

AC 2007-552: DEVELOPING AN INTERACTIVE LEARNING NETWORK USING TABLET PCS IN SOPHOMORE-LEVEL ENGINEERING COURSES

Amelito Enriquez, Canada College

Professor of Engineering and Mathematics Cañada College 4200 Farm Hill Blvd. Redwood City,
CA 94061

Developing an Interactive Learning Network Using Tablet PCs in Sophomore-Level Engineering Courses

Abstract

The importance of active and interactive learning in science and engineering education has long been recognized, and interactive and collaborative teaching and learning techniques are routinely employed in small laboratory and discussion sessions. Wireless technology coupled with pen-based computing technology that is suited for analyzing and solving engineering problems provides an ideal venue for these interactive teaching and learning methods to be applied to a larger, more traditional lecture setting. This study focuses on how Tablet PCs and wireless technology can be used during classroom instruction to create an Interactive Learning Network (ILN) that allows real-time student assessment and assistance. The ILN is designed to enhance the instructor's ability to solicit active participation from all students during lectures, to conduct immediate and meaningful assessment of student learning, and to provide needed real-time feedback and assistance to maximize student learning. This interactive classroom environment is created using wireless Tablet PCs and a software application, NetSupport School, which allows various levels of interactions between the instructor and the students during lectures, thereby enhancing the instructor's ability to systematically monitor and control individual student progress, assess their understanding through instant surveys, and provide immediate feedback and assistance through the wireless network. Results from two separate controlled studies of the implementation of this model of interactive teaching and learning in sophomore-level Engineering Dynamics courses show statistically significant positive impact on student performance. Additionally, results of student surveys show overwhelmingly positive student perception of the effects of this model of classroom environment on their learning experience. These results indicate that the interactive classroom environment developed using wireless Tablet PCs has the potential to be a more effective teaching pedagogy compared to traditional instructor-centered teaching environments, and should be applied to math, science and other engineering courses with traditionally high attrition rates.

1. INTRODUCTION

The fundamental problem addressed by this study is the lack of active participation of students during classroom instruction in the traditional 50-minute lecture setting. Studies have long shown that the traditional instructor-centered lecture format is an ineffective learning environment, and that active participation and interactive and collaborative teaching and learning methods are more effective in various areas of science and engineering education including Chemistry¹, Physics², Engineering³, and Computer Science⁴. Various uses of technology have been found to be effective in enhancing the classroom experience to achieve more interactive and

collaborative environments. These techniques include handheld wireless transmitters in Personal Response Systems (PRS)⁵, various forms of computer-mediated collaborative problem solving⁶ and the use of wireless Tablet PC technology⁷.

The combination of wireless technology and Tablet PC's pen-based technology that is suited for analyzing and solving engineering problems provides an ideal venue for previously proven collaborative teaching and learning techniques commonly employed in smaller engineering laboratory and discussion sessions to be applied to a larger, more traditional lecture setting. Currently, the range of use of Tablet PCs in the classroom includes enhancing lecture presentations⁸, digital ink and note taking⁹, E-Books (books in electronic format) that allow hyperlinks and annotations¹⁰, and Tablet-PC-based in-class assessments⁷. As the use of Tablet PCs in the classroom grows, there is a growing need to understand how these various uses and applications can facilitate and enhance student learning.

This paper summarizes the preliminary results of a series of studies on how Tablet PCs and wireless technology can be used during classroom instruction to create an Interactive Learning Network (ILN) that allows real-time student assessment and assistance, and how such a system impacts learning in the classroom. Specifically, the paper will address the effects of these technology-enhanced interactions and collaborations on student performance, on student attitude towards the ILN model of instruction and the use of Tablet PCs in the classroom, and on student level of engagement and confidence in the learning process. It is expected that these studies will show that compared to courses taught with a traditional instructor-centered mode, the Interactive Learning Network can lead to:

- higher retention and success in the courses where the technology is implemented, as indicated by better student grades on homework, quizzes and tests compared to courses that do not use the technology,
- positive attitude towards the use of ILN model of instruction, and towards student use of Tablet PCs in the classroom,
- better student engagement in courses using the technology, as evidenced by higher attendance rates, higher on-time completion of homework, and more time spent on assigned tasks outside class time, and
- higher student confidence in their mastery of the subject.

