

IMPACT OF TABLET PC-ENHANCED INTERACTIVITY ON STUDENT PERFORMANCE IN SOPHOMORE-LEVEL ENGINEERING DYNAMICS COURSE

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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 applying these interactive teaching and learning methods 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, that 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 interactive model of instruction in sophomore-level Dynamics course show a statistically significant positive impact on student performance. Additionally, results of student surveys show overwhelmingly positive student perception of

the effects of this 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

Introduction

The fundamental problem addressed by this study is the lack of active participation of students during classroom instruction in the traditional lecture setting. Studies have long shown that the traditional instructor-centered lecture format is an ineffective learning environment, and that active participation, as well as interactive and collaborative teaching and learning methods, are more effective in various areas of science and engineering education including Chemistry [1], Physics [2], Engineering [3], and Computer Science [4]. 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 solving [6], and the use of wireless Tablet PC technology [7].

Tablet PCs are essentially laptop computers that have the added functionality of simulating paper and pencil by allowing the user to use a stylus and write directly on the computer screen to create electronic documents that can be easily edited using traditional computer applications. This functionality makes Tablet PCs more

suitable than laptop computers in solving and analyzing problems that require sketches, diagrams, and mathematical formulas. Combined with wireless networking technology, Tablet PCs have the potential to provide an ideal venue for applying previously proven collaborative teaching and learning techniques commonly used in smaller engineering laboratory and discussion sessions to a larger, more traditional lecture setting. Currently, the range of use of Tablet PCs in the classroom includes enhancing lecture presentations [8], digital ink and note taking [9], E-Books (books in electronic format) that allow hyperlinks and annotations [10], and Tablet-PC-based in-class assessments [7]. 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 a model that is highly interactive. In this paper, this model will be referred to as an Interactive Learning Network (ILN). Figure 1 is a schematic of the ILN model of instruction showing the various two-way interactions between the instructor and the students during lecture sessions. This paper will also 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 the 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 model, the Interactive Learning Network can lead to:

- better student performance 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 the 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 and more time spent on assigned tasks outside class time, and
- higher student perceived confidence in their mastery of the subject.

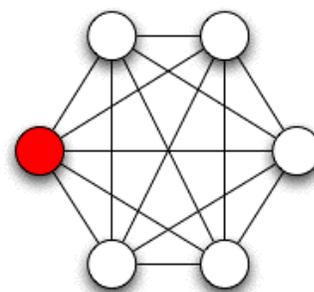


Figure 1. Schematic of the Interactive Learning Network showing the interactions between the instructor (red) and the students (white).

Methodology

The Dynamics Class at Cañada College

Cañada College is part of the 108-school California Community College system, and is one of 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 fifteen to twenty students transferring to a four-year institution every year. The Dynamics course at Cañada College is a three-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 sixteen weeks, and covers topics in particle and rigid body plane motion kinematics and kinetics. In the traditional

instructor-centered approach to teaching Dynamics, the instructor presents new concepts, derives important equations related to the concepts, and then presents a collection of illustrative sample problems that are solved by the instructor in detail. Additional examples are assigned as homework problems. Periodic assessment of student learning is done in the form of quizzes and tests given during the duration of the semester. Success in this course using this approach has been limited, as Dynamics has traditionally been an engineering course that has high attrition rates.

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, that 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 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 (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 Dynamics classes will be the focus of this paper.

The Two Case Studies

To study the impact of the Interactive Learning Network model of instruction, two case studies were done: Study 1 involved comparing two Cañada College Dynamics courses, the Fall 2005 class that used the ILN model, and the Fall 2004 class that used the traditional instructor-centered model. Study 2 involved comparing two Dynamics courses from two different institutions in the Fall 2006 semester, a class at Cañada College that used the ILN model, and a class at San Francisco State University that used the traditional model.

Study 1: Cañada College Fall 2005 and Fall 2004. The Interactive Learning Network was first implemented in a Dynamics class of seventeen students at Cañada College in Fall 2005. Since Cañada College offers only one section of this class every fall semester, a comparison group could not be established for

the study. Instead, the performance of the Fall 2005 experimental group that used the ILN model was compared with that of the Fall 2004 Dynamics class of eighteen 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.

