

AC 2008-2895: FACULTY AND STUDENT USE OF TABLET PCS: PERSPECTIVES ON THEIR PEDAGOGICAL EFFECTIVENESS

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Faculty and Student Use of Tablet PCs: Perspectives on Their Pedagogical Effectiveness

ABSTRACT

The Tablet PC is gaining in popularity as a digital teaching tool in engineering education. Instructors report its use as a flexible platform for seamless interweaving of lectures, software demonstrations, web access and other classroom needs: a single device functionally equivalent to a blackboard, computer, computer data projector and overhead projector. Much of the emphasis to date, however, has been on the instructor's sole use of the Tablet PC: during the class period students still mostly rely on paper/pencil or traditional workstations. This paper presents instructors' and students' initial impressions on the use of Tablet PCs within selected courses in different engineering programs at the University of the Pacific.

As with any technological teaching tool, Tablet PCs have their advantages and disadvantages. Their main instructional advantage lies in their flexibility. Within the same class period, students can use the 'tablet' mode for annotating course notes using different colors or for developing a design, then link to the internet to gather data and information, and change to 'PC' mode to run a model and incorporate model results into their class notes. The simple feature that allows the screen to be oriented in different directions allows students to readily share their work and ideas with others, facilitating use of active learning group exercises in classes. One main advantage identified by students was the ability to organize and archive their class notes and associated materials. Despite some administrative issues such as boot-up time at the start of class and network connectivity issues from time to time, Tablet PCs were found to be appropriate for use in certain engineering courses and they can serve as effective multi-functional teaching and learning tools.

Introduction

Means of instruction at a university can range from the simplest and traditional, black or whiteboards, to sophisticated Tablet PC-based settings allowing full student-student and student-instructor interaction¹. A Tablet PC allows the user to annotate or draw directly on a variety of widely used software programs such as Word, Excel, or PowerPoint, together with programs specifically written for the Tablet PC, including Windows Journal and Classroom Presenter^{2,3}. In addition, within a wirelessly networked environment, students and instructors can work between and among groups while still maintaining access to design software and online resources⁴. Whether simple or technologically advanced, effective teaching requires organization, clear and interactive classroom presentations, effective use of resources, and appropriate use of technology to promote student learning⁵. The Tablet PC can serve as a useful tool to help keep students engaged and enhance student learning⁶.

Twenty-one Tablet PCs, received in 2006 as part of a Hewlett Packard "Technology for Teaching" grant, are shared among all departments at the University of the Pacific, but are currently used for different courses taught in the Civil, Electrical, and Computer Engineering, and Engineering Management programs. Some types of courses may lend themselves more readily to use of Tablet PCs than others. For example, in design courses or courses that integrate

use of online resources, modeling software, or other technologically-based exercises, in-class use of Tablet PCs can help streamline the class presentation and learning activities. Only Tablet PC use in courses at the upper division level is discussed in this paper.

Engineering Management courses discussed in this paper each had over 20 students in a section, and the instructor presented materials using a Tablet PC while students took notes on course handouts. The other three courses each had fewer than 10 students, and thus lent themselves readily to testing and use of Tablet PCs by both the instructors and the students. A student feedback survey, shown in Figure 1, was administered in each of these three courses and is discussed in later sections.

TABLET PC USE SURVEY		
Identify positive aspects of using the Tablet PC. Did you identify any advantages over taking notes using pen and paper?		
Identify negative aspects of using the Tablet PC. Did you identify any disadvantages over taking notes using pen and paper?		
Does using a Tablet PC help or hinder your ability to learn the material or follow in class? How? Can you suggest any improvements?		
Over the course of the semester, did the tablets get easier/harder/same to use as you got used to them?		
Did you print out the notes for the exam?		
For next term, would you recommend:	Keep using Tablets	Get rid of them

Figure 1. Tablet PC Student feedback survey

Tablet PC Use in Courses

This section includes a brief description of courses in which Tablet PCs were used, together with a discussion of experiences with use of the Tablet PC as a teaching and learning tool.

1. Computer Engineering Course

Computer Networks (ECPE 177) is a hands-on course in which students learn the fundamentals of how computer networks operate. The class includes an integrated lab where students have the opportunity to set up routers, switches, firewalls and local area networks (LANs). The classroom

portion of the course has traditionally relied on PowerPoint material developed by the instructor over recent years and included by the authors of the course textbook. The amount of material covered in each 80-minute class is copious and often involves many acronyms.