2. THE INTERACTIVE LEARNING NETWORK (ILN)

The Interactive Learning Network (ILN) is designed to enhance the instructor's ability to solicit active participation from all students during lectures, to conduct immediate and meaningful assessment of student learning, and to provide needed real-time feedback and assistance to maximize student learning. This interactive classroom environment is created using wirelessly networked Tablet PCs and a software application, NetSupport School, which allows various levels of interactions between the instructor and the students during lectures. In this model of instruction, less time is spent by the instructor delivering content through traditional instructor-centered lectures. The lectures focus on introducing new concepts and applying them to a few simple examples with more complex examples given as guided exercises. Students can access the instructor's presentation and add their own annotations using Windows Journal or MS

PowerPoint. Throughout the lecture, the NetSupport School software allows the instructor to quickly assess individual student understanding of concepts using instant student surveys. At the end of each lecture, more involved examples are introduced as exercises that students work on individually or in groups on their Tablet PCs using Windows Journal and/or other appropriate software (MS Excel, MATLAB, MultiSIM, PSPICE, AutoCAD, etc.). While students work on more challenging problems, the instructor has the capability to scan and monitor students' work from the instructor's tablet PC, and guide the students and assess their progress through NetSupport's Survey mode using a series of short, previously prepared leading questions. Individual student questions are received through the Help Request feature, and individual assistance can be provided using the Monitor, Share and Control features. The instructor is also able to effectively manage the various interactions through group chat, use of an electronic whiteboard, file transfer and distribution, as well as control of student computer applications and web activity. The effectiveness of this model comes from the ability of the instructor to monitor and interact with individual students while they analyze problems on the computer using an input device that allows them to write and manipulate formulas, and make sketches and diagrams.

This method of instruction was developed and implemented in a number of sophomore-level engineering courses at Cañada College from fall 2005 to fall 2006. Results of the implementation on two engineering Dynamics classes will be the focus of this paper.

3. STUDY 1: Cañada College Fall 2005 and Fall 2004 Dynamics Classes

The Interactive Learning Network was first implemented in a Dynamics class of 17 students at Cañada College in fall 2005. Since Cañada College offers only one section of this class every fall semester, a control group could not be established for the study. Instead, the performance of the fall 2005 experimental group that used the ILN model is compared with that of the fall 2004 Dynamics class of 18 students. Similar homework, quizzes and exams were given to both Dynamics classes. An attitudinal survey was also administered at the end of the fall 2005 semester to evaluate students' opinion of and satisfaction with the use of the ILN model and Tablet PCs in the classroom.

3.1 Description of Course and Students

Cañada College is part of the 108 school California Community College system, and is of one the smallest community colleges in the San Francisco Bay Area with approximately 6,000 students. The college is a federally-designated Hispanic Serving Institution with approximately 42 percent Latino students. Cañada's Engineering Department is a two-year transfer program with approximately 15 to 20 students transferring to a four-year institution every year. The Dynamics course at Cañada College is a 3-unit, sophomore-level lecture course required of all Civil and Mechanical Engineering majors, and some Electrical Engineering and Computer Engineering majors depending on the student's transfer institution. The class meets for three hours a week for 16 weeks.

The two Dynamics classes being compared in this study are very similar demographically. The fall 2005 class which used the ILN model started with 17 students, and the fall 2004 (non-ILN)

class started with 18 students. For both years, more than 85% of the students were male, and a majority of the students were Mechanical Engineering majors. For both years, the ethnic distribution was diverse with no majority ethnic group.

3.2 Results: Study 1

In this section, performance of the two groups of students, fall 2005 class with ILN format and fall 2004 class with traditional format, will be compared. To help understand the sources of any differences in the performance of the two groups, an attitudinal survey on student perception of and satisfaction with the ILN model of instruction and the use of Tablet PCs was done.

