THE IMPACT OF TECHNOLOGY-ENABLED ACTIVE LEARNING ON STUDENT PERFORMANCE, GENDER AND ACHIEVEMENT LEVEL

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Abstract: Technology Enabled Active Learning (TEAL) is an innovative pedagogical method emphasizing active, interactive learning. It is implemented in a technology-rich, multimedia studio. The National Chung Cheng University (CCU) is the first university in Taiwan to use the TEAL studio to teach science courses. The purpose of this study is to assess the impact of TEAL on student learning at CCU, including the influence on genders and achievement levels. A quasi-experimental research was designed to conduct this study. Data sources consist of a pre-test, a post-test, and a survey. The preliminary results indicate that (1) the experimental (TEAL) students significantly outperformed the control (traditional classroom) students, (2) the experimental male students outperformed their counterpart male students, (3) the learning gain achieved by the experimental female students was more significant than that of their counterpart female students, and (4) the experimental low-achieving students achieved the highest learning gain among the different achievement-level groups. Narrowing the learning gap between different achievement levels of students through the use of this technology-enhanced learning approach appears promising. Nonetheless, continuing to improve the teaching innovation is necessary, particularly in terms of more effectively integrating technology-enabled features into teaching.

1 RESEARCH BACKGROUND

Technology-Enabled Active Learning (TEAL) was developed by MIT (Massachusetts Institute of Technology) in 2001. It is an innovative teaching and learning format featuring multimedia-equipped studios to facilitate students learning science and technology-related courses. TEAL emphasizes group discussion and interaction during the teaching process. The group interaction and discussion is accomplished through the support of built-in assessment processes, such as the personal response system (PRS), which some educators consider a powerful tool for teaching science courses (e.g. Beatty & Gerace, 2009; Beatty, et al., 2006). In Taiwan, the National Chung Cheng University (CCU) is the first university using TEAL to improve student learning.

At CCU, students majoring in sciences and engineering disciplines are required to take the General Physics (GP) course in their freshman year offered by the Physics Department. In order to help students better understand the abstract concepts associated with basic physics, the notion of technology-enabled active learning was introduced to its campus in 2004. Similar to the TEAL studio established at MIT, the CCU TEAL studio was equipped with tables, big-screen projectors around the walls, and blackboards in between the projectors. Figure 1 shows an overhead view of the TEAL studio and Figure 2 displays a scene of a hands-on activity.

Figure 1: An overhead view of the TEAL studio.

Figure 2: A hands-on Activity.

In 2005, CCU began to use the TEAL studio to teach

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the GP course to the physics major students. By the year of 2007, there were three classes of department-wide students studying the GP course in the TEAL studio. Based on the students' learning outcomes in 2007, the experimental (TEAL) students and the control (traditional classroom) students achieved about the same learning gains in the first semester (6.43% vs. 6.34%); however, the experimental students achieved much higher learning gain than their counterpart students in the second semester (18.09% vs. 11.20%). Nevertheless, this learning gain of below 20% was still considered relatively small (Hestenes & Halloun, 1995). Improvements for implementing the innovative pedagogy were identified, including improving teaching skills, reconsidering the content coverage, and more deliberately integrating the lab activities into the lecture content. More detailed findings are to be published elsewhere.

The purpose of this study is to continue assessing the impact of TEAL on student learning demonstrated in 2008. In addition to comparing the learning outcomes of the experimental and control groups, this study also examines the learning gains achieved by the different genders and different academic achievement-levels. Three research questions are addressed in the study:

1. To what extent does technology-enabled active learning impact student learning for the experimental and control groups?
2. To what extent does technology-enabled active learning impact student learning between the genders?
3. To what extent does technology-enabled active learning impact student learning among high, intermediate, and low achieving levels?

2 LITERATURE REVIEW

Many researchers have studied the social aspect of cognitive activities, such as communities of scientists and learners (Duschl & Hamilton, 1998). The transformation from a focus on individuals to a focus on participants of the learning community requires both conceptual change (Strike & Posner, 1985) and a fundamental change in the educational environments established for learning the desired content (Dori & Belcher, 2005). Educational technology plays an important role in supporting a social, active, constructive learning environment (Jonassen, Carr & Yueh, 1998). The capabilities of new technologies and the methods that use them are viewed as being better able to attract student attention to the lectured topic (Beichner, et al., 1999) and to facilitate students' learning (Kozma, 1994). Educational technology has the potential not only to improve student performance, but also to prepare students to be productive, employable citizens (Dusick, 1998). Hake (1998) found that students engaged in active learning significantly improved their performance in undergraduate physics. Nonetheless, some researchers have cautioned that facilitating students to learn in an interactive, active environment is a challenging task. For instance, the instructor must acquire classroom management skills to facilitate the process of the activities (Maclsaac & Falconer, 2002), be able to identify an appropriate extent and timing of intervention during discussion (Bell & Gilbert, 1996), and be perceptive of the content and context of students' responses and reactions to questions raised (Roth, 1996).