Table 1 shows a comparison of student demographics for the two Dynamics classes that were compared in this part of the study. The two Dynamics classes were very similar demographically. The Fall 2005 class (ILN model) started with seventeen students, and the Fall 2004 (non-ILN) class started with eighteen students. For both years, more than 80% 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.

Demographics	Experimental Fall 2005 (ILN)		Comparison Fall 2004 (non-ILN)	
	N	%	N	%
Gender				
Female	1	5.9%	3	16.7%
Male	16	94.1%	15	83.3%
Total	17		18	
Ethnicity				
Afro-American	0	0.0%	0	0.0%
Asian	4	23.5%	3	16.7%
Caucasian	6	35.3%	4	22.2%
Filipino	0	0.0%	2	11.1%
Hispanic	5	29.4%	5	27.8%
Other	2	11.8%	4	22.2%
Total	17		18	
Major				
Civil Engr	1	5.9%	5	27.8%
Mechanical Engr	13	76.5%	11	61.1%
Electrical Engr	1	5.9%	1	5.6%
Computer Engr	0	0.0%	1	5.6%
Other	2	11.8%	0	0.0%
Total	17		18	

Table 1. Demographic comparison of Fall 2005 and Fall 2004 Dynamics students.

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 (SFSU), 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 comparison 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 was the student use of Tablet PCs and NetSupport School in the Cañada College class to create the Interactive Learning Network. Students in the

Cañada class use Tablet PCs to take notes, to analyze and solve problems using software applications such as Window's Journal, MATLAB and Excel, and to interact with the instructor through NetSupport School software's Instant Survey, Electronic Whiteboard, Chat and Help Request features.

The Dynamics course at SFSU was a three-unit lecture course that met three hours a week for fifteen weeks, one week shorter than Cañada's sixteen-week course. The first fifteen weeks of the Cañada class covered topics that were 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 was

not included in the analysis and comparison of the performance of the two groups.

Table 2 shows a comparison of the demographics of the two groups of students for Study 2. The class sizes for the both classes were smaller than normal with only ten students in Cañada's Dynamics class, and seventeen 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 had a slightly higher percentage of female students (30% vs. 23.5%).

	Experimental		Comparison	
	Cañada 2006 (ILN)		SFSU 2006 (non-ILN)	
Demographics	N	%	N	%
Gender				
Female	3	30.0%	4	23.5%
Male	7	70.0%	9	76.5%
<i>Total</i>	10		17	
Ethnicity				
Afro-American	0	0.0%	0	0.0%
Asian	4	40.0%	3	17.6%
Caucasian	2	20.0%	11	64.7%
Filipino	1	10.0%	1	5.9%
Hispanic	3	30.0%	1	5.9%
Other	0	0.0%	4	5.9%
<i>Total</i>	10		17	
Major				
Civil Engr	2	20.0%	13	76.5%
Mechanical Engr	4	40.0%	4	23.5%
Electrical Engr	2	20.0%	0	0.0%
Computer Engr	0	0.0%	0	0.0%
Other	2	20.0%	0	0.0%
<i>Total</i>	10		17	

Table 2. Demographic comparison of Fall 2006 Dynamics students at Cañada College and San Francisco State University.

To better compare the two groups of students in Study 2, an online first week survey was given to both groups in the beginning of the

semester. The first week survey determined, among other things, the number of units students were taking for the semester, the

expected number of hours of work, the number of hours a week students were planning to devote to studying for the class, the percentage of time students planned to study in a group, and the expected grade for the class.

Table 3 shows a summary of the responses of the students to the online first week survey. As can be seen, Cañada College students were

taking on the average 3.1 less units, were expecting to work about 5.2 hours more every week, were expecting to study slightly more for the Dynamics class, had about the same expected average grade for the class, and a slightly higher but statistically insignificant grade in the prerequisite Physics course when compared with the students from SFSU.

