E-Learning in Hong Kong: comparing learning outcomes in online multimedia and lecture versions of an introductory computing course

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Abstract

This paper evaluates the effectiveness of Web-based, highly interactive, and multimedia-rich e-learning materials by comparing students' learning outcomes in the lecture and online versions of an introductory computing course. The course versions differed only in that face-to-face lectures were replaced with e-learning modules in the online course; the other course elements (laboratory sessions, use of computer-mediated communications, examinations) were the same. The e-learning trial took place at the Hong Kong University of Science and Technology, where the first author taught the lecture course to 105 students, and the online course to 180 and 129 students in the following semesters. The lecture and online students achieved comparable factual learning outcomes and the online students outperformed the lecture students in applied-conceptual learning. Findings suggest that the use of carefully designed interactive e-learning modules fosters higher-order learning outcomes.

Introduction

E-learning can be defined as using the Internet and Internet-related technologies in instructional development and distribution of educational resources. The Internet offers communication channels in the form of email, bulleting boards (discussion groups), and live chat. The World Wide Web provides a platform for displaying course materials as Web pages that may combine hypertext with downloadable files, graphics, animations, audio, and video. Web technologies enable human-computer interaction ranging from navigation to dynamically tailoring the displayed materials to fit student profile. E-learning tools and techniques have the potential to capture, and even enrich and individualize, the communications and interactions that normally take place in the classroom. In the wide variety of today's online courses, instructors are finding ways to supplement or replace traditional teaching methods and materials with e-learning,

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and are simultaneously assessing how these changes influence students' learning outcomes.

Distance e-learning courses, where students access the course materials through the Web and where the classroom communications are replaced entirely with computer-mediated communications, have resulted in lower but not statistically significant (Collins, 2000), comparable (Johnson *et al*, 2000; Parker and Gemino, 2001; Schulman and Simms, 1999; Wegner *et al*, 1999), and higher (Schutte, 1997; Zhang, 1998) student performance as compared to the corresponding lecture course. These results indicate that the combination of Internet communications and Web technologies yields positive learning outcomes.

Results are also emerging on the effectiveness of particular e-learning tools and technologies. Carswell *et al* (2000) found that using email and newsgroups versus using regular mail and telephone in a distance-learning course resulted in comparable learning outcomes. Coates and Humphreys (2001) found that practice with online quizzes and participation in bulleting board discussions correlated positively with performance in a lecture course, whereas Web-page navigation and reading of bulleting board postings ("lurking") did not. Gretes and Green (2000) found that supplementing a lecture course with online practice quizzes resulted in better performance on examinations. These results suggest that engaging computer-based and computer-mediated interactions facilitate learning, and therefore are key components of e-learning, as advocated by Bork (2001).

The Web platform facilitates the use of interactive multimedia where the user controls the navigation of materials that incorporate text, sound, and moving and still images. Herrington and Oliver (1999) observed higher-order thinking in students' talk when using an interactive multimedia program. Kettanurak *et al* (2001) found that interactivity positively influenced learners' attitudes, which, in turn, enhanced learner performance. Frear and Hirschbuhl (1999) observed that the use of interactive multimedia enhanced problem-solving skills. These studies provide evidence toward McFarland's (1996) conclusion that the proper use of interactive multimedia in tertiary education can lead to positive learning experiences and higher-order learning outcomes.

This paper reports on an introductory computing course that the first author taught once in lecture format and twice in online format at the Hong Kong University of Science and Technology. The lectures that in the lecture course were delivered in a lecture theater were substituted in the online course with Web-based, highly interactive, and multimedia-rich e-learning modules. Both lecture and online courses held weekly computer laboratory sessions. The reason for not adopting a full distance-learning model was to investigate the effect of replacing traditional lecturing with an e-learning experience while keeping the other course parameters constant. Furthermore, this online course was one of the first large-scale attempts at e-learning with Hong Kong Chinese students. The labs provided a weekly observation point of student reactions to the novel learning experience.

We evaluate the effectiveness of Web-based, highly interactive, and multimedia-rich e-learning materials by comparing students' capacity to answer questions in the midterm and final examinations in the lecture and online versions of the introductory computing course. We also provide indications on students' learning experience by analyzing the end-of-semester course evaluation results. This study compares three courses: the lecture course with 105 students, and two repetitions of the online course with 180 and 129 students held in the following two semesters. In addition to the controlled and limited change between the course versions, a strong feature of this study is that the University automatically assigned the students to their course version on a pre-determined semester, thus eliminating any self-selection bias. Furthermore, Internet communication tools were used limitedly and uniformly across the three courses. In each course, email was used for broadcasting course-related information and reminders. An electronic bulleting board was created for each class, but the students did not use it. Thus, the comparison of course versions is not confounded by the use of communication tools.

