the experiments.

There were three treatments in each experiment: the fully interactive LBA group, the less interactive LBA group, and the traditional classroom group. A total of 155 undergraduate students participated in the experiments (Table 1). Participants in the two experiments were different.

Many studies on learner control have used a single session as the unit of analysis (Reeves 1993). Others have employed a longitudinal field experiment (Piccoli, Ahmad, and Ives 2001). There is a trade-off between the two approaches. Although the second approach can mitigate a potential problem of the first approach, which the limited duration of experiments may be partially responsible for the lack of convergent findings (Reeves 1993), it has its own problems. For a longitudinal experiment, it would be difficult to

Table 1. Participation by Groups

	Groups	Group Size	Lecture Topic
	Fully interactive LBA	17	
Experiment 1	Less interactive LBA	17	Relational algebra
	Traditional classroom	17	
	Fully interactive LBA	35	
Experiment 2	Less interactive LBA	35	Internet search engines
	Traditional classroom	34	

Note: LBA = Learning By Asking.

control and monitor learning activities of participants. For example, few longitudinal studies have been able to report or compare the learning time spent by online students and by traditional classroom students. If e-learning students were to spend more time mastering knowledge than traditional classroom students, even though their test scores may not differ significantly, e-learning would not be considered as effective as classroom learning. Therefore, both experiments used a single lecture session rather than an entire semester.

Experiment 1

Fifty-one undergraduate students (56.9% were male, average twenty-one years old) participated in this experiment. They were either sophomores or juniors recruited from an introductory database course at a large public university in the United States. Each group was then randomly assigned to one of three treatments. From a preliminary survey completed by participants two weeks before the experiment, participants' demographic information such as age, computer proficiency, and prior experience of e-learning was collected. There was no significant difference among three groups on those dimensions. None of the participants had previous e-learning experience.

The lecture topic used in this experiment was relational algebra, which was listed in the course syllabus. So the problem of asking participants to learn a subject matter that was out of their course context or did not have real consequences for them was avoided. The instructor who gave the lecture to the classroom group also prepared online instructions in advance, including a videotaped lecture.

The traditional classroom group had the lecture in a regular classroom, but participants in the two e-learning groups were asked to participate in experiments in a research laboratory. Each participant in e-learning groups had his or her own computer with a headphone so that he or she could listen to the soundtrack of the video without disturbing others.

Although participants in both e-learning groups took the lecture using the interactive e-Classroom of the LBA system, they had different system setups. The primary difference between the two e-learning groups was the level of learner–content interaction. Students in the fully interactive e-learning group were able to use control buttons to perform random access to content. In addition, at any time during a session, they could select a preferred format for content presentation, such as "video + slides," "video + slides + lecture notes," "audio + slides," and "slides + lecture notes." For the less interactive LBA group, the system did not provide control buttons. If participants wanted to locate a piece of information, they had to sequentially go through the material in order to find it. Besides, the function of media format selection was disabled. Students could use only the default interface, which displayed video, slides, and lecture notes.

In the experiment, participants in both e-learning groups went through the same procedure as follows:

1. Brief description of experiment's objective and procedure. At the beginning of each session, the objective and procedure of this experiment were introduced to all participants, who were also informed that they would be given up to five extra course credits for participating in the experiment.
2. Pretest. Next, participants were required to answer a number of questions in a written test. Those questions covered basic concepts about the subject matter that the lecture would be introducing to examine how much a participant already knew about the topic.
3. The LBA system training. Then, participants were given a brief live demonstration on how they could take an online lecture using the LBA system. They were also given an opportunity to familiarize themselves with the system. No participant reported any difficulty with the system.
4. Online lecture session. After all participants understood how the system worked, they were given forty-five minutes to watch the online lecture. The instructional video lasted about twenty-seven minutes. This gave participants some time to review learning material before the next step.
5. Posttest and questionnaire. At the end of each experiment, participants were given another written exam. The questions in the posttest were similar but, as opposed to the pretest, more specific and difficult. After the test, each participant was also required to fill out a questionnaire to assess his or her perceived satisfaction and provide feedback on the system and learning experience.