Question	Experimental Cañada (ILN) N=10	Comparison SFSU (non-ILN) N=17
How many units (including this class) are you taking this semester?	11.1	14.2
Approximately how many hours a week are you planning to work this semester?	19.0	13.8
How many hours a week (outside class time) do you expect to study for this class?	6.5	5.9
What grade do you expect in this class? (Scale: A=4.0, B = 3.0, C=2.0, D=1.0, F=0.0)	3.6	3.5
What was your grade in the first semester Physics class, or its equivalent? (Scale: A=4.0, B = 3.0, C=2.0, D=1.0, F=0.0)	3.0	2.7

Table 3. Comparison of responses to the online first week survey. The figures shown in the table represent the average of the responses given by the students in each class.

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 both groups to ascertain whether the students' levels of preparation for the class were comparable. The diagnostic test consisted of ten multiple-choice questions measuring student knowledge of basic Mechanics concepts and their applications. These questions involved topics that were covered in the prerequisite Physics course. Results of this diagnostic test showed no statistically significant difference in the average and median scores of the two student groups.

Procedures

Classroom Formats

Table 4 summarizes the similarities and differences in the classroom structure of the experimental and comparison groups of the two case studies. For the two experimental groups that used the ILN model, students used Tablet PCs during lectures, and interactivity during delivery of new topics was achieved using NetSupport's Instant Survey and electronic whiteboard features that allow participation from all students. As previously described, most of the illustrative examples were given as

exercises that students solved using the Tablet PCs while the instructor observed and guided their progress, and provided individual assistance through the NetSupport School software. For the comparison, non-ILN groups, the class structure was instructor-centered and non-interactive both during the introduction of new topics and solutions of illustrative examples.

The last row of Table 4 shows that for three of the four groups (2005 Cañada, 2006 Cañada, and 2006 SFSU) the instructor used the same method in generating and delivering lecture notes to the students. For these three groups, the instructor used a Tablet PC in combination with PowerPoint and Windows Journal to deliver class material. The Tablet PC 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 that were then posted on the class website. This allowed subject material to be covered more efficiently and adjustment of the class agenda to be done more easily to accommodate student progress. For the non-ILN Fall 2004 Cañada group, the traditional chalk and blackboard was the main medium for generating and delivering lecture notes.

Classroom Format	Study 1		Study 2	
	Experimental Cañada 2005 (ILN)	Comparison Cañada 2004 (non-ILN)	Experimental Cañada 2006 (ILN)	Comparison SFSU 2006 (non-ILN)
Student Use of Tablet PC	Yes	No	Yes	No
Lecture Delivery of New Material	Interactive with Students using NetSupport	Not Interactive	Interactive with Students using NetSupport	Not Interactive
Presentation of Illustrative Sample Problems	Interactive with Students using NetSupport	Instructor only	Interactive with Students using NetSupport	Instructor only
Instructor Lecture Notes	Tablet PC	Blackboard and Chalk	Tablet PC	Tablet PC

Table 4. Comparison of classroom formats for the experimental and comparison groups of Study 1 and Study 2.

Data Analysis

To measure the impact of the Interactive Learning Network on learning, the performance of the ILN and non-ILN groups for each of the two case studies were compared. For each case study, scores of the two groups of students on fifteen homework sets, five quizzes, four tests,

and a final examination were compared. Identical homework problems were assigned from the textbook for the ILN and non-ILN groups within the same case study (Study 1 or Study 2). The average scores each group were computed and independent Student *t*-tests were used to evaluate the statistical significance of the results.

To determine students' attitudes towards the use of Tablet PCs and the Interactive Learning Network model of class instruction, an attitudinal survey was given to the two experimental groups at the end of the semester. This survey has two parts: one on NetSupport School use and one on student use of Tablet PCs. It was designed to determine students' perceptions of the impact of the ILN model on student learning and teaching effectiveness. Simple averages of student responses were computed to summarize the results.

For the two student groups of Study 2, additional surveys were designed and administered. An end-of-semester survey was designed to determine students' attitudes towards the course, study habits during the semester, expected grade in the course, and confidence in their performance in and knowledge of the class. Simple averages of student responses were computed and compared between the experimental and comparison groups.

Results

Study 1: Cañada College Fall 2005 and Fall 2004

In this section, performance of the two groups of students, Fall 2005 class with ILN format and the Fall 2004 class with a traditional format, will be compared. Additionally, results of the attitudinal survey on student perception of and satisfaction with the ILN model of instruction and the use of Tablet PCs will be presented.

