Abstract

Lack of student engagement in course work is a concern for college educators. The Computer Theory course, one of four required for a computer science major, was selected for redesign because its content is abstract and complex, requiring graphical figures and mathematical notation. Tablet technology increased student engagement by introducing problem solving activities whose solutions, captured on tablets, are shared; the full process of solution development is shown and captured in tablet-based class notes; and all in-class notes were shared on a website for later review.

Keywords: Tablet Computer, Theory of Computing, Ubiquitous Presenter
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1 Deployment and Usage of the Tablets — Quick Facts

The HP tablets had their home base in room SE 102, a tablet computer classroom shown in Figs. 1, 2, and 3, but were also used at other locations around the campus.

![Figure 1: Professor Gallizzi and students in room SE102](image)

1.1 Courses Impacted

During the 2006–07 academic year the following 19 classes, taught by 6 different professors, were taught in the tablet computer lab (SE102):

- Autumn 2006, Digital Arts Computing (Debure)
Figure 2: Equipment deployed in room SE102

Figure 3: Left-hand side of room SE102
• Fall 2006, Computer Science (CS) 110 Survey of Computing (taught using the Ubiquitous Presenter [2] system) (Mauch)
• Fall 2006, CS 143 Introduction to Computer Science (Debure)
• Fall 2006, CS 221 Data Structures (Gallizzi)
• Fall 2006, CS 301 Theory of Computing (focus of our redesign, taught using the Ubiquitous Presenter [2] system) (Mauch)
• Fall 2006, CS 310 Computer Architecture (Gallizzi)
• Fall 2006, CS 410 Computer Science Seminar — 1st semester (Mauch)
• Fall 2006, CS 310 Computer Science Seminar — 3rd semester (Mauch)
• Fall 2006, CS 410 Computer Science Seminar — 4th semester (Mauch)
• Fall 2006, CS 415 Computer Networks (Gallizzi)
• Fall 2006, Sociology (SO) 160 Statistical Methods (Flaherty)
• Winter Term 2007, Culture thru the Camera’s Lens (Brunson)
• Spring 2007, CS 143 Introduction to Computer Science (Debure)
• Spring 2007, CS 221 Data Structures (taught using the Ubiquitous Presenter [2] system) (Mauch)
• Spring 2007, CS 334 Bioinformatics (Spence)
• Spring 2007, CS 360 Database Systems (taught using the Ubiquitous Presenter [2] system) (Mauch)
• Spring 2007, CS 2410 Computer Science Seminar — 2nd semester (Mauch)
• Spring 2007, CS 4410 Computer Science Seminar — 4th semester (Mauch)
• Spring 2007, CS 431 Evolutionary Computation (taught using the Ubiquitous Presenter [2] system) (Mauch)

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In addition, there were a lot of additional events, classes and meetings of groups, which used this facility whenever the regular classes were not being held. Most of these met in the room numerous times. Some, but not all, of the professors teaching in these events were given instruction in the use of the tablet features of the laptops so that they could take greater advantage of the tablet capability.

During the 2007–08 academic year the following classes were taught in the tablet computer lab (SE102):

- Autumn 2007, AT-7 Digital Arts Computing (Debure)
- Fall 2007, CS 143 Introduction to Computer Science (Debure)
- Fall 2007, CS 301 Theory of Computing (focus of our redesign, taught using the Ubiquitous Presenter [2] system) (Mauch)
- Fall 2007, CS 310 Computer Architecture (Gallizzi)
- Fall 2007, CS1 410 Computer Science Seminar — 1st semester (Mauch)
- Fall 2007, CS3 410 Computer Science Seminar — 3rd semester (Mauch)
- Fall 2007, Sociology (SO) 160 Statistical Methods (Flaherty)
- Winter 2008, WT-7 Software Engineering with Java (Mauch)
- Spring 2008, CS 143 Introduction to Computer Science (Debure)
- Spring 2008, CS 221 Data Structures (taught using the Ubiquitous Presenter [2] system) (Mauch)
- Spring 2008, CS 350 Graphical User Interface Design (Debure)
- Spring 2008, CS 411 Operating Systems (Gallizzi)
- Spring 2008, CS2 410 Computer Science Seminar — 2nd semester (Mauch)
- Spring 2008, CS4 410 Computer Science Seminar — 4th semester (Mauch)
In addition, the following professors have used the tablet computing lab for brief sessions for one or more days (discipline/event in parentheses).