The course

"COMP101 Computing Fundamentals" is a non-major computing course, and compulsory to biology or chemistry students. The course aims at improving students' computer literacy and practical computing skills. In the lecture format (spring 2000), the course held two 50min lectures each week. In the online format (fall 2000, spring 2001), the semesters started with two 1h50min lectures to introduce the course and the new self-regulated learning mode, and to ensure that all students acquired the necessary familiarity with the University's computing environment. In addition, the classes met for the midterm and final examinations. The weekly 1h50min laboratory sessions were organized the same way in the lecture and online courses. The students were divided in groups of about 35 and the groups worked under the supervision of a teaching assistant. The students completed the same laboratory exercises in all courses.

The e-learning modules

The lecture notes, examples, and demonstrations that the lecturer would present during face-to-face lectures were converted into a Web-based, multimedia-rich, and highly interactive format for the online course. The computer literacy materials, prepared for the lecture course as PowerPoint presentations, were edited into full but compact sentence structure format and organized into 13 concept modules with two levels of subsections; in total, the concept modules contained 247 "chunks" of materials implemented using Flash. The materials on computing skills, also prepared for the lecture course as PowerPoint presentations, contained illustrated step-by-step guides for using different software. These materials were organized into 12 skill modules by saving each presentation as Web pages; in total, the skill modules contained 227 illustrated slides. Students accessed the modules from the LearningSpace course delivery platform. The modules allowed both sequential and random access navigation.

Several multimedia and interactive elements were added to the lecture modules. Thirteen short videos were recorded, each for introducing a concept module. The textual content of the concept modules was enriched with 31 hyperlinks, 171 still and 22 interactive graphics, 9 narrated and 12 non-narrated animations, and 38 narrated screen capture recordings (screencams). In addition, the concept modules contained 7 interactive exercises (games). The skill modules included 43 screencams for the software demonstrations the lecturer would make using a computer and a LCD projector in the lecture course; the skill modules contained also 14 hyperlinks and 12 downloadable zip files containing all software demo files. The final interactive element was a set of five self-assessment questions for each concept and skill module; these questions included all questions that the lecturer used in the lecture course during review sessions. The self-assessment tests were implemented using a quiz tool incorporated in the LearningSpace platform.

The students

Enrollment process

The chemistry majors were automatically enrolled to take the course on their year-1 fall semester and the biology majors on their year-1 spring semester. Other students chose the course as a free elective. Table 1 shows the enrollment distributions by seniority and major in the lecture and online courses.

As the first author was the sole lecturer to offer the course and she offered the course only in lecture or online format, the students could not choose their course version when they enrolled in the course. Consequently, there is no self-selection bias affecting our findings on students' learning outcomes.

Students' computing experience

Students' computing experience was assessed at the beginning of the course with a paper-and-pen checklist asking the following yes-no questions:

1. I have a PC.
2. I know how to copy files to a floppy disk using Windows 95/98/2000.
3. I know how to log into a PC using a campus computer.

Table 1: Student distributions by seniority and major in the Spring 2000 lecture course, and Fall 2000 and Spring 2001 online courses

		Spring 2000 Lecture course	*Fall 2000 First online course*	*Spring 2001 Second online course*
Enrolled students		105	180	129
Students by seniority	year-1	101	157	111
	year-2	2	14	3
	year-3	2	9	15
Students by majors	biology	87	152	85
	physics	9	13	–
	math	5	5	1
	chemistry	2	–	15
	economy	2	10	28

4. I know how to read/send e-mail messages.
5. I know how to use Netscape or Internet Explorer.
6. I have created my own web page.
7. I know how to edit documents using a word processing program (for example, Microsoft Word).
8. I know how to use spreadsheet / statistical software (for example, Microsoft Excel).
9. I know how to prepare presentations using a presentation graphics program (for example, Microsoft PowerPoint).
10. I have written computer programs (for example, in Pascal or in C).

"Yes" answers were scored as 1 and "No" answers as 0, and a student's computing experience score was obtained by summing up his/her answers.