Class Performance Comparison. A summary of the comparison of the performances of the two groups of Dynamics students is shown in Table 5. Quiz Average is the average of five quizzes, Homework Average is the average of fifteen homework sets, and Test Average is the average of four tests. The last column of Table 5 is the difference between the average scores received by Fall 2005 students and Fall 2004 students. There is a significant difference between 2004 and 2005 results in each of the categories, with the biggest differences for homework and quizzes. The difference between the 2004 and 2005 results is statistically significant for homework [$t(1,19) = 3.084$, $p < .01$], for quizzes [$t(1,27) = 3.425$,

Categories	Experimental	Comparison	Difference*
	Fall 2005 (ILN) N=15	Fall 2004 (non-ILN) N=15	
Quiz Average	84.0	71.4	12.6
Homework Average	92.8	83.0	9.8
Test Average	86.1	77.0	9.1
Final Exam	84.9	70.9	14.0

Table 5. Comparison of Dynamics student performance for fall 2005 and fall 2004. For each category, the difference in the results for the ILN and the non-ILN groups is statistically significant [$p < .05$].

$p < .005$], for tests [$t(1,22) = 2.393$, $p < .05$] and for the final exam [$t(1,20) = 2.308$, $p < .05$].

Attitudinal Survey on the Use of Tablet PC and NetSupport School: Fall 2005 only. Table 6 summarizes the results of the attitudinal survey administered in the Fall 2005 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 creating a better learning environment.

Use of NetSupport School Software Response Scale: 4 – Strongly Agree, 3 – Agree, 2 – Disagree, 1 – Strongly Disagree, 0 – No Opinion.	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 Response Scale: 4 – Strongly Agree, 3 – Agree, 2 – Disagree, 1 – Strongly Disagree, 0 – No Opinion.	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

Table 6. Summary of student opinions of NetSupport School and Tablet PC use in the classroom.

Study 2: Fall 2006 Dynamics at Cañada College and San Francisco State University

The performance of the two groups of Dynamics students, the ILN Cañada class and the SFSU class that use the standard instructor-

centered approach will be compared in this section. Additionally, results of the survey on student engagement, expectations and confidence on mastery of course content will be presented.

Class Performance Comparison. Table 7 shows a comparison of the performance of the two groups of Fall 2006 Dynamics students. Quiz Average is the average of five quizzes, Homework Average is the average of the fourteen homework sets, and Test Average is the average of four tests. The last column of Table 7 is the difference between the average scores received by Cañada students and SFSU students. It is significant to note that none of the Cañada students withdrew from the class while four (or 24% of the original seventeen) 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 [$t(1,20) = 5.108$, $p < .001$] and Homework Average [$t(1,14) = 2.178$, $p < .05$]. The differences for the Test Average and Final Exam are not statistically significant. However, the corresponding letter grade for the Test Average was a “B” for the Cañada College class, and a “C” for the SFSU class. Furthermore, the difference of 6.7 points on the Test Average most likely would have been statistically significant if the class sizes were larger.

Categories	Experimental Cañada (ILN) N=10	Comparison 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

Table 7. Comparison of Fall 2006 dynamics student performance for the Cañada College class and the SFSU class. The difference is statistically significant [$p < .05$].

End-of-Semester Surveys: Levels of Student Engagement, Expectations and Confidence.

For this research, student level of engagement in the course was indicated by their attendance and time spent studying for the course outside class time. 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. Table 8 shows that the average student-estimated number of hours of absence was much higher for the SFSU class. The table also indicates that

the end-of-semester student-estimated number of hours of study outside class time was higher for Cañada than SFSU. For Cañada students, the average of 7.2 hours a week of study represented an increase compared to the first-week survey estimate of 6.5 hours. For SFSU, the average of 5.2 hours a week was lower than the first-week survey estimate of 5.9 hours. These survey results, showing better attendance and more study hours, are indications that the Cañada group was more engaged in the course than the SFSU group.