Both pretests and posttests were closed book, closed notes. During online lecture sessions, participants could take notes, but were not allowed to communicate with each other, thus eliminating the influence of peer interaction on participants' performance. The potential test scores ranged from zero to fifteen. The duration for the online lecture session and tests was constant for both e-learning groups. The classroom group was given the same lecture during the regular class time by the same instructor. The content of the classroom lecture was well controlled by the instructor to ensure its consistency with that of the online lecture. Participants in the classroom group went through a procedure similar to that in the e-learning groups, except steps three and four were replaced by a forty-five minute regular in-class lecture and a review session. They were allowed to ask questions during the lecture.

The individual learning performance was measured by the margin between individual posttest scores and pretest scores. Two graduate teaching assistants who were not involved in this research graded the pretests and posttests. In the questionnaire, participants were asked to provide their satisfaction levels on learning effectiveness using a seven-point Likert scale, ranging from 1 (*extremely dissatisfied*) to 7 (*extremely satisfied*).

Pretest and posttest scores of each group are shown in Table 2 (the numbers in the brackets indicate how many students achieved that score). There was no significant difference among the three groups in terms of pretest scores ($F(2, 48) = 0.01$, $p = .991$). Table 3 shows the means and standard deviations of dependent variables of the three groups.

The results of a series of independent-samples *t* tests are reported in Table 4, showing that students in the fully interactive e-learning group achieved significantly better performance and higher levels of satisfaction than those in the less interactive e-learning group and traditional classroom. Therefore, the findings in this study have positively supported all four hypotheses. Based on the system log, five students in the fully interactive LBA group changed the content presentation format from the default setup (video + slides + lecture notes) to another one. The LBA system also captured every (control) button click by each participant in the fully interactive e-learning group, which indicated that every participant had performed random content access (mean: 8.6 times per participant; min: five; max: eleven).

Experiment 2

The second experiment was conducted one month after the first one was finished. It inherited exactly the same treatment, procedure, and measure-

Table 2. Minimum, Maximum, and Mean Scores of Pretests and Posttests

	Pretest Scores			Posttest Scores		
Treatment	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**
Fully interactive LBA	0 (3)	4 (3)	1.78	8 (1)	15 (2)	12.35
Less interactive LBA	0 (2)	6 (1)	1.82	7 (1)	14 (2)	10.41
Traditional classroom	0 (2)	4 (4)	1.76	8 (2)	14 (1)	10.47

Note: LBA = Learning By Asking.

Table 3. Means and Standard Deviations of Dependent Variables

	Learning Performance (Learning Gain)		Satisfaction	
Treatment	***M***	***SD***	***M***	***SD***
Fully interactive LBA	10.88	2.29	6.18	0.88
Less interactive LBA	9.82	2.21	4.65	1.00
Traditional classroom	9.24	2.14	4.88	0.96

Note: LBA = Learning By Asking.

Table 4. Results of Independent-Samples *t* Tests

Dependent Variables	Group (I)	Group (J)	*t*	*d.f.*	Sig. (One-tailed)
Learning performance	Fully interactive LBA	Less interactive LBA	2.805	32	.004**
		Traditional classroom	2.666	32	.006**
Satisfaction	Fully interactive LBA	Less interactive LBA	3.961	32	.000**
		Traditional classroom	4.308	32	.000**

Note: LBA = Learning By Asking.
**$p < 0.01$.

ment used in the first one but with a doubled group size, a different lecture, and different participants (see Table 1). There were 104 undergraduate students recruited from several departments at the same university who were taking an introductory course to management information systems. They were randomly assigned to one of three groups: fully interactive LBA group (thirty-five), less interactive LBA group (thirty-five), and traditional classroom group (thirty-four). 59.6% of participants were male. There was no significant difference found among the three groups in terms of learner characteristics, and none of the participants had prior e-learning experience.

The lecture topic used in the second experiment was about Internet search engines, which was a part of the Internet technology chapter listed in the course syllabus. Again, the instructor (different from the instructor in the first experiment) who prepared for the online material also gave the in-class lecture to the classroom group. The pretest and posttest scores ranged from zero to fifty. Two experts who were not in the research group helped grade the pretests and posttests.