Students' HKALE scores
The general college entry requirement is a passing grade in the Use of English test in the Hong Kong Advanced Level Examination (HKALE), and in a set of other HKALE subjects depending on major. In each course, the students were asked to report their HKALE grades in a survey questionnaire administered shortly before the midterm exam. The HKALE grades provide insight to the students' proficiency in English and general level of preparedness for university studies. The grades were given numerical values: A = 7, B = 6, C = 5, D = 4, E = 3, F = 2, U = 1. A student's "HKALE English" score is the value of the corresponding letter grade and the "HKALE other subjects" score is the mean of the tests taken by the student.

Learning outcomes
Students' learning outcomes were assessed in proctored midterm and final examinations. The midterms had 21 and the finals 25 multiple-choice questions in common between the three courses. Seven of the 21 midterm and 10 of the 25 final questions were classified as testing factual learning. The remaining 14 midterm and 15 final questions were classified as testing applied-conceptual learning, that is, higher-order learning defined as the capacity to understand deeply and to apply the learned concepts and skills. The exam data yielded four learning outcome measures per student: the percentage of correct responses to the factual and applied-conceptual questions in the midterm and final.

How did students' learning outcomes differ?
Factual learning
Table 2 describes the distributions of students' learning outcomes and background variables across the three courses. The mean percentage of correct responses to the factual questions was higher in the lecture course compared to the online courses. We examined between-courses differences by two separate univariate analysis of variance (ANOVA) models, one for the midterm and one for the final, in which the percentage of correct responses was the dependent variable and Course (lecture, first online, second online) the between-subjects factor. The between-courses differences were not significant in the midterm ($F_{2,409} = 1.018$, $p < .363$) and final ($F_{2,410} = .242$, $p < .786$). The

Table 2: Means and 95% confidence intervals of the percentage of correct responses in the factual and applied-conceptual questions in the midterm and final examinations, and background variables for the lecture and online courses

	% correct responses				*Background variables*		
	Midterm		*Final*				
Course	*Factual*	*Applied-Conceptual*	*Factual*	*Applied-Conceptual*	*Computing experience*[(a)]	*HKALE English*[(b)]	*HKALE other subjects*[(b)]
Lecture	61.8	72.7	70.2	64.8	6.7	3.6	3.9
(95% CI)	(58.1–65.5)	(69.3–76.0)	(67.4–73.0)	(61.4–68.1)	(6.4–7.0)	(3.5–3.8)	(3.7–4.0)
N	105	105	105	105	83	89	91
First online	59.2	69.6	69.1	70.3	6.5	3.5	4.0
(95% CI)	(56.4–62.0)	(67.2–71.9)	(67.1–71.0)	(68.0–72.6)	(6.2–6.8)	(3.4–3.6)	(3.9–4.0)
N	180	180	179	179	179	165	166
Second online	58.4	66.2	69.7	72.8	7.3	3.7	4.0
(95% CI)	(55.2–61.5)	(63.2–69.2)	(67.3–72.1)	(70.1–75.5)	(7.1–7.5)	(3.6–3.9)	(3.9–4.2)
N	127	127	129	129	121	84	84

(a) range 1–10
(b) range 1–7, A = 7, B = 6, C = 5, D = 4, E = 3, F = 2, U = 1

Helmert contrast comparing both online courses jointly with the lecture course was not significant in the midterm ($p < .162$) and final ($p < .598$).

The mean percentage of correct responses grew from midterm to final in all courses. This positive trend could be due to learning, experience accumulated in answering multiple-choice questions, or simply to the fact that the questions in the final were relatively easier to answer. We examined whether the improvement of learning outcomes differed across courses by using repeated measures ANOVA, in which the percentage of correct responses was the dependent variable measured in the two exams, Exam (midterm, final) was the within-subjects factor, and Course (lecture, first online, second online) the between-subjects factor. The main effect of Exam was significant ($F_{1,408} = 82.099$, $p < .001$) indicating that the learning outcomes improved overall from midterm to final, and the interaction Exam x Course was not significant ($F_{2,408} = .488$, $p < .615$) indicating that the improvement did not differ between courses. This pattern of results was replicated by fitting the model with the two online courses combined. In sum, the factual learning was comparable across courses.

Applied-conceptual learning

The mean percentage of correct responses to applied-conceptual questions in the lecture course was higher in the midterm and lower in the final compared to the online courses. Separate ANOVA models for the midterm and final yielded significant between-courses differences in both exams ($F_{2,409} = 4.351$, $p < .014$ and $F_{2,410} = 7.351$, $p < .001$). The Helmert contrast comparing both online courses jointly with the lecture course was significant in the midterm ($p < .013$) and final ($p < .019$).