- Jing Shen (Chinese)
- Beth Moses (Biology)
- Eileen Mikals-Adachi (Japanese)
- Michael Earle (Resourceful Writing class)
- Patti Cooksey-Fisher (LLV Technology Tutorials)
- Alison Ormsby (Environmental Studies)
- Jared Stark (Caribbean literatures and Film)
- Susan Harrison (CLA testing)
- Victoria Baker (Anthropology)
- Tom Oberhofer (Economics)
- Steve Sizoo (Marketing and International Business)
- David Hastings (Marine Science)
- Alexander (Ad. Sys. analysis)
- Beth Forys (Environmental Biology)

1.2 Other Tablet Activities at Eckerd College

In order to support this program, the college purchased 4 additional, identical HP tablet computers when we obtained the grant so that various professors could prepare materials on them in their offices before meeting classes in SE 102 and/or use tablets in other rooms where only the instructor would have a tablet laptop. In addition a number of new professors were given tablet laptop computers during the past two years and some of the professors received tablet computers when their computers were upgraded. Another group of professors have tried out the tablets for a week or two and are anxious to have a tablet computer of their own as soon as funds can be allocated from the Eckerd College budget. All of these have received training in using the tablet features, with the emphasis being on its use in class.
Eleven professors in the areas of computer science, physics, biology, environmental science, marine science and chemistry have a tablet PC as their office computer. Another 6 professors (in the areas of sociology, economics, theater, physics, marine science, and chemistry), plus new hires, will have tablet PC as their office computer by Fall 2007. Another 5 professors (in the areas of chemistry, Spanish, Chinese, and marine science) have tried out a tablet for a week or two and are anxious to have one as the Eckerd College budget allows.

1.3 Ubiquitous Presenter

The Ubiquitous Presenter program [2] is a very powerful program to increase student learning when tablet computers are available. This open source program was developed by Washington State University and the University of California at San Diego. Eckerd College is one of the first colleges to have successfully installed this program locally on an Eckerd server and has already had classes using tablet computers where both students and professor are running the program off of the local Eckerd server. The University of California at San Diego has received an NSF grant to train professors in the use of the Ubiquitous Presenter program and to enable them to carry on a collaborative research program to investigate increases in student learning caused by the use of this program with tablet computers. Eckerd College is one of the colleges whose applicants have been accepted to participate in this program. As a result the team from Eckerd College, Professors David Hastings (Marine Science and Chemistry) and Steven Weppner (Physics), will be two more professors who will have their own tablet computers as of Fall 2007. They will be training and encouraging professors from all disciplines in the effective use of tablet laptops.

1.4 Quick Facts

- As of May 2008, 37 classes, taught by 6 different professors have been directly impacted (they were taught in the tablet computing lab). These include:
  - 26 courses in computer science
  - 2 courses in sociology
  - 2 courses in art

- Assuming an average class size of 15, the estimated number of students impacted so far is $15 \times 37 = 555$. 

• At least 22 additional professors from natural sciences, behavioral sciences, arts, and foreign languages will be “tablet-ready” by Fall 2008.

2 Design of the Evaluation Process

For the design steps of the evaluation of our project we follow the steps mentioned in [1].

2.1 Main Goals

The main goals of our project are as follows:

• Improve student engagement in theory of computing course
• Give feedback to students in real-time for formative assessment (test, quiz, student presentation)
• Increase collaborative learning experiences and the quality of group-work exercises
• Improve student understanding of difficult theoretical concepts in computer science.
• Improve the accuracy of student notes.

2.2 Course Redesign to Achieve Goals

Initially the focus of the course redesign was on the theory of computing course, but we are already introducing a partial redesign of some of the other computer science courses mentioned in Sect. 1.1 as well. We implemented the following project components:

• Students are able to submit inked documents during the lecture using the Ubiquitous Presenter system [2]. Solutions to in-class exercises are submitted (as ink-based documents) and discussed in class, so even quiet students will speak up to defend their solution.

• Feedback is provided in real-time using UP [2], or by polling students using the “clickers” system, an in-class polling program, developed by the director of instructional technology at Eckerd College. This helps the goal to produce more powerful interaction and anonymous presentation of students’ responses.
• The results of group discussions are submitted to the whole class and are discussed immediately. This helps to meet our goal of increasing collaborative learning experiences.

• We make specific use of the pen-based capabilities. The instructor can draw figures, which will automatically be recorded on the web. This helps the goal of improving student understanding of difficult theoretical concepts in computer science and the goal of improving the accuracy of student notes.

2.3 Evaluation Questions (Research Hypotheses)
We focused on the following specific evaluation questions for the purpose of a quantitative analysis (see Sect. 4).

• After the course redesign, are students gaining a deeper conceptual understanding of
  – discrete state machines and context-free grammars in theoretical computer science

than they did before the course was redesigned?

2.4 Specific Target Learning Outcomes
We define the following low-level, specific learning outcomes:

• Student design of context-free grammars, push-down automata, and Turing machines in the theory of computing course improves.

• The number of collaborative learning experiences in the theory of computing course increases after the redesign.

• Students have a better understanding of the proof concept in the theory of computing course.

2.5 Sources of Emerging Evidence
We identified the following, quantifiable measures that can illustrate the changes that occurred in the theory of computing course, in the teaching of the theory of computing course, and in the students of theory of computing course.
• Student performance on regular course assessments (homework assignments, in-class presentations, labs, exams).

• Self-report data from student surveys (see App. B and App. C).

• Student attendance.

3 Measurement Plan

In this section we describe our plan to measure the difference in knowledge gained from tablet-based instruction vs. traditional instruction.

The content of Computer Theory courses is essentially standard in colleges and universities. At Eckerd College, there is one section, taught every Fall semester. This allows us to compare data before tablets were introduced (group 1, traditional course) with data obtained after the implementation of the tablet project (group 2, tablet-enhanced course). The differences between the two groups are held minimal, so changes should not be the result of other factors.