3.2.1 Comparison of Class Performance

A summary of the comparison of the performances of the two groups of Dynamics students is shown in Table 1. Quiz Average is the average of 5 quizzes, Homework Average is the average of 15 homework sets, and Test Average is the average of 4 tests. The last column of the Table 2 is the difference between the average scores received by fall 2005 students and the fall 2004 students. The tabulated results show significant improvements from 2004 to 2005 in all of the categories, with the biggest improvements for homework and quizzes. The difference between 2004 and 2005 results is statistically significant for homework [independent Student *t*-test: $t(1,19) = 3.084$, $p < .01$], for quizzes [$t(1,27) = 3.425$, $p < .005$], for tests [$t(1,22) = 2.393$, $p < .05$] and for the final exam [$t(1,20) = 2.308$, $p < .05$]. There is also a slight reduction in the percentage of students who withdrew from the class.

Table 1. Comparison of Dynamics student performance for fall 2005 and fall 2004.

Categories	Fall 2005 (ILN) N=15	Fall 2004 (non-ILN) N=15	Difference
Quiz Average	84.0	71.4	12.6
Homework Average	92.8	83.0	9.2
Test Average	86.1	77.0	9.8
Final Exam	84.9	70.9	14.0
%Withdrew	12%	17%	-5%

3.2.2 Attitudinal Survey on Tablet PC and NetSupport School: Fall 2005 only

Table 2 summarizes the results of the attitudinal survey administered in the ILN class at the end of the semester. They show overwhelmingly positive attitudes towards the use of both NetSupport School software and Tablet PCs in the classroom. With respect to the use of NetSupport School, the “Help Request” feature was perceived most positively by students, with the control features (locking of student computers, Internet and Applications controls) viewed the least positively. With respect to the use of Tablet PCs in the classroom, students viewed them as helpful in improving student performance and the instructor’s teaching efficiency, and created a better learning environment.

Table 2. Summary of student opinions of NetSupport School and Tablet PC use in the classroom.

Use of NetSupport School Software	Average Response* (N=15)
NetSupport School program was helpful in improving my performance.	3.30
NetSupport improved the instructor's teaching effectiveness.	3.42
NetSupport enhanced the teacher's ability to measure student learning.	3.45
The "Help Request" feature of NetSupport was useful to me.	3.75
The "Lock," "Internet Control," and "Applications Control" features helped me pay attention to the lecture.	3.17
My overall experience with NetSupport School has been positive.	3.45
Use of Tablet PCs	Average Response* (N=15)
Using the Tablet PCs in class helped me improve my performance.	3.36
Tablet PC use improved the instructor's teaching effectiveness.	3.42
Tablet PCs available for use during class created a better learning environment than without them.	3.62
I found "Windows Journal" and the stylus intuitive and easy to use.	3.77
I would like to have Tablet PCs available for student use in other courses.	3.85
My overall experience with Tablet PCs has been positive.	3.77

*Note: For each question, the response scale is as follows: 4 – Strongly Agree, 3 – Agree, 2 – Disagree, 1 – Strongly Disagree, 0 – No Opinion.

3.3 Analysis: Study 1

In assessing the impact of the Interactive Learning Network on the performance of the class, it is important to determine how the different components of the model positively affect student learning. One of the most important components of this teaching model is immediate assessment of student learning and immediate feedback on student performance. Research on learning theory has long shown that immediate feedback is an effective tool in increasing learning efficiency¹¹. For the case study at hand, the effect of immediate feedback is reflected by the trend that students in the fall 2005 class had highest improvement on quiz and homework scores. As a result of solving problems in class with instructor's guidance, the fall 2005 students not only learned material but gained confidence on the material such that they were more successful in completing homework assignments and were better prepared for quizzes. Consequently, the completion and submission rates of homework assignments for the fall 2005 were observed to be much higher compared to the fall 2004 class.

Students in the fall 2005 class attributed the improved performance on increased focus and attentiveness during class as a result of instructor's survey questions, and the awareness that the instructor observed their progress. Furthermore, the "Help Request" feature of NetSupport was found most useful by the students because it allows them to ask specific questions anonymously.

Another advantage of having students solve problems in class immediately after being introduced to a new concept was that it enabled the instructor to identify common student misconceptions early in the learning process thereby reducing student frustrations when dealing with the homework problems. This early assessment of student learning sometimes presented a need for the instructor to adjust course material, making the class more dynamic and more responsive to the needs of the students.