We examined whether there was an interaction Exam × Course by using repeated measures ANOVA as was done for factual learning. The main effect of Exam was not significant ($F_{1,408} = .042$, $p < .839$) indicating that the learning outcomes did not overall change from midterm to final, and the interaction Exam × Course was significant ($F_{2,408} = 18.163$, $p < .001$) confirming the observed between-courses differences in learning trends from midterm to final. In sum, applied-conceptual learning in the online courses was poorer in the midterm, but became superior to the applied-conceptual learning of the lecture course by the final.

Controlling for background variables

Table 2 shows that the computing experience and HKALE English scores were higher in the second online course compared to the other courses, and the HKALE academic score was higher in the online courses compared to the lecture course. We examined whether the findings on learning outcomes were an artifact of differences in students' backgrounds by refitting the models of factual and applied-conceptual learning as analysis of covariance models (ANCOVA) using the background variables as three covariates.

The univariate ANCOVA models of the midterm and final showed that the three covariates were positively associated with factual and applied-conceptual learning, and confirmed the findings on between-courses differences in learning outcomes from the ANOVA models. The repeated measures ANCOVA models of factual and applied-conceptual learning showed that all interactions of the background variables by Exam were not significant, implying that student's background has the same positive effect in the midterm and final. The model of factual learning confirmed the absence of the interaction Exam × Course, and the model of applied-conceptual learning confirmed the presence of the interaction. In sum, the positive effect of background on learning outcomes is constant from midterm to final and does not confound the comparison of learning outcomes between the lecture and online courses.

Figure 1 shows the trends of mean learning outcomes for the three courses adjusted for the background variables. Factual learning scores (a) grow from midterm to final for all courses, and the trends of the three courses are nearly parallel. Applied-conceptual learning scores (b) decrease from midterm to final in the lecture course, and grow from midterm to final in the online courses, particularly in the second.

Learning experience

Table 3 shows the course evaluation history of COMP101 over nine semesters. Students rated the statements "Overall impression of the course" and "Overall impression of the instructor" in an anonymous end-of-semester survey. Different lecturers taught the first six courses in lecture format; the last three lines refer to the courses under investigation here.

The upward jump in the course and instructor scores in Spring 2000 compared to Spring 1997–Fall 1999 scores can be explained by the fact that the lecturer was quite

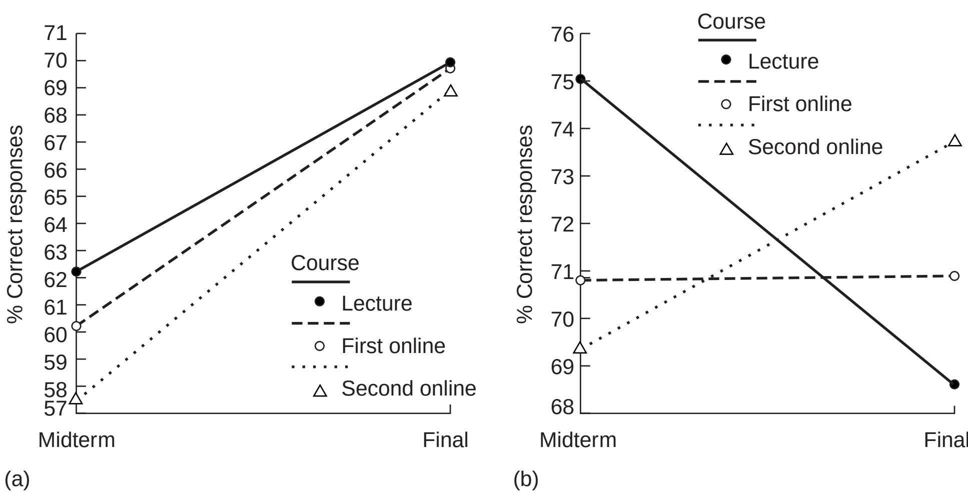

Figure 1: Trends of mean (a) factual and (b) applied-conceptual learning outcomes for the three courses adjusted for background variables