3.1 Measurement of Student Scores

We will compare exam scores for like-courses achieved by computer science majors instructed using the following methods.

Comprehensive exam grades: Eckerd has years of historic test data for four required courses taught traditionally (Theory of Computing, Computer Architecture, Introduction to Computer Science and Data Structures). It is anticipated that tablet taught students will achieve significantly higher scores than non-tablet taught students on these courses.

Department policy requires retention of exam questions for end-of-semester course finals and for comprehensive exams. Therefore, identical exam questions will be reused to compare the test performance of students newly instructed with tablet technology vs. those traditionally instructed for, the courses to be modified.

Longterm retention of knowledge can be measured using the change in comprehensive exam scores.

Homework grades can also be measured and compared to previous grades.

3.2 Self-report Data: Measurement using a Survey

See App. B and App. C for the forms used for a qualitative evaluation. Quantitative measures can also be obtained from the official Eckerd Col-
lege course evaluations, in particular: time on task (Q20), and perceived
difficulty level of a course (Q19).

3.3 Evidence of Classroom Environment Changes

Evidence can be measured by the following:

- Number of group work and collaboration assignments.
- Variety of formative assessment strategies: polling, in-class exercises
  submitted anonymously via UP
- Number of formative assessment events: count how often students were
  polled, count number of in-class exercises
- Percentage of course activities and assignments that require students
  to use tablet technology.
- Amount of feedback provided to students (e.g. how many corrected,
  red-inked slides?)

3.4 Other Measurement

It is suggested [1, p.11] that “good” student behavior is an indicator for
student engagement. Good student behavior can be measured by

- Class attendance (see Sect. 4.1)
- Percentage of completed homework assignments (see Sect. 4.2)
- Students arriving early, leaving late (see Sect. 4.3)

4 Comparison Evaluation Data Analysis

One objective of this project is to determine whether the use of tablet PCs
in connection with Ubiquitous Presenter [2] resulted in an improvement of
student grades in the Theory of Computing course when compared to a
traditionally taught course. We analyzed test scores and grade data for the
following courses:

- Fall 2005, CS301 Theory of Computing (taught traditionally using the
  blackboard)
Fall 2006, CS301 Theory of Computing (taught using tablet PCs and the Ubiquitous Presenter [2] system)

Fall 2007, CS301 Theory of Computing (taught using tablet PCs and the Ubiquitous Presenter [2] system)

The Fall 2005 course was taught in a traditional lecture style; paper handouts contained an overview of the material to be covered during the lecture; the blackboard was used for elaborating the material in-depth, both additional textual notes and graphical concepts were presented on the board. In-class exercises were solved on the blackboard; student solutions to in-class and homework exercises were presented by the students on the blackboard, if there was a student volunteer (which was rarely the case.) There were 9 students enrolled in this course, but we dropped one student’s data as outlier data – the student was enrolled on paper, but never showed up for any class meeting (and therefore scored 0 on all exams, quizzes, and homeworks.) So the total sample size was \( N = 8 \).

The Fall 2006 course was taught in a computer lab, equipped with tablet PCs. Every student had an HP tablet PC tc4200 in front of him/her that was connected wirelessly to the Internet. Lectures were run using the Ubiquitous Presenter (UP) software [2]; the instructor inked slides which were specifically prepared for this purpose. (The content of these slides was almost identical to the paper handouts used in the Fall 2005 course, but the layout underwent a complete overhaul, so to leave space for inked instructor or student annotations; also in-class exercises were integrated into the deck of slides.) The blackboard was not used a single time in the Fall 2006 course. If a question arose that required written elaboration, then the whiteboard feature of UP was used, and electronic ink was used instead of chalk. There were 6 students enrolled in this course, but again we dropped one student’s data as outlier data – again the student was enrolled on paper, but stopped showing up after the first week of class (and therefore scored 0 on all exams, quizzes, and homeworks.) So the total sample size was \( N = 5 \).

The Fall 2007 course was taught in the same setting as the Fall 2006 course. The slides went through minor modifications, mostly correcting typos; but otherwise remained identical to the Fall 2006 slides. There were \( N = 7 \) students enrolled.

An effort was made to keep most other variables that might influence student scores constant, or at least very similar, across the three courses. It certainly helped that the content of a Computer Theory course is essentially standard across colleges and that its content — unlike other computer science courses — does not change rapidly from one year to the next. The Fall
2005, the Fall 2006 and the Fall 2007 courses were all taught by the same instructor (Mauch), using the same textbook [3], using the same timeline for the same topics, giving the same number of quizzes, exams, and homework assignments. Individual quiz, homework, and exam questions were only altered slightly (so to prevent 1:1 copying) from course to course. Therefore the course assessments were all reasonably comparable. The one parameter that could not be controlled was the make-up of the set of students taking the course; future courses will provide us with additional data, and a statistical analysis of the data using large sample techniques will be conducted once we have collected a large enough data set needed for this purpose. The complete data set is provided in App. A.