4. STUDY 2: Fall 2006 Dynamics at Cañada College and San Francisco State University

For fall 2006, two sections of Dynamics courses were studied, one at Cañada College and one at San Francisco State University, with both classes taught by the same instructor. As noted above, Cañada College offers only one section of Dynamics every fall semester. To study the impact of the ILN model on student performance in the Dynamics class at Cañada College, the Dynamics class at San Francisco State University was selected to be the control group. In both courses, the instructor used a Tablet PC and a combination of PowerPoint and Windows Journal presentations to deliver lectures. The only major difference between the two classes is the student use of Tablet PCs and the NetSupport School software in the Cañada College class to create the Interactive Learning Network.

4.1 Description of Classes and Students

The Dynamics course at SFSU is a 3-unit lecture course that meets 3 hours a week for 15 weeks, one week shorter than Cañada's 16-week course. The first 15 weeks of the Cañada class covers topics that are identical to SFSU's topics. For the last week the Cañada class covered a topic that was not covered at SFSU and not included in any of the tests. The last homework set at Cañada is not included in the analysis and comparison of the performance of the two groups.

The class sizes for the both classes are smaller than normal with only 10 students in Cañada's Dynamics class, and 17 in SFSU's Dynamics class in the beginning of the semester. A comparison of the demographics of the two groups of students showed that the Cañada College class was more diverse in ethnicity and majors than the SFSU class where students were 76% Civil Engineering majors, and 65% Caucasian. With respect to gender, the Cañada group has a slightly higher percentage of female students (30% vs. 23.5%).

In the beginning of the semester, a survey of student expectations for the class and the semester was given to both groups of students. From this survey, it was found that Cañada College students were taking on the average 3.1 less units (11.1 vs. 14.2), were expecting to work about 5.2 hours more every week (19 vs. 13.8), were expecting to study slightly more for the dynamics class (6.5 hrs vs. 5.9 hrs. per week), and had about the same expected average grade for the class (3.6 vs. 3.5 on a scale of 0-4) when compared with the students from SFSU. The average grade point received by the students in the prerequisite Physics course has no statistically significant difference between the two groups.

Due to the inherent differences between the two groups of students in Study 2 (Cañada College being a community college, and SFSU being a university), a diagnostic test was given to the both

groups to ascertain that the students' levels of preparation for the class are comparable. The diagnostic test consists of 10 multiple-choice questions measuring student knowledge of basic Mechanics concepts and their applications. These questions involve topics that were covered in the pre-requisite Physics course. Results of this diagnostic test show no statistical difference in the average and median scores of the two student groups.

4.2 Results: Study 2

A comparison of student performance similar to what was done for Study one above will be done for the ILN Cañada class and the SFSU class of Study 2. Additionally, to help understand the sources of any differences in the performance of the two groups, an end-of-semester survey was designed to measure student expectations, study habits, note-taking strategies, attitude towards the courses and confidence on knowledge of subject matter.

4.2.1 Class Performance Comparison

Table 3 shows a comparison of the performance of the two groups of fall 2006 Dynamics students. Quiz Average is the average of 5 quizzes, Homework Average is the average of the 14 homework sets, and Test Average is the average of 4 tests. The last column of Table 3 is the difference between the average scores received by Cañada students and SFSU students. The last row of the column shows that none of the Cañada students withdrew from the class while 4 (or 24% of the original 17) of the SFSU students withdrew. The tabulated results also show higher scores for the Cañada (ILN) class in all categories. Again, as with the results of Study 1 above (Cañada's fall 2005 ILN class versus fall 2004 non-ILN class) differences between the scores are statistically significant for Quiz Average [independent Student t -test: $t(1,20) = 5.108$, $p < .001$] and Homework Average [$t(1,14) = 2.178$, $p < .05$]. The differences for the Test Average and Final Exam are not statistically significant. It should be noted, however, that for the Test Average, the resulting corresponding letter grade equivalent is "B" for the Cañada College class, and "C" for the SFSU class. Furthermore, the difference of 6.7 points in the Test Average would have been statistically significant if the class sizes were larger.

Table 3. Comparison of fall 2006 dynamics student performance for the Cañada College class and the SFSU class.

