Wireless Notebooks as Means for Fostering Active Learning in Higher Education

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Traditional engineering courses are based on three elements: lectures, tutorials and laboratories. In the current study, an alternative paradigm - studio-based learning - was introduced into one of the leading programming courses at the Massachusetts Institute of Technology (MIT). Studio-based learning combines lectures with in-class demonstrations, active learning exercises, and on-task feedback through the use of wireless notebooks. This paper reports on a study aimed at investigating the effect of studio-based learning via wireless laptop computers on students' learning performances. The study included 171 undergraduate students that were divided into two research groups by level of participation in the studio-based sessions. Pre- and post-tests were administered to assess the students' learning outcomes. Our results indicated that studio-based learning had a positive effect on improving students' knowledge in object-oriented programming. Our results also indicated that students who participated in studio-based learning presented complex, in-depth and thorough answers to conceptual questions. Their explanations included multiple ways of representing knowledge (i.e. graphs, tables, and drawings) that were rarely found among their counterparts' answers.

Literature Review

Undergraduate students in engineering, science, and mathematics programs are usually expected to acquire programming skills as a part of their education. Several studies have found that learning a new programming paradigm or language is difficult, and that students' understanding is hampered by preconceptions that turn into misconceptions (Milne & Rowe, 2002; White, 2001). Hence, it is imperative to provide students with a learning environment that supports construction of knowledge and conceptual understanding.

Recently studies have examined the use of technology as a means for integrating innovative pedagogical theories, presenting evidence for positive effect on students learning (Barak & Dori, 2005; Barak & Rafaeli, 2004; Dori, Barak and Adir, 2003; Dori & Belcher, 2005). Amongst the various technologies, wireless laptop computers or notebooks are becoming prominent in education.
Wireless laptop computers promote flexible online environments, allowing users to access printers and servers as well as the Internet from a non-tethered computer in settings where the user is most comfortable (Maughan, Petitto & McLaughlin, 2001). They support use of computational tools in lectures, tutorials, and during examinations. In the past few years studies investigating the use of laptops found several educational benefits such as increasing students' motivation and collaboration, strengthening connections between disciplines, improving students' problem solving skills, and

promoting academic achievement (Kiaer, Mutchler & Froyd, 1998; Mackinnon and Vibert, 2002; Siegle and Foster, 2002; Stevenson, 1998).

Studio-based learning as implemented in our study provided a multimodal learning environment in which lectures, recitations and laboratories are combined and mutually reinforce one another. It also provided a context for real-life learning, hands-on assignments, and problem solving. The origins of studio-based learning in U.S. universities are found in schools of architecture. In fact, the studio became a model of human-problem engagement, where participants learn how to learn (Boyer & Mitgang, 1996). Research on studio-based learning found that it increased students' performance and interest in the subject matter by emphasizing learning experience and active learning (Foulds, Bergen and Mantilla, 2003). Though studio-based instruction is highly praised, only a small number of universities integrate it into their curricula.

Research Objective, Population and Methodology

The objective of this study was to investigate the effect of studio-based instruction of Java programming on undergraduates' learning outcomes and conceptual understanding. The research population included 171 students (N_{fall}=73, N_{spring}=98) who studied the course: *Introduction to Computers and Engineering Problem Solving*. New concepts and programming principles were introduced during the lectures followed by an exercise that required students to solve a programming problem related to the newly introduced concepts. The exercises often involved hands-on real-world problems related to engineering, science, or management topics. The aim of using wireless notebooks in this course was twofold: to provide students with an easy and convenient access to hands-on computing and to examine the supportability of this technology. Loaner laptops equipped with wireless cards were provided for students who did not own one. The laptops included an Integrated Java Development Environment (IDE) that facilitated the development, testing, and deploying of Java programs. During the studio-based sessions, students downloaded parts of Java code from the course website onto their disks and used them as the starting point for solving problems.

In order to investigate the effect of studio-based instruction on undergraduates' learning outcomes and conceptual understanding of Java programming, we analyzed data that was collected from several resources:

(1) Academic Index - determined the MIT entrance scores that estimate the students' academic level on arrival at MIT.
(2) Studio-based learning level - determined the students' participation in the studio-based classes by signing a class attendance sheet.
(3) Pre-test - investigated students' prior knowledge in programming.
(4) Problem sets - investigated students' ability to solve programming problems.
(5) Quiz and final examination (post-test) - investigated students' learning outcomes and conceptual understanding.

The students were divided into two groups according to their participation in the course: ‘High studio-based learners’ included students that attended more than 80% of the sessions (N=91); the rest were defined as the ‘Low studio-based learners’ (N=80).

Findings

In order to investigate our hypothesis that studio-based learning, via wireless notebooks has a positive effect on improving students’ understanding of Java programming, we calculated students’ ‘relative improvement’ using Hake’s normalized gain equation (Hake, 1998 pg. 65). The student’s ‘relative improvement’ was the ratio of his/her actual gain to the maximum possible gain as follows:

$$<g> = \frac{\%Correct_{post-test} - \%Correct_{pre-test}}{100 - \%Correct_{pre-test}}$$

The pre-test administered at the beginning of the course estimated the student’s initial Java programming knowledge and the final examination (the post-test) grade measured their learning outcomes. The students’ ‘relative improvement’ factor was on a 0.0 to 1.0 scale. While 0.0 indicated no improvement, 1.0 indicated maximum improvement (i.e. receiving 100 points on the final examination).