2.1 Gender Gap

The TIMSS report showed that the percentage of high-achieving boys was significantly higher than that of the counterpart girls on average science achievement across countries (Martin, et al., 1999). Science educators have been engaged in promoting the participation rate of female students and achieving a more equitable gender balance in the past 30 years (Hodgson, 2000). It was found that gender difference can be attributed to sociological influences, such as culture (e.g. the creation of gender identity and gender equity), attitude (e.g. intrinsic interest and reading attitudes) and choice (e.g. personal preference), and biological influences, such as neurology (e.g. the structural shape of the brain), chemistry (e.g. the levels and use of hormones in genders) and imagery (e.g. the availability of imaginal mediators) (Kitchenham, 2002). Kitchenham (2002) contended that achievement differences between genders could be reduced through sound pedagogical methods; for example, alternating between group discussion and structured instruction to accommodate different learning needs for both genders, promoting mixed-gender team teaching, and encouraging the use of technology in the classroom for both genders. Similarly, Hodgson (2000) urged that science-related gender stereotyping issues be resolved through curriculum and pedagogy. Lorenzo, et al. (2006) found that interactive engagement instruction, such as encouraging in-class peer interaction, effectively eliminated the gender gap in the conceptual understanding of an introductory calculus-based physics course. Beichner, et al. (1999) reported that female students were found to be as engaged in the class discussion and group work as male students in a highly collaborative, technology-rich, activity-based learning environment. They emphasized that socialization among peers played a critical role in the success of students in the physics component of the curriculum.

2.2 Low - and High - Achieving Gap

According to the National Assessment of Educational Progress (NAEP) report reported by Freeland (1983), high achievers' skills in science and math were declining, while low achievers' skills were improving. Lau and Chan (2001) found that the gap among underachievers and high achievers could be attributed to motivational variables, such as having a low academic self-concept, placing low attainment value on learning, and deficiency in using learning strategies. Martin (1985) revealed that among low achievers, negative motivation, such as anxiety and frustration, was almost twice that of high achievers. Bailey (1971) stated that self-estimates and desired levels of college ability were positively associated with the level of students' actual achievement. Dori and Belcher (2005) reported that although students studying in a technology-rich, active learning environment improved their performance significantly, the net learning gain of the low-scoring group was the highest compared with intermediate- and high-scoring groups. Likewise, Lorenzo, Crouch, and Mazur (2006) revealed that interactive engagement in physics courses appeared to have more effectively reduced the percentage of low-achieving students, particularly female students, than that of high-achieving students. In other words, appropriate instructional approaches could significantly improve the performance of low-achieving students, especially female students.

However, She (1998) found that most female students in Taiwan, particularly elementary and middle-school students, were incapable of picturing themselves pursuing a science-related profession due to worrying about being labeled as too competent when compared with their counterpart male students. Therefore, whether the TEAL setting established at CCU can assist female students and low-achieving students to accomplish learning outcomes that are as significant as those demonstrated in western countries is thus of interest.

3 METHOD

3.1 Research Context

A quasi-experimental research was designed to conduct the study. There were four classes of students studying the GP course at CCU in the first semester of 2008. Three of the classes studied the course in the TEAL studio and were regarded as the experimental group, whereas the class studying in the traditional classroom was seen as the control group.

3.2 Data Collection and Analysis

Three sources of data were collected, consisting of:

1. Pre-test: All students studying the GP course were scheduled to take the pre-test at the beginning of the semester. Force Concept Inventory (FCI), developed by Hestenes, Wells, and Swackhamer (1992), was used to assess the students' understanding of fundamental physics concepts in *mechanics*. The FCI consists of 30 multiple-choice questions.
2. Post-test: The students were scheduled to take the post-test (the same test content as the pre-test) at the end of the semester.
3. Survey: A self-report survey was administered at the end of the semester to gather TEAL students' learning experiences. A 5-point Likert scale ranging from 5 (strongly agree) to 1 (strongly disagree) was used to collect the survey data.

4 PRELIMINARY RESULTS

4.1 The Test Results

There were 410 students registered in the four GP classes, including 281 experimental students and 129 control students. A total of 342 students completed both the pre- and post-tests. Table 1 displays the test results of the four classes, including the mean scores of the pre- and post-test, and learning gains, where learning gain is defined by Hake (1998) as:

$$\langle g \rangle = (\text{post test - pre test}) / (100 - \text{pretest}))\%$$

Table 1 indicates that the learning gain of the experimental group (14.51%) is significantly higher than that of the control group (2.19%).

Table 2 lists the learning outcomes broken down by gender. Although the mean scores of the pre-test

Table 1: The tests results by group.

Group	Experimental (N=252)		Control (N=90)	
Pre-/Post Test	Pre	Post	Pre	Post
Mean	75.26	78.85	73	73.59
Std. Dev.	15.29	13.95	15.55	13.00
t-test p-value	< .001*		.584	
<g>	14.51%		2.19%	

* P-value of the paired t-test < .001

Table 2: The test results by gender.