Categories	Cañada (ILN) N=10	SFSU (non-ILN) N=13	Difference (Cañada – SFSU)
Quiz Average	91.2	67.0	24.2
Homework Average	90.6	76.5	14.1
Test Average	83.4	76.7	6.7
Final Exam	84.1	81.5	2.6
%Withdrew	0%	24%	-24%

4.2.2 End-of-Semester Survey: Student Engagement, Expectations and Confidence

For this research, student level of engagement in the course is indicated by their attendance and time spent studying for the course outside class time during the semester. Since the instructor did not take roll during the semester for either class, the end-of-semester survey asked students to estimate their total number of hours of absence. The average student-estimated total number of hours of absence was much higher for the SFSU class (8.5 vs. 2.3). The students were also asked to estimate the average number of hours they studied for the class outside class time. The estimated number of hours of study outside class time was higher for Cañada than SFSU. The average of 7.2 hours a week of study for Cañada students is higher than the first-week survey estimate of 6.5 while the average of 5.2 hours a week for SFSU is lower than the first-week survey estimate of 5.9. These two factors (better attendance and more study hours) are indications that the Cañada group was more engaged in the course than the SFSU group.

The end-of-semester survey also determined students' expected grades in the class. The average grade the students expected to receive in the class is higher for Cañada students than SFSU students, 3.40 vs. 2.92, respectively. Both expected grades are slightly higher than the actual final grades that the students received, 3.33 for Cañada and 2.67 for SFSU. It should be noted that these grades are very different from each other although the students' expected grades from the first-week survey were very close to each other (3.6 for Cañada vs. 3.5 for SFSU), indicating that the two groups had very similar expectations in the beginning of the semester.

The end-of-semester survey also measured student attitude towards the Dynamics course, and their perceived confidence in their knowledge of the material. When asked how difficult the class was compared to other science and engineering courses students have previously taken or were currently taking, Cañada students found the class to be between "as difficult" and "slightly more difficult" while SFSU students found it to be between "slightly more difficult" and "much more difficult" than other science and engineering courses. When asked to compare the amount of time spent in the Dynamics class compared to other science and engineering courses, Cañada students' average response was between "about the same" and "slightly more" while SFSU students' average response was between "slightly more" and "much more." When asked to rate their confidence in having learned the material in class, the Cañada group's average response was between "very confident" and "confident" while the SFSU group was between "confident" and "neutral."

4.2.3 Attitudinal Survey on Tablet PCs and NetSupport School: Cañada only

The results of the survey of Cañada student opinions on the use of NetSupport School and Tablet PCs are shown in Table 4. These responses are even more positive when compared to those of the ILN Cañada Dynamics class of fall 2005 in Study 1. Most students agree or strongly agree that both the NetSupport School and Tablet PCs have positively impacted their performance in class, and improved teaching effectiveness. As was observed in the ILN class of Study 1, the "Help Request" feature of the NetSupport School software is viewed most favorably by the students.

Table 4. Summary of student opinions of NetSupport School and Tablet PC use in the classroom.

Use of NetSupport School Software	Average Response* (N=10)
NetSupport School program was helpful in improving my performance.	3.78
NetSupport improved the instructor’s teaching effectiveness.	3.78
NetSupport enhanced the teacher’s ability to measure student learning.	3.67
The “Help Request” feature of NetSupport was useful to me.	4.00
The “Lock,” “Internet Control,” and “Applications Control” features helped me pay attention to the lecture.	3.75
My overall experience with NetSupport School has been positive.	3.78
Use of Tablet PCs	Average Response* (N=10)
Using the Tablet PCs in class helped me improve my performance.	3.56
Tablet PC use improved the instructor’s teaching effectiveness.	3.78
Tablet PCs available for use during class created a better learning environment than without them.	3.88
I found “Windows Journal” and the stylus intuitive and easy to use.	3.67
I would like to have Tablet PCs available for student use in other courses.	3.56
My overall experience with tablet PCs has been positive.	3.89

*Note: For each question, the response scale is as follows: 4 – Strongly Agree, 3 – Agree, 2 – Disagree, 1 – Strongly Disagree, 0 – No Opinion.