Categories	Experimental	Comparison
	Cañada (ILN) N=10	SFSU (non-ILN) N=17
Student-estimated number of hours of absence	2.3	8.5
End-of-semester student-estimated number of hours a week of study outside class time	7.2	5.2
First-week survey estimated number of hours of week outside class time students are planning to study	6.5	5.9
Frequency of studying with at least one other student Never = 0, Seldom = 1, Sometimes = 2, Often = 3, Always = 4	1.5	1.5

Table 8. Summary of survey results on student engagement.

Table 9 shows a comparison of the averages of student expected grades at the beginning of the semester based on the first-week survey, the end-of-semester survey, and the actual grade obtained in the class. Although student expectations in the beginning of the semester were very similar, the expectations in the non-

ILN SFSU class decreased dramatically at the end of the semester, both compared to their initial expectations and when compared to the ILN Cañada class. For both groups, the expected grade at the end of the semester was slightly higher than the actual class grade.

Grades (Scale: A=4.0, F=0.0)	Experimental Cañada (ILN) N=10	Comparison SFSU (non-ILN) N=13	Difference (Cañada – SFSU)
Expected Grade (First Week Survey)	3.6	3.5	0.1
Expected Grade (End of Semester)	3.4	2.9	0.5
Actual Grade	3.3	2.7	0.6

Table 9. Comparison of student expected grades in the beginning of the semester, expected grades at the end of the semester, and actual grades.

The end-of-semester survey also measured student attitudes 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 taken or were taking, Cañada students found the class between “as difficult” and “slightly more difficult” while SFSU students found it to be between “slightly more difficult” and “much more difficult.” When asked to compare the

amount of study time spent in the Dynamics class compared to other 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.”

Question	Experimental Cañada (ILN) N=10	Comparison SFSU (non-ILN) N=17
Compared to other Engineering or Science courses you have taken or you are currently taking, how difficult is the material covered in this class? Much easier = 0, Slightly easier = 1, About the same = 2, Slightly more difficult = 3, Much more difficult = 4	2.8	3.3
Compared to other Engineering or Science courses you have taken or you are currently taking, how much time did you spend studying for this class? Much less = 0, Slightly less = 1, About the same = 2, Slightly more = 3, Much more = 4	2.4	3.2
How confident are you about having learned the material covered in this class? I should take the class again = 0, Not confident = 1, Neutral = 2, Confident = 3, Very confident = 4	3.2	2.3

Table 10. Summary of the end-of-semester survey results on confidence in and attitude towards the Dynamics course.

Attitudinal Survey on Use of Tablet PCs and NetSupport School: Cañada only. A survey of student opinions on the use of NetSupport School and Tablet PCs in the classroom was administered to the Fall 2006 Cañada class at the end of the semester. The results of the survey are shown in Table 11. As with the ILN class of Fall 2005, the “Help Request” feature was perceived most positively by students. Most students agreed or strongly agreed that both the NetSupport School and Tablet PCs had

positively impacted their performance in class, and improved teaching effectiveness. When asked the open-ended question what they like most about the NetSupport School software and the Tablet PCs, students responses included increased attentiveness and focus during lectures, real-time assessment of their knowledge through polling, immediate feedback on their work, increased one-on-one time with the instructor, ease of communication with instructor, and quick assistance when needed.

Table 11. Summary of student opinions of NetSupport School and Tablet PC use in the classroom.

Use of NetSupport School Software Response Scale: 4 – Strongly Agree, 3 – Agree, 2 – Disagree, 1 – Strongly Disagree, 0 – No Opinion.	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 PCsResponse Scale: 4 – Strongly Agree, 3 – Agree, 2 – Disagree,
1 – Strongly Disagree, 0 – No Opinion.**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

Summary And Conclusions

In assessing the impact of the Interactive Learning Network on student performance, it is important to determine how the different components of the model positively or negatively affected student learning. One of the most important components of the Interactive Learning Network teaching model is the immediate assessment of student learning and feedback on their performance. Research on learning theory has long shown that immediate feedback is an effective tool in increasing learning efficiency[11]. For the case study at hand, the effect of immediate feedback can be seen in quiz and homework scores of the ILN classes. As a result of solving problems in class with the instructor’s guidance, students not only learned the material but gained confidence 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 interactive classes were observed to be much higher compared to the traditional instructor-centered classes. This difference maybe attributed to a tendency observed by the instructor for students in the non-interactive classes to delay studying class material until immediately before a test. For example, during exam review sessions many of the questions raised by students in the non-interactive classes were similar to those raised by students in the interactive classes much earlier in the learning process.