Table 1. Analysis of variance of the student’s ‘relative improvement’ <g>, by studio-based learning groups

Research groups	N	Mean <g>	SD	F	p<
Low studio-based learning	80	0.65	0.22	8.62	0.01
High studio-based learning	91	0.74	0.18		

The results presented in Table 1 support our hypothesis that studio-based learning has a significant positive effect on improving students’ knowledge in Java programming.

Factors that predict student’s ‘relative improvement’

A linear regression model was employed to investigate factors that might predict students’ ‘relative improvement’ (dependent variable). Students’ studio-based learning was only one possible predictor; we wanted to investigate other factors such as students’ academic index and their performance on their problem sets. Table 2 present the results of the linear regression test.

Table 2. The student's studio-based learning percentage, academic index, and problem set mean scores, as predictors to their 'relative improvement', N=171

'Relative improvement' predicting variable	Mean	SD	β	p
Studio-based learning percentage (on a 0-100 scale)	72.38	30.51	0.16	0.03
Academic index (on a 0-50 scale)	39.77	6.82	0.13	0.07
Problem set mean score (on a 0-100 scale)	91.18	10.89	0.33	0.00

Table 2 shows that 'studio-based learning percentage' and 'problem set scores' are the best predictors for students' 'relative improvement' in Java programming. This suggests that students who work well on their problem sets throughout the semester and participate in studio-based learning gain better understanding of the learning material. These findings fortify the results presented in Table 1. Interestingly, we found only a borderline statistical significance in the relations between students' academic level and their 'relative improvement'.

Our next step was to investigate how students' academic level (i.e. academic index) influences other variables that predict students' relative improvement. We hypothesized that no statistically significant difference would be found between students starting from different academic levels. For this investigation, the research population was divided into two groups: 'High' and 'Intermediate' academic level groups, using the median of their MIT academic index as the splitting point. The 'High academic level' group included students that obtained an academic index from 40 to 50 (originally 4.0 to 5.0), the rest were defined as the 'Intermediate academic level' group. Table 3 presents the 'relative improvement' predictors by academic levels.

Table 3. The 'relative improvement' predicting variable divided by academic levels

	Relative improvement predicting variable	Mean	SD	β	p
Intermediate academic index (N=76)	Studio-based learning	68.73	0.22	0.26	0.01
	Problem set mean score	87.56	14.14	0.39	0.00
High academic index (N=95)	Studio-based learning	75.29	29.77	0.06	0.55
	Problem set mean score	94.08	6.27	0.24	0.02

Table 3 shows that intermediate academic level students' 'relative improvement' is statistically significant related to both their work on solving problem throughout the semester and their participation in the studio-based classes. However, high academic level students' 'relative improvement' has a statistically significant relationship only with problem set mean score.

Though our initial findings showed that studio-based learning has a positive effect on improving students' knowledge in general, we further can conclude that studio-based learning has a more significant effect on intermediate academic level students.

The effect of studio-based learning on students' conceptual understanding

In order to investigate the effect of studio-based learning on students' conceptual understanding, their responses to conceptual questions on the quiz and final examination were examined. Unlike most of the questions on the tests that required students either to write segments of code or select from multiple choice, the conceptual questions required students to explain a phenomenon and provide examples or strategies to support their answer. An analysis of variance (ANOVA) test was conducted to examine the difference between the research groups (high vs. low studio-based learning) on their answers to the conceptual questions.

Results showed a statistically significant difference between the research groups. It was found that high studio-based learning students were able to conceptualize programming principles better than their peers, as presented in table 4.

Table 4. Means, standard deviations, and ANOVA tests of students' conceptual question scores, by studio-based learning level, on the quiz and final examination

Conceptual question	High studio-based learning (N= 40)		Low studio-based learning (N= 33)			
	Mean	SD	Mean	SD	F	p<
On the Quiz (0-5 points)	4.25	1.35	3.15	1.92	8.16	0.01
On the Final examination (0-10 points)	8.65	2.14	7.10	3.21	5.90	0.05

Table 4 shows that students, who participated in the studio-based classes answered the conceptual questions more correctly than their peers. In addition, it was found that on average (considering both the quiz and the final examination), 60% of the students in the 'high studio-based learning' group received the maximum score, and only 5% of them, did not answer the question or answered incorrectly. Contrary to that, only 40% of the students in the 'low studio-based learning' group received the maximum score, and about 15% of them did not answer the question or answered incorrectly.

Conclusions

By confronting different ideas and being critiqued by others, students can check their own knowledge (Mason, 2001). Meta-conceptual awareness of one's own mental representations has been acknowledged as essential in conceptual understanding (Hennessey, 1993; Mason, 1994). By participating in class, being active in hands-on problem solving and even teaming up to form learning groups students have improved their learning outcomes and conceptual understanding of Java programming. During the studio-based sessions, students had many opportunities to discuss their ideas with their peers and instructors in the process of learning new concepts. While solving a real-life management or engineering problem, students were not only engaged in writing code, but also explained it, and received immediate feedback on it.

Since our findings show that participating in studio-based classes is important to intermediate academic level students and students with no prior-experience in programming, we strongly recommend on integrating this new pedagogy in hope that education in academic institutions will evolve from lecturing to studio-based instruction, and from individual learning to collaborative studio-based learning.

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