4.1 Student Attendance

Attendance was measured sample-style by computing, for each student, the ratio of the number of submitted pop quizzes to the total number of pop quizzes given.

The mean of the attendance ratios across all students increased from 84% in Fall 2005 to 97% in Fall 2006. According to personal communications with students the tablet PCs played a big factor in this. Students found lectures taught in the redesigned style so valuable that they made every effort not to miss a single class.

This improved student behavior is an indicator for improved student engagement.

In Fall 2007 student attendance was considerably lower at 71%, which can be attributed to the change in time slot for the Computer Theory course. While in Fall 2005 and Fall 2006 the course took place twice a week from 1:30–2:50 p.m., in Fall 2007 the course took place twice a week during the unpopular time slot from 8:00–9:20 a.m.

4.2 Homework Submissions

Another way to measure good student behavior is by counting the percentage of homework assignments submitted.

The percentage of homework assignments submitted increased from 77.8% in Fall 2005 to a combined 88.9% for Fall 2006 and Fall 2007. According to personal communications with students the tablet PCs indirectly played a role in this. Students being completely lost occurred less frequently, since there was always the opportunity to access web-stored inked solutions to sample exercises; in the traditional course the students’ notes were some-
times too inaccurate to be of any use, so students did not know “where to get started”.

This improved student behavior is an indicator for improved student engagement.

4.3 Students Arriving Early and Leaving Late

In Fall 2006 students taking the redesigned, tablet-based course very often would arrive early in the classroom and prepare themselves by logging into the UP system, browsing through the web-based repository of the last lecture’s slides, and previewing the slides of the current lecture. This student behavior was not observed in the traditional course in Fall 2005; in part because the material to be covered in the current lecture had yet to be developed on the blackboard. In Fall 2007, this student behavior was observed rarely, probably because of the change in the time slot to 8:00 a.m.

In the redesigned course in Fall 2006 and Fall 2007 students would sometimes stay a few additional minutes, downloading the slides inked by the instructor, the inked submissions of other students, or simply discussing the results of some of the in-class polling (“How many did you get correct today?”). This student behavior was rarely observed in the traditional course in Fall 2005, when occasionally students who had fallen behind copying the notes from the blackboard had to stay a few extra minutes to complete their notes.

This improved student behavior is an indicator for improved student engagement.

4.4 Overall Student Performance

Do our data present sufficient evidence to indicate that the mean of the total numerical scores of theory of computing students taught with tablet PCs and UP is larger than the mean of the total numerical scores of theory of computing students taught the traditional way? The small-sample technique used in the following requires the sampled populations of student scores to be normal, or approximately so [4, p.362]; there is no reason to suspect that this requirement is violated for our student data.

Let $\mu_1$ be the mean score when the course is taught using tablet PCs and let $\mu_2$ be the mean score when the course is taught using the traditional way. We test the null hypothesis $H_0 : \mu_1 = \mu_2$ versus the alternative hypothesis $H_A : \mu_1 > \mu_2$. The sample means are $\bar{x}_1 = 73.14$ for the aggregated Fall 2006 and Fall 2007 courses and $\bar{x}_2 = 70.11$ for the traditional course in Fall 2005.
The standard deviations of the two samples are calculated as $s_1 = 14.6832$ and $s_2 = 23.3096$.

The rule of thumb [4, p.381] suggests that the two variances are close enough to use the pooled estimate $s^2$ for $\sigma^2$ as follows:

$$s^2 = \frac{(n_1 - 1)s_1^2 + (n_2 - 1)s_2^2}{n_1 + n_2 - 2} = \frac{(12 - 1)215.60 + (8 - 1)543.34}{12 + 8 - 2} = 343.05$$

So the test statistic ("Student $t$") is

$$t = \frac{\bar{x}_1 - \bar{x}_2 - D_0}{\sqrt{s^2(1/n_1 + 1/n_2)}} = \frac{73.14 - 70.11 - 0}{\sqrt{343.05(1/12 + 1/8)}} = 0.3582.$$ 

The degrees of freedom are computed by the formula

$$df = n_1 + n_2 - 2 = 12 + 8 - 2 = 18.$$ 

For $\alpha = 0.05$, we could reject $H_0$ if $t > 1.734$; since the observed value of the test statistic does not exceed the critical value $t_{0.05} = 1.734$, we cannot reject the null hypothesis.

So although we have observed an increase in the mean score from the traditional to the tablet-based course, we cannot yet conclude that this increase is statistically significant. We will have to wait for additional data and then repeat this analysis. But the trend observed so far looks promising.

4.5 Final Exam Questions Scores Analysis

Since the total numerical scores examined in Sect. 4.4 include components which are not directly related to student learning (e.g. attendance and class participation) [5], we now focus on a numeric score that is directly linked to students’ performance.

An in-depth analysis of the test scores of two of the final exam questions for the Fall 2005 semesters, and the Fall 2006 semester is presented here. We compared the scores of individual questions. The questions themselves were very similar in nature; the only changes made from Fall 2005 to Fall 2006 were replacing some of the numbers to plug in, grammars to use, or example languages with different but very similar problem instances. So the difficulty level of both exams was ensured to be nearly identical.