Table 3: COMP101 course evaluation summaries over nine semesters

Course version/ Semester	*Course: Mean (SD)*	*Instructor(s): Mean (SD)*	*Students*	*Response rate*
LECTURE				
Spring 1997	66.1 (15.8)	64.7 (18.8)	130	26.9%
Fall 1997	59.0 (17.6)	58.1 (18.9)	158	74.7%
Spring 1998	63.4 (17.0)	64.7 (15.8)	117	22.2%
Fall 1998	63.6 (17.6)	67.4 (16.4)	152	55.9%
Spring 1999	62.1 (18.6)	58.8 (19.0)	164	51.2%
Fall 1999	62.3 (19.6)	67.7 (19.0)	187	86.1%
Spring 2000	**74.2 (18.6)**	**80.1 (14.6)**	**105**	**74.3%**
ONLINE				
Fall 2000	**63.5 (22.9)**	**60.4 (21.2)**	**180**	**80.0%**
Spring 2001	**74.8 (17.2)**	**71.9 (17.9)**	**129**	**71.1%**

Score key: Very good (100)—Good (83.3)—Above average (66.7)—Average (50)—
Below Average (33.3)—Bad (16.7)—Very Bad (0).

popular at that particular moment. She had won a top-ten teacher award based on a university-wide student vote and a teaching excellence award based on high course evaluations.

The drop in the course and instructor scores in Fall 2000 corresponds to the introduction of the online course. A likely explanation is that the students did not appreciate being the test cases in the University's first attempt at e-learning. In addition, the students may have experienced difficulties in adapting to the self-regulated learning mode, given that the majority of students were first-semester students. These explanations seem viable given the upward development in the course and lecturer scores in the Spring 2001 course; these students knew that the online course had already been run successfully and they were going through at least their second semester of college studies.

Conclusions

Overall, the online course proved to be at least as effective as the lecture course in terms of students' learning outcomes. The online students' capacity to answer factual questions improved from midterm to final, as it did for the students of the lecture course, and the overall factual learning outcomes were similar in the two course versions.

As to applied-conceptual questions, we observed interesting differences between the lecture and online courses. First, the capacity of the lecture students to answer applied-conceptual questions decreased from midterm to final, while the online students grew better at answering such questions. Second, the online students performed worse in applied-conceptual questions in the midterm, but the situation was reversed in the final. Martin and Taylor (1997) pointed out that students have a learning curve in adapting to the challenges of new educational technology. It is likely that the online students had to adjust to the new learning experience, and that adjustment caused inferior performance in applied-conceptual questions in the midterm, but yielded superior performance in the final.

As pointed out by Joy and Garcia (2000), comparisons of the effectiveness between technology-based and conventional delivery media are often, almost inevitably confounded because there are many correlated parts within each treatment that can influence the outcome but cannot be disentangled. Nevertheless, a likely explanation to the online students' improved applied-conceptual learning in the final is the access to interactive graphics, practice quizzes, and short games. The e-learning modules allowed the students to access an elevated number of carefully designed graphics, animations, screencams, and videos. In the virtual classroom, each student can be prompted to explore an illustration, solve a problem, or answer a question, and provided immediate and specific feedback; similar personalized interaction is hardly possible in a lecture theater in the presence of more than 100 students. The online students' performance in applied-conceptual questions, that is, questions measuring higher-order learning, suggests that the e-learning modules used interactive multimedia effectively. This study converges with previous studies (Herrington and Oliver, 1999; Hirschbul, 1999; McFarland, 1996) in indicating that carefully designed e-learning modules facilitate engaging interactions with the content materials and, in turn, foster higher-order learning outcomes.

We analyzed the course evaluations over nine semesters, of which the last three were obtained when the first author was the sole lecturer of the course. She was a popular teacher, which is reflected in the evaluations of her lecture course. However, the first online course received a mixed response: the course rating returned to its usual level, while the instructor rating plummeted. The decline of course ratings was overturned in the second online course. These findings are consistent with a twofold interpretation. First, as Martin and Taylor (1997) pointed out, students' learning curve in facing new educational technologies has a social dimension that encompasses the whole college environment. Second, as Larose and Witten (2000) pointed out, carefully designed and implemented interactive e-learning modules provide students with a form of immediacy that, although different from that provided by a good teacher in the classroom, fosters affective learning in addition to cognitive learning. Therefore, the enhanced evaluations of the second online course suggest that, after the student community adapted to the novelty, some of the best-course/best-instructor perception of the lecture course was reproduced in the virtual classroom. In all, the student response was positive enough to justify replacing face-to-face lectures with the e-learning modules, especially because the more relevant measure, the course rating, was within an acceptable range in both online courses with respect to the course history.

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