Semester	1st semester of 2008							
Gender	Male				Female			
Group	Experiment (N=209)		Control (N=66)		Experiment (N=43)		Control (N=24)	
Pre-/Post Test	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Mean*	75.50	79.28	74.95	75.35	74.11	76.74	67.64	68.75
Std. Dev.	15.88	14.12	12.99	12.98	12.10	13.02	13.92	12.03
t-test p-value	< .001*		.086		.744		.626	
<g>	15.43%		1.60%		10.16%		3.43%	

* P-value of the paired t-test < .001

Table 3: The tests results by achievement.

Semester	1st semester of 2008											
Achievement	High				Intermediate				Low			
Group	Experiment (N=122)		Control (N=38)		Experiment (N=99)		Control (N=36)		Experiment (N=31)		Control (N=16)	
Tests	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Mean*	87.35	86.86	85.53	82.28	69.73	74.65	69.17	70.28	45.38	60.75	51.88	60.42
Std. Dev.	26.43	60.66	32.00	78.14	34.39	146.67	37.06	131.03	119.02	246.45	16.25	102.04
P-Value	.258		.007*		< .001***		.27		< .001***		.002**	
<g>	-3.87%		-22.46%		16.25%		3.60%		28.14%		17.75%	

* P-value of the paired t-test < .05   ** P-value of the paired t-test < .005   *** P-value of the paired t-test < .001

of the experimental male group and the control male group were about the same (75.50 vs. 74.95), the experimental male group, performed better than its counterpart control male group in the post-test (79.28 vs. 75.35, p-value <.001 and .086 respectively). The learning gains achieved by the two male groups were 15.43% and 1.6% respectively. Compared with their pre-test scores (74.11 and 67.64 respectively), the experimental and control female groups did not significantly improve their learning outcomes in the post-test (76.74 and 68.75 respectively). However, the learning gain achieved by the experimental female group (10.16%) was much higher than that of the control female group (3.43%).

The students' learning outcomes were also analyzed based on their achievement levels. Three levels of achievement were categorized, using the students' pre-test scores: (1) high (80 or higher), (2) intermediate (60-79), and (3) low (below 60). The results are shown in Table 3. As indicated in Table 3, both the high-achieving experimental and control groups had negative improvement in their post-test, -3.87% and -22.46% respectively. The intermediate- and low-achieving experimental groups and the low-achieving control group, however, improved their post-test significantly (16.25%, 28.14%, and 17.75% respectively), with p-value < .001, <.001, and <.005, respectively. In accordance with the findings reported by Dori and Belcher (2005), this study also found that the students in the low-achieving group benefited most from engaging in TEAL. Dori and Belcher (2005) stated that it was probably due to more room for the lower achieving students to make improvement.

4.2 The Survey Results

A total of 239 surveys were collected from the three TEAL classes, representing an 85% (239/281) return rate. The survey information reveals that the TEAL students were inclined to agree that there was more interaction taking place between the instructor and students in the TEAL studio (mean=3.74), when compared with traditional classroom learning experiences. They also tended to agree that there was more interaction taking place among peers in the TEAL course (mean=4.02). Although they felt more nervous studying the GP course in the TEAL studio than in the traditional classroom (mean=3.61), they, overall, preferred to study in the TEAL studio than in a traditional classroom.

The three methods most frequently used by the students to resolve problems encountered were: 1) discussing the problems with peers, 2) self-studying, and 3) reviewing the lecture clips posted online. The top three items (among 14 items[1]) that the students considered most helpful for their study are: (1) self study, (2) the instructor's instructional style and teaching skills, and (3) the teaching assistants' in-class assistance. Suggestions made by the students for improving future TEAL implementation revealed that quite a few students were impressed with the high-technology equipped studio. However, a number of students stated that the instructional pace was too fast, formula derivative occurred too often, and more demonstrations and clearer explanations of the lecture content were preferred.

5 CONCLUSIONS

Consistent with the findings disclosed in 2007, this study found that the experimental students not only showed positive attitudes toward the technology enabled learning environment, but also achieved higher learning outcomes than the control students. This study also disclosed that the learning gain achieved by the low-achieving TEAL students (28.14%) was the highest among the groups. Helping low-achieving students learn more effectively, and narrowing the learning gap, has been a common goal for many educators. The results reported here appear encouraging in this regard.

In addition, the survey results reveal that when students encountered problems they would discuss them with their peers in class, which indicates that the peer-discussion feature of TEAL did provide a venue for students to solve their problems. However, it is also noticed that the top three items that the students considered most helpful to their study were self-study, the instructor's instructional skills, and the teaching assistants' in-class assistance. In other words, the students do not yet seem to have fully benefited from some of the TEAL features, such as the use of personal response system and simulation demonstrations. In sum, integrating technological features into instructional design remains the most challenging task to the instructors. Nevertheless, it is hoped that the findings reported here could provide useful insights and cautions to educators who are interested in strengthening their teaching through the use of technology reinforced learning approaches.

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[1]The 14 items include (1) the instructor's instructional style and teaching skills, (2) the use of PRS, (3) attendance requirement (4) the instructor's after-class assistance, (5) teaching assistants' in-class help, (6) recitation sessions taught by teaching assistants, (7) peers' in-class discussion, (8) classmates' after-class assistance, (9) self study, (10) video clips posted on the web, (11) 3D simulation, (12) lab activities, (13) frequent tests, and (14) homework.

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