In the following sections we picked two typical, representative questions of a theory of computing course. Final exam question 17 is asking to develop graphical representation of a finite state machine. In contrast, final exam question 12 is asking for the manipulation of a given context-free grammar,
a task that is largely algebraic in nature, and which cannot be illustrated by figures. It turned out that the largest final exam score increases were found in questions that involve graphical representations such as question 17, while for questions that are algebraic in nature such as question 12 no significant increases were observed.

4.5.1 Final Exam Question 17

Question 17 of the final exam of Fall 2005 and Fall 2006 reads like this:

For the following context-free grammar (CFG) $G$, construct a push-down automaton (PDA) $M$ such that $L(M) = L(G)$.

The provided CFG was of similar difficulty for both exams. Following the same statistical data analysis procedure as in Sect. 4.4, let $\mu_1$ be the mean score of question 17 when the course is taught using tablet PCs and let $\mu_2$ be the mean score when the course is taught using the traditional way. We test the null hypothesis $H_0 : \mu_1 = \mu_2$ versus the alternative hypothesis $H_a : \mu_1 > \mu_2$. The sample means are $\bar{x}_1 = 2.6$ and $\bar{x}_2 = 2.0$. The standard deviations of the two samples are calculated as $s_1 = 0.5477$ and $s_2 = 0$ (all students scored 2 out of 3 points in Fall 2005). We use the test statistic

$$t = \frac{\bar{x}_1 - \bar{x}_2 - D_0}{\sqrt{s_1^2/n_1 + s_2^2/n_2}} = 2.4495.$$  

The degrees of freedom are approximated as

$$df \approx \left[ \frac{\left(\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}\right)^2}{\frac{(s_1^2/n_1)^2}{n_1-1} + \frac{(s_2^2/n_2)^2}{n_2-1}} \right] = 4.$$  

For $\alpha = 0.05$, we can reject the null hypotheses $H_0$ since $t > t_{0.05} = 2.132$; so for question 17 we have observed a significant increase in the mean score from the traditional to the tablet-based course.

Since question 17 deals with a problem that is graphical in nature (the PDA is a quite complex figure), the use of tablet PCs in the lecture to illustrate the CFG to PDA construction process has probably helped to clarify student understanding of this difficult theoretical concept. This is shown in Fig. 4, where the instructor’s solution to the problem is shown in colored ink, which allows for an easy connection of CFG rules to the corresponding PDA parts. Actually, two questions of this type were presented to the class.
as in-class exercises (see Figs. 4 and 6). For the first exercise in Fig. 4, the instructor started the design process by providing parts of the PDA in ink, and then asked the students to complete the design. Then, as shown in Fig. 5, an incorrect student submission has been corrected by the instructor after the class discussed the incorrect submission. Immediate feedback on common mistakes made on this type of question might have helped the students to perform better on a final exam question of this type. Then the aforementioned correct solution of Fig. 4 was presented, so students would have accurate notes. This example nicely shows how tablet PCs in connection with UP make it possible to teach the full process of solution development.

In contrast, in the Fall 2005 course the two in-class exercises shown in Figs. 4 and 6 were solved by the instructor on the blackboard — student interaction was limited since none of the students was willing to present his/her solution in front of the class on the blackboard (maybe because of the fear of embarrassment?), so students could not learn directly from their mistakes. Mistakes when copying down the notes from the blackboard might also have been a reason why none of the Fall 2005 students received full credit for this type of question in the final exam.

Figure 4: Instructor’s solution of an in-class exercise, making use of colored ink.
4.5.2 Final Exam Question 12

Question 12 of the final exam of Fall 2005 and Fall 2006 reads like this:

Use the algorithm from the lecture to eliminate Lambda-productions from the following grammar. Show the set \( N \) of nullable variables.

Again, the provided CFG was of similar difficulty for both exams. The mean score of question 12 when the course was taught using tablet PC was \( \mu_1 = 1.6 \) while the mean score when the course is taught the traditional way was \( \mu_2 = 1.625 \), obviously no significant increase (actually a slight decrease).

5 Conclusions

Comparing the traditional vs. tablet-PC based theory of computing course, final exam scores increased mainly for those questions whose solutions involves some means of a graphical representation and for which examples of such type of questions have been discussed as in-class exercises allowing ink-based student submissions. At this point our limited data set does not
show the same significant increase for questions which are mostly algebraic in nature. This is pretty much in line with our expectations. Ink drawings of finite state machines and the student submission feature for these drawings make good use of the potential of tablet PCs. In a traditional style lecture only very few, if any, students experience the opportunity to have their graphical solution to a problem reviewed and discussed by the class and the instructor. Solutions to algebraic problems can easily be announced orally, and the advantage of having inked submissions is not as obvious (still, there is the advantage of having the repository of student submissions available on the web after class.) These findings are also confirmed qualitatively by the student feedback shown in App. B.2.2.

These results suggest a course redesign of other computer science courses that also involve problems that have graphical solutions. We have already started to redesign the data structures course, which involves various pictorial representations of lists, and trees. Other courses have similar potential.