Minimum, maximum, and mean scores of pretest and posttest are shown in Table 5. Similarly, no significant difference among the three groups in terms of pretest scores was found ($F(2, 101) = 0.787$, $p = .458$). Table 6 shows the means and standard deviations of dependent variables of three groups. The results of several independent-samples *t* tests are reported in Table 7.

Results showed that participants in the fully interactive e-learning group achieved significantly better performance and higher levels of satisfaction than those in the less interactive e-learning group and the traditional class-

Table 5. Minimum, Maximum, and Mean Scores of Pretests and Posttests

	Pretest Scores			**Posttest Scores**		
Treatment	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**
Fully interactive LBA	0 (2)	18 (1)	8.06	31 (1)	50 (1)	42.20
Less interactive LBA	0 (3)	17 (2)	7.43	28 (1)	45 (2)	35.09
Traditional classroom	0 (2)	20 (1)	8.62	23 (3)	48 (1)	32.29

Note: LBA = Learning By Asking.

Table 6. Means and Standard Deviations of Dependent Variables

	Learning Performance (Learning Gain)		**Satisfaction**	
Treatment	***M***	***SD***	***M***	***SD***
Fully interactive LBA	34.14	8.87	6.46	0.56
Less interactive LBA	27.66	8.85	5.94	0.84
Traditional classroom	23.67	8.79	5.03	0.67

Note: LBA = Learning By Asking.

Table 7. Results of Independent-Samples *t* Tests

Dependent Variables	Group (I)	Group (J)	*t*	*d.f.*	Sig. (One-tailed)
Learning performance	Fully interactive LBA	Less interactive LBA	3.062	68	.003**
		Traditional classroom	5.796	67	.000**
Satisfaction	Fully interactive LBA	Less interactive LBA	2.657	68	.005**
		Traditional classroom	7.234	67	.000**

Note: LBA = Learning By Asking.
**$p < 0.01$.

room. Therefore, all four hypotheses were supported again in the second experiment. During this experiment, seven students selected a content presentation format different from the default setup. The average number of random content access was 7.3 times per participant.

Implications and Future Research

This empirical study reveals that when a multimedia-based e-learning environment offers more learner–content interaction, learning performance and learner satisfaction can be improved. Although different participants and lecture topics were used, all hypotheses were consistently supported in both experiments. Most participants in the fully interactive e-learning groups commented that they especially liked the interactivity and flexibility that the LBA system provided.

There are several plausible explanations as to why fully interactive e-learning groups significantly outperformed traditional classroom groups. In a traditional classroom setting, learning is instructor-centered and is a sequential process. The instructor controls content and learning pace. Most students do not question or ask for repetition in the class even if they do not understand instructors. In addition, they do not have an opportunity to listen repeatedly to what instructors explained. An interactive multimedia e-learning environment such as LBA enables learner-centered activities and provides necessary learner–content interaction. Another possible reason is that both lectures used were technology-related topics, which are relatively structured and may be more suitable to e-learning. Finally, the participants in this study were adult learners. According to adult learning theory, such learners are more apt to commit to learning when goals and objectives are considered realistic and important to them. They benefit from having time to engage in both active and reflective modes. The fully interactive LBA group in this study may have had an opportunity for controlling those modes to a greater extent.

This study implies that to create effective learning, e-learning environments should provide interactive instructional content that learners can view on a personalized, self-directed basis. The simple conversion of existing paper-based multimedia instruction into its digital equivalent and making it available on the Internet will not lead to effective learning (Sims, Dobbs, and Hand 2002) due to a lack of an appropriate mix of content richness, interaction, and engagement.

As with any similar type of study, the reader should be mindful of limitations while interpreting the results. First, the scope of content dynamics in the study was relatively limited. It will be interesting to evaluate the learning effectiveness using different types of instructions. There appears to have been little research effort in this area. Second, student participants in e-learning groups might be more focused in the experiments than those in traditional classrooms due to the excitement, novelty, and potential interest in multimedia-based e-learning. Third, the experiments used single sessions for analysis. Finally, because the margins between pretest scores and posttest scores as individual learning gain were used (in both studies, every participant had a higher posttest score than his or her pretest score), the author did not use Analyses of Covariance (ANCOVA) by using pretest scores as the covariate. Given the very small p values found in the current report, the results of the ANCOVA should be very similar to what is already reported.

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