4.2.4 Survey on Note-Taking Strategies: Cañada and SFSU

For both Dynamics classes of fall 2006 (the ILN Cañada class and the non-ILN SFSU class), the instructor used a Tablet PC in combination with PowerPoint and Windows journal to deliver class material. The Tablet PC has replaced the blackboard and chalk (or whiteboard and pen), making it possible to have an electronic record of all the lecture notes prepared before and during class. An outline of the day’s lecture was usually prepared using a combination of PowerPoint and Windows Journal presentations. During lectures, the instructor added and saved handwritten annotations, sketches, derivations, illustrative problems and problem solutions to the lecture notes which were then posted on the class website. This allowed subject material to be covered more efficiently, and adjustment of class agenda to be done more easily to accommodate student progress. This also produced a change in the note-taking strategies of students in the class. To understand the effect of the delivery of the course content brought about by the instructor’s use of the Tablet PC, a survey of note-taking habits and attitudes of students was administered in the two fall 2006 Dynamics classes.

In the survey, students in both groups indicated changes in their note-taking habits. Among SFSU students 54% of students reported not taking any notes during class and 31% taking less

notes in their dynamics class compared to other classes. For Cañada students, 40% do not take any notes and 50% take fewer notes than other classes. Both groups found that the posted lecture notes were useful, that the instructor's use of Tablet PC increased teaching effectiveness, that taking fewer notes during class has allowed them to focus more on the lectures, and that they preferred notes created using Tablet PCs over those using blackboard and chalk. Among the advantages of this Tablet PC use by the instructor as noted by students include less effort on keeping up with lecture notes and more focus on understanding and participating in the lecture, better graphics (color and computer generated), better reliability compared to student-generated notes, and ease of editing by both students and instructor.

4.3 Analysis: Study 2

The observed differences in student performance between the ILN and non-ILN classes of Study 2 are similar in nature but, in some instances, less dramatic than the observed differences between the ILN and non-ILN classes of Study 1. The differences in the quizzes and homework were statistically significant for both studies but the gains in Test Average and Final Exam are not statistically significant for Study 2. The less dramatic results for Study 2 (fall 2006) can be attributed to a number of factors including the small class sizes, and the added benefit of instructor's use of Tablet PC during lectures for the non-ILN SFSU 2006 class of Study 2. As revealed by the survey of students' note-taking strategies and habits, students in both the ILN and non-ILN classes of Study 2 perceived an increase in student learning and teaching effectiveness as a result of the instructor's Tablet PC use during lectures. For the non-ILN Cañada 2004 class of Study 1, the blackboard was the main medium of delivering content during lectures, and hence did not have the benefits gained from the instructor use of Tablet PC during lectures. Furthermore, the instructor believes that the lessons learned in the ILN Cañada 2006 class of Study 2 helped improve teaching effectiveness not only in the ILN class but in the non-ILN class as well. For instance, many of the common misconceptions, difficulties and problems that students exhibited in the ILN class during interactive problem-solving sessions were discussed and addressed by the instructor in the non-ILN class.

5. SUMMARY AND CONCLUSIONS

Although the sample sizes use in the studies done here were small, results show that the interactive learning environment produced statistically significant improvements in student performance compared to the traditional instructor-centered learning environment. These gains can be attributed to enhanced two-way student-instructor interactions, real-time assessment and feedback on student performance, individualized instruction and early intervention, increased student engagement, and enhanced and more efficient delivery of content.

The Interactive Learning Network also resulted in better student engagement as evidenced by higher attendance rates, higher on-time completion of homework, and more time spent on assigned tasks outside class time. Students also expressed positive attitude towards the use of ILN model of instruction, and towards student and instructor use of Tablet PCs in the classroom. The instructor reported increased ability to identify and address common student misconceptions

early in the learning process thereby reducing student frustrations. This early assessment of student learning sometimes presented a need for the instructor to adjust course material, making the class more dynamic and more responsive to the needs of the students.