We are also looking into new ways of presenting text-based or algebraic content in a more graphical way. One idea is to use animated flow charts, rather than pseudocode to describe algorithms in the courses theory of computing, survey of computing, database systems, and bioinformatics.
Designing suitable in-class exercise for this purpose will hopefully increase student scores and student understanding in these other areas as well.

6 Project Visibility

Some of the results of our project *Tablets: The Prescription to Strengthen Student Engagement in Computer Science Instruction* have been presented at a “Teaching and Learning Conversation” in Spring 2008, which is a College-wide interdisciplinary event where instructors discuss old and new teaching strategies, an other aspects of education. We will give another another presentation of this kind in the academic year 2008/2009, where we will show the new insights of the past year to our colleagues. Also, we will prepare a paper for WIPTE 2008 which highlights some of our findings in this report.

7 Future Plans

We will continue to do formative evaluations of other Computer Science courses in addition to Theory of Computing; we have started to collect data for

- Spring 2006, CS460 Artificial Intelligence (taught traditionally using the blackboard)
- Spring 2006, CS431 Bioinformatics (taught traditionally using the blackboard)
- Spring 2006, MA143 Discrete Mathematics (taught traditionally using the blackboard)
- Fall 2006, CS110 Survey of Computation (taught using tablet PCs and the Ubiquitous Presenter [2] system)
- Spring 2007, CS221 Data Structures (taught using tablet PCs and the Ubiquitous Presenter [2] system)
- Fall 2007, CS110 Survey of Computation (taught using tablet PCs and the Ubiquitous Presenter [2] system)
• Spring 2008, CS110 Survey of Computation (taught using tablet PCs and the Ubiquitous Presenter [2] system)

• Spring 2008, CS221 Data Structures (taught using tablet PCs and the Ubiquitous Presenter [2] system)
A Grade/Score Comparison Data

This section shows grade data for the following computer science courses at Eckerd College:

- Fall 2005, CS301 Theory of Computing (taught traditionally using the blackboard)
- Fall 2006, CS301 Theory of Computing (taught using tablet PCs and the Ubiquitous Presenter [2] system)
- Fall 2007, CS301 Theory of Computing (taught using tablet PCs and the Ubiquitous Presenter [2] system)

[Because of privacy concerns, no individual grade data is provided here. The small sample size might make it possible to identify individual students, even after their names are blacked out.]

B Technology Use Feedback Evaluation (Fall 2006)

Appendix B.1 shows the feedback form that was used at midterm of the Fall 2006 semester for the following computer science courses at Eckerd College:

- CS110 Survey of Computing
- CS301 Theory of Computing

Appendix B.2 shows the data collected by this feedback form.

B.1 Feedback Form Used in Fall 2006

The tablet computers in this classroom are part of an ongoing grant project that focuses on course redesign using mobile technology. Detailed answers to the following questions will be highly appreciated. Please write your name on the top of this page (which would allow me to get back to you for feedback).

1. Active learning: To what extent did the use of tablet PCs get you actively involved as a learner?

2. Any suggestions on how to use the tablets in additional ways, so that you get even more engaged?
3. To what extent did the use of tablet PCs address potential misconceptions of content during class?

4. To what extent did the use of tablet PCs clarify difficult concepts?

5. To what extent do you feel that the use of tablet PCs increased efficiency compared to chalkboard-based courses. E.g. think about the time spent on copying notes, etc. Any suggestions on how to use the tablets to improve efficiency?

6. When turning in solutions to in-class exercises did the use of tablets and the anonymity of this process rather encourage or discourage your participation?

7. How useful is the web-based repository that allows access to all course materials? Compared to other courses, do you have easy access to course materials? Any suggestions on how to ease access?

8. What effect did the use of tablet PCs and the resulting web-based repository have on the accuracy of your notes? Any suggestions on how to use the tablet technology to improve this accuracy?

9. Any additional comments on the tablets?

B.2 Feedback Data Fall 2006

This section describes the student responses to the feedback form used in Fall 2006. (The questions of the form are shown in App. B.1.)

B.2.1 CS110 Survey of Computing Feedback

1. Responses to question 1:

- Highly! Its very important to have the computers. It allowed you to follow along and interact which helped enforce the ideas. It also allowed me to use the web to find important extra information to clarify questions.

- It is very helpful, because I can look at the slide-show at my own pace

- Being able to do an ink submission during the presentations helps a lot with understanding the concepts. Also being able to go back and access the presentations helps.
• I think they are useful, but it can be a little irrelevant since what is being shown on the tablets is identical to what is on the overhead. They are useful for the Java labs, however.
• They helped greatly for participation in class and to interact with the professor more.
• I think they are good in terms of active involvement. More people answer questions when they can write them on the computer screen, than when we are asked to answer them out loud (that at least applies to me). I enjoy the slide shows and being able to do in class activities. Overall, I think they are really good.
• With the instant submission of my answers.
• The use of these tablet PC’s has gotten me much more involved than I normally would be. They are probably the only reason I am surviving in this course.
• Not a lot. Just when answering questions in the lecture.