Students in the interactive classes also attributed their improved performance to 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 useful by the students because it allowed 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 frustration when solving problems on their own. 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 Interactive Learning Network resulted in better student engagement as evidenced by lower attrition, higher attendance rates, and more time spent on assigned tasks outside class time. Students also expressed positive attitudes towards the use of the ILN model of instruction, and towards student and instructor use of Tablet PCs in the classroom.

The use of Tablet PCs in the classroom further resulted in a number of distinct advantages that could have contributed to the improved performance of the ILN students. From the students’ point of view, the use of Tablet PCs during lectures provided enhanced note-taking ability, and improved their ability to organize

class materials and allowed them to integrate hand-written notes and course materials. These features make a Tablet PC highly adaptable to individual students' learning strategies [4]. 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, derivations, and animations increased teaching efficiency by allowing the instructor to cover more material during a shorter period of time. These class notes, along with annotations generated during lectures, can easily be stored in electronic format and made available for student use outside class.

For the two case studies considered in this paper, there was a statistically significant improvement in performance on homework and quizzes for the interactive classes as compared to the traditional classes. The observed gains in the Test Average and Final Exam were statistically significant for the Fall 2005 interactive class, and not statistically significant for the Fall 2006 class, due primarily to higher scores of the Fall 2006 non-ILN SFSU class compared to the Fall 2004 non-ILN Cañada class. Although the average scores on tests and the final exam for the Fall 2006 non-ILN SFSU class were higher than those for the Fall 2004 non-ILN Cañada class, a statistical comparison of the two non-ILN groups could not be justified because the Cañada group was not given a diagnostic test to ascertain whether the groups were comparable. However, the observed better performance of the SFSU class on the tests and the final exam can be attributed to a number of factors including the small class sizes, and the added benefit of the instructor's use of Tablet PC during lectures for the non-ILN SFSU 2006 class.

As revealed by the survey of students' note-taking strategies and habits, the SFSU class 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, the blackboard

was the main medium of delivering content during lectures. Furthermore, the instructor believes that the lessons learned in the ILN Cañada 2006 class 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 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.

In summary, the studies done here show that the interactive learning environment resulted in 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.

Implications

Classroom

The persistent decline of student enrollment in STEM (Science, Technology, Engineering, 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. Such skills will maximize students' opportunity for academic success in these highly demanding fields. The results of the limited studies done here indicate that the Interactive Learning Network developed using wirelessly networked Tablet PCs has the potential to be a more effective teaching pedagogy compared to traditional instructor-centered teaching environments.

As technology is infused into the classroom, mathematics, science and engineering faculty in all levels of education should consider using Tablet PCs over laptop and desktop computers in the classroom. Networked Tablet PCs enable

students and faculty to analyze problems, collect data, take notes, and combine hand-written and other electronic class materials. They also offer the flexibility to write and manipulate mathematical formulas, draw sketches and add ink annotations when solving and analyzing problems.

Future Research

The sample sizes involved in the studies done were small, and bigger class sizes are needed in 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, studies should be done in a larger institution using multiple sections of the same course to ensure that the experimental and comparison groups are comparable, thus increasing 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, the guided questions during problem solving, the individual monitoring of student progress, the individual assistance and instruction, or some combinations of these factors are responsible for improved student performance.

Additionally, these studies should attempt to delineate the effects of Tablet PC use by the instructor from the effects brought about by enhanced interactivity due to student use of Tablet PCs in the classroom. This can be done by comparing student performance of three groups of students: a group with Tablet PCs used by both the instructor and the students (ILN), a second group wherein only the instructor uses a Tablet PC and only for delivering content (instructor-centered with Tablet PC), and a group wherein the instructor uses chalk and blackboard (instructor-centered without Tablet PC).

Similar studies should be done on courses with high attrition rates, courses that are traditional “bottle necks” for STEM students, and courses that are problem-solving intensive and requiring high levels of critical thinking. Finally, other software applications that promote interactivity in the classroom should be considered in conjunction with Tablet PC use.

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