The use of Tablet PCs in the classroom also resulted in a number of distinct advantages that could have contributed to the improved student performance. From the students' point of view, the use of Tablet PCs during lectures provided enhanced note-taking ability, and improved ability to organize class materials and integrate hand-written notes and course materials. This makes a Tablet PC highly adaptable to individual student's learning strategies⁴. From the instructor's point of view, the use of PowerPoint and Windows Journal in presenting material coupled with the ability to incorporate hand-written annotations, sketches, mathematical equations and derivations, and animations increased teaching efficiency by allowing the instructor to cover more material during a shorter period of time. These class notes with annotations generated during lectures can easily be stored in electronic format and be made available for student use outside class. Having these notes available to students provided additional benefits – the students were able to focus on the lecture and participate more actively rather than be absorbed in note taking.

The sample sizes involved in the studies done here are small, and bigger class sizes are needed for further studies to verify that the benefits of individualized instruction, immediate assessment and feedback, early intervention and increased student engagement brought about by the Interactive Learning Network model of instruction can be extended to larger class sizes. Furthermore, the studies should be done in a larger institution with multiple sections of the course being targeted to ensure that the experimental and control groups are comparable in order to increase the reliability of the results. These studies should attempt to isolate the impact of the various components of the Interactive Learning Network on student learning to determine whether the immediate feedback through instant polling during lectures, or the guided questions during problem solving, or the individual monitoring of student progress, or the individual assistance and instruction, or some combinations of these factors are responsible for student improved performance.

The persistent decline of student enrollment in STEM (Science, Technology, Engineering, and Mathematics) majors and the increasing importance of these fields in our nation's global competitiveness warrant the development of pedagogies that develop quantitative and analytical skills to maximize students' opportunity for academic success in these highly demanding fields. The Interactive Learning Network model of instruction developed using wirelessly networked Tablet PCs has the potential to be a more effective teaching pedagogy compared to traditional instructor-centered teaching environments, and should be applied to math, science and other engineering courses with traditionally high attrition rates.

6. ACKNOWLEDGEMENTS

This project was supported by Hewlett Packard through the Technology for Teaching grant, and the @ONE Scholar Program. The author would also like to thank Darla Cooper and Michelle

Barton of the @ONE Scholar Program, and Charles Iverson of Cañada College for invaluable input, discussions, comments and suggestions.

7. REFERENCES

¹ Birk, J., and J. Foster. "The importance of Lecture in General Chemistry Course Performance." *Journal of Chemical Education* 70 (1993): 180-182.

² Meltzer, D. E., and K. Manivannan. "Promoting Interactivity in Physics Lecture Classes." *The Phys. Teacher* 34 (1996): 72-76.

³ Felder, R.M., G.N. Felder, and E.J. Dietz. "A Longitudinal Study of Engineering Student Performance and Retention. V. Comparisons with Traditionally-Taught Students," *J. Engr. Education*, 87(1998): 469-480.

⁴ Rodger, S.H. "An Interactive Lecture Approach to Teaching Computer Science." Proceedings of the twenty-sixth SIGCSE technical symposium on Computer science education, 1995, Nashville, Tennessee, United States, 278 – 282.

⁵ Beekes, W. "The 'Millionaire' Method for Encouraging Participation." *The Journal of the Institute for Learning and Teaching* 7 (2006): 25-36.

⁶ Rummel, N., and H. Spada. "A Learning to Collaborate: An Instructional Approach to Promoting Collaborative Problem Solving in Computer-Mediated Settings." *The Journal of the Learning Sciences* 14 (2005): 201-241.

⁷ Koile, K., and D.A. Singer. "Development of a Tablet-PC-based System to Increase Instructor-Student Classroom Interactions and Student Learning." Proc WIPTE 2006 (Workshop on the Impact of Pen-Based Technology on Education), Purdue University, April, 2006.

⁸ Ellis-Behnke, R., J. Gilliland, G.E. Schneider, and D. Singer. "Educational Benefits of a Paperless Classroom Utilizing Tablet PCs." Massachusetts Institute of Technology, Cambridge, Massachusetts, 2003.

⁹ Colwell, K. E. "Digital Ink and Notetaking," *TechTrends* 48 (2004): 35-39.

¹⁰ Goodwin-Jones, B. "E-Books and the Tablet PC." *Language Learning & Technology* 7 (2003): 4-8.

¹¹ Shute, V. *Handbook on Research on Educational Communications and Technology Research and Development Division, Educational Testing Service*. Princeton, New Jersey, 1994.