2. Responses to question 2:

• Some group projects in class. Exploring different functions of the computer. Learning shortcuts to make using them easier.
• Possibly offer more examples that require submissions or to increase the amount of programming for the class in which the tablets are used.
• Maybe more questions that we can write the answers on the slides and discuss in class. I think those are generally very helpful.
• Digital art. Maybe photo shop design then manipulate pictures.
• Make in-class questions
• No, but using submission to power point questions more often would be great.

3. Responses to question 3:

• High. The tablets are the most important tool. It allows us to use the web to answer questions and also clarify answers.
• Often it’s a good idea to check the slides or go back to a previous one if I didn’t get something.
• Many times tablet PC’s helped me to grasp a previously foreign concept because I could actively participate in the discussion.
4. Responses to question 4:

- The tablets were great. We could interact, submit answers and search the web if we had questions. Tablets were great at clarifying hard concepts.
- With things such as programming where we could each do our own and figure it out instead of watching the teacher.
- They helped clarify difficult concepts because you had the problem right in front of you as well as on the projector and the professor was still able to lecture on it.
- When submitting answers with use of tablet pen onto lecture screen
- Many times using table PC’s helped me to clarify difficult concepts because they made it so I could clearly see answers to difficult questions right in front of me.
- To some extent. Its good to have the notes already up so that you can pay attention to specifics.
- Not sure. Being able to run the Java program was beneficial though.

5. Responses to question 5:

- I loved the computers! It allowed me to stop copying notes so that I could focus on learning the material at that moment rather than copying. I loved that all the slides were on-line to study especially for the midterm.
- It helps me save time because I can already have the class notes and write them into mine (instead of writing notes in class, then “at home” putting them together)
- The only thing would be putting the answers to the questions in the power points on the websites after we go over it.
- Much faster connections. If anything we lose time waiting for the notes to appear and slides to change (power point)
- I think they are a great improvement and easier to see than copying notes from a chalkboard. I like how each lesson can be accessed at any time to be viewed at my leisure.
• Didn’t have to copy notes. Could access course material nearly instantly. Internet activities, try to find programs, games, etc. Certain types of useful tools for modern computers.
• Having power points instead of notes helps prevent any content confusion.

6. Responses to question 6:
• Encourage! Even if you thought your answer was wrong it was great to submit a guess and learn what you did wrong.
• Encourage
• It definitely encouraged participation because it is anonymous so no one but you knows how wrong or right you are.
• Encouraged participation because you could submit anything even if you were wrong
• It encourages because I don’t want people to see my wrong answers
• This encouraged my participation greatly because I did not have the fear of feeling stupid after a wrong answer. I simply learned from them.

7. Responses to question 7:
• Its great to access however sometimes it took awhile because it was slow
• I always re-look-up all the class materials in class, just to refresh myself (so it is very helpful)
• Access is easy but explain it more in the beginning. It was a rocky start.
• The ease of access is great and very useful. No other class I have allows me to view each lecture in my own time.
• It is very useful, actually one of the most useful tools in the course. Compared to other courses, yes, I do have easy access to course materials.
• It is very useful and yes the easy access is awesome.
• Most of my course materials are easy access on net. Its all pretty easy to access the stuff/ material
• Yes, compared to all my other courses, having access via the web has helped me greatly in getting homeworks and power point lectures.

8. Responses to question 8:

• They were great. Cleared up all my questions and allowed me to study rather than worry about organizing my notes.
• Closest accuracy I’ve ever had in note-taking
• Made everything very easy to access and get a grasp of as far as course content goes.
• Worse notes because I feel I don’t need to take them because I can look it up later.
• Most of the notes I take come from the overhead, so half of the time I’m not looking at the tablet. I find most of the usefulness of the tablets is in the problem submissions and lab work.
• I believe the accuracy was very good with using both the tablet and the web.
• They were exact copy notes. We could all get copies of submitted stuff relayed back to us.
• They were pretty good since they are the same ones we use during class.
• Very accurate notes, helped a lot.

9. Responses to question 9:

• Great tools, I love the functions! We should learn how to use them a little more in depth though; such as different thing/ shortcuts they can do.
• Somehow take the quizzes on the tablets and then after they are graded we can go back and look at answers to study with.
• We should do a mixture of chalk and tablet words
• Well, we don’t really do much on them except the submit answer part so maybe we could learn more about using the tablets to their full potential.
B.2.2 CS301 Theory of Computing Feedback

1. Responses to question 1:

- The ability to anonymously submit answers as a class is nice because I can try a problem and then have my errors addressed for the benefit of the whole class, without my name on the work.
- It in a way kept me focused for having to go through the slides with you. I enjoy being “hands on.”
- It is good/helpful to be able to answer questions on the overhead during class. Also, having the lectures prepared and able to be accessed later allows me to focus on the presentation, and take handwritten notes only about things I find especially important.
- I think being able to submit problem solutions anonymously is a great advantage of the tablets and I think they have helped me become more involved in class.
- I liked the ability to easily share guesses of solutions to problems. Its nice to be able to work together and receive feedback in class on each approach.
- They have helped only slightly, I feel they complicate the discussion and make it harder to approach the teacher about specific problems.

2. Responses to question 2:

- I think software that would allow us students to make slides might be helpful, as sort of a way for us to demonstrate more than we are that we know what were doing.
- Some function that allows students to directly take notes on the presentation, and link to specific slides (maybe a separate “folder”).
- I think it would be helpful to provide more space for submissions as I often run out of room on a slide. More interactive problems or demos for the students I think would help. Also a homework problem or two could be done online so the answer could be examined in class.

3. Responses to question 3:
I think the ease of creating visual representations of thinks like DFAs really helps follow what they do.

I thought the tablet kept us engaged but at the same time it slowed everything down way too much because of the speed of the network.

If you are unsure of something, you can look back to previous parts of the lectures/other lectures and check against stuff you do understand.

I think it helped through submitted work because if my answers were incorrect the reasoning would be discussed, thus clearing up any misunderstandings I had.

4. Responses to question 4:

- It allows the teacher to demonstrate complex ideas to us on a personal level without the need to ask.
- The ability in UP to see the professor’s pen stokes in order is nice, so I can follow the steps of a problem in order as often as I need to.
- It makes it easier to do real time problems, have students submit answers, and get immediate feedback on specifics.
- I’m not sure that the tablets helped much in this area. Some sort of interactive demos could possibly help in this area.
- Due to the way the UP program works, we can see how problems are addressed step by step. We can also go back alter to review notes.

5. Responses to question 5:

- We need our own server for UP. Submitting answers is nice, but sometimes it takes way too long.
- Students being able to create a list of specific slides they find important.
- It definitely helps having the ability to go to the notes online anytime I need them (usually during homework) and I feel that even with lagging taken into account that it presents material faster and more clearly.
• It makes it easier for students to do ex. problems. Also, it allows me to control the slides so that if I write slowly, I can finish even if the prof. has moved on.
• I think it actually distances you from the lecture and causes drowsiness and boredom because it is a lot less teacher active.

6. Responses to question 6:
• If I still dont know the answer I still feel discouraged to try and answer.
• It encouraged me to at least try if I had any clue.
• Neither. I would answer either way, and usually say when it is my answer on the screen.
• Definitely encouraged my participation but at the same time caused me to worry less knowing I would not have to submit something that I did not understand and would still be able to see an answer.
• No effect because it doesn’t bother me to be wrong. However, if I’m feeling lazy, it discourages me. But we can participate more easily vs. a chalkboard.

7. Responses to question 7:
• It helps because if I miss something it is never erased. I can go back and look at it and even go online at another time.
• The access to course materials is good and the loading time does not bother me because I can look at the projector when needed. The idea of having access to the notes all the time is more important to me.
• It’s very easy to not only access the lectures but in-class notes, which wouldn’t otherwise be possible.

8. Responses to question 8:
• My notes have essentially become the lectures
• I did not take other notes because I had access to the ones online which presented one problem. It causes me to lose the ability of only taking notes when needed and it is then often hard to look through everything to find what I need.
9. Responses to question 9:

- Often missing their pens or pens won’t come out.
- The tablets make it too easy to be distracted by the internet. I feel compelled to check my e-mail, etc. But, the short breaks make it easier to stay focused.

C Tablet Questionnaire (Spring 2007)

Appendix C.1 shows the questionnaire that was used at the end of the Spring 2007 semester for the following computer science courses at Eckerd College:

- CS221 Data Structures
- CS360 Database Systems
- CS431 Evolutionary Computation

Appendix C.2 shows the aggregate data collected by these questionnaires.

C.1 Tablet Questionnaire

The tablet computers in this classroom are part of an ongoing grant project that focuses on course redesign using mobile technology. Use the Likert scale (5=strongly agree, 4=agree, 3=neutral, 2=disagree, 1=strongly disagree) when responding to the following statements.

1. I learn well when the instructor uses a Tablet PC in the lecture and produces inked slides as lecture notes.

2. I am more engaged in the lecture when the instructor uses a Tablet PC to highlight or add material to a projected visual aid.

3. I am more engaged in the lecture when the instructor uses in-class exercises that allow me to submit answers, and get feedback, instantaneously (using a system such as Ubiquitous Presenter, or similar).

4. When turning in solutions to in-class exercises the use of tablets and the anonymity of this process encouraged participation.

5. The use of tablet PCs helped to clarify potential misconceptions of content during class.
Table 1: Responses to the questionnaires

<table>
<thead>
<tr>
<th>Question</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
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<tr>
<td>Median</td>
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<td>4</td>
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<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
</tbody>
</table>

6. The use of tablet PCs helped to clarify difficult concepts during class.

7. The web-based repository containing all inked lecture notes is easy to access and improved the accuracy of my own note taking.

8. I wish more courses would use tablet PCs.

9. I wish I had my own tablet.

10. The inked slides are legible.

Please provide any additional comments on the tablets, the Ubiquitous Presenter system, the classroom setup, etc., here:

C.2 Questionnaire Data

Table 1 shows aggregate statistics of the \( N = N_{CS221} + N_{CS360} + N_{CS431} = 3 + 9 + 6 = 18 \) responses to the questionnaires of App. C.1.
References