In Fall 2007, ECPE 177 was well-suited for the use of Tablets PCs; the class size was relatively small (eight students), the PowerPoint files were available well in advance of each class period, and the classroom had wired network support (Ethernet cables at each seat). Furthermore, some topics included material which could best be demonstrated using a networked computer (for example, examining the exchange of information between computers using protocols such as HTTP and SMTP). The use of Tablet PCs was not initially planned for this course; however, students were asked during the third week of class if they were interested in using them for note-taking and most responded positively.

The first day the Tablets PCs were used in class, each student selected one and logged into the campus network. The student was then “assigned” that Tablet PC for the remainder of the semester. Prior experience of one of the other authors had shown that on the first use, configuration files created for the user resulted in a particularly long boot-up period (up to 5 minutes). Reuse of the same computer by the same student removed this inefficiency after the first use. For subsequent classes, the instructor arrived approximately 10 minutes prior to class and unlocked the Tablet PC storage cart. Students picked their Tablet PC from the cart as they entered the classroom, booted up, and logged into the campus network. They then either downloaded a new copy of the PowerPoint presentation for the class from the course web site, or accessed a previous copy from their networked drive. While students were getting ready for the class, the instructor prepared the LCD projector and connected to his laptop computer. At the end of class, students logged out of their account, shut down the Tablet PC, and replaced them into the storage cart which also serves as the charging station.

Students learned the basics of Tablet PC use very quickly. None had used a Tablet PC before this experience. Students enrolled in this course were upper-level computer science, computer engineering, or electrical engineering undergraduates. Approximately ten minutes were spent on the first day to allow students to become accustomed to rotating the display (some students preferred a portrait orientation versus the PowerPoint slides’ typical landscape orientation), activating the stylus, saving files, and so on. Battery life was not a problem for the 80-minute class period as each Tablet PC was equipped with an auxiliary battery. The storage cart was located in the room, and power cords could easily be accessed, if needed.

Both the students’ and the instructor’s impression of the Tablet PCs’ usefulness in this particular situation was generally favorable. Previously, students would either have to take notes from the PowerPoint slides projected while trying to follow the instruction, or they printed hard copies of the PowerPoint slides and took notes on them. Tablet PCs allowed students to do both things simultaneously.

Only two disadvantages were noted while using the Tablet PCs in this course, one logistical, and the other, possibly inherent to students’ use of computers in a classroom. First, occasional reliability issues with the wireless network would cause a student to lose connectivity and so would not be able to access their network drives (hence statements of frustration such as “I can’t

find any of my files”). This problem was easily remedied by hardwiring each computer with an Ethernet cable prior to booting the computers. The second disadvantage was that of computers in a classroom setting; it was only too easy for students to periodically be tempted to surf the web instead of following the class material.

All students enrolled in the course were asked to complete the use survey (Figure 1) at the end of the term; five students responded. Four of the five students recommended continuing use of the Tablet PCs. The other observations were:

- The positive aspect identified by all was the ability to take notes directly on the slides. Students found it easier to follow the class, organize their notes, and to search later. Two of the five respondents also specifically noted that using the computers also made it easy to cross-reference information in the slides by searching the Internet.
- The two negative aspects identified were that it was easy to be distracted (surfing the web, playing games, etc.) and the Tablet PCs’ speed, i.e. boot-up times and time required to open applications, etc. Only one noted that it was more time-consuming to take notes on the computer than with pen and paper.
- Four of the five students felt the Tablet PCs helped their performance, while one was neutral. The suggestions for improvements mirrored the negative aspects; remove games from the computers and get faster computers. (The one student who recommended faster computers noted that the animations in the PowerPoint presentations helped their understanding of the material; it was not clear whether the animation speed was an issue.)
- The students were divided over whether they printed out copies of their notes (three did, two did not). Those who did print out notes said they found it easier to study from a hard copy. However, the same students also preferred to take notes on the Tablet PCs rather than on paper.

2. Engineering Management Courses

Starting with the Spring 2007 semester, the Tablet PC has been used as the primary classroom instructional means for one engineering management course per semester. These courses, project management and systems engineering, can be viewed as ‘professionally-oriented’ engineering courses in that, although technically based, they are not as analytically intensive as most engineering and computer science courses, focusing primarily on effective uses of resources and management skills. The pedagogy for these types of engineering courses stresses the elusive nature of right answers, and focuses on the complexity of applying relatively simple concepts to complex and unique situations⁷. Aware of these pedagogical needs, the instructor structured the class format to take advantage of Tablet PC capabilities. This section discusses use of a Tablet PC with a data projector as a more sophisticated extension to the now almost routinely used PC and data projector combination.

In the engineering management courses, partially completed notes (either Word or PowerPoint documents) were made available online and students were expected to have them available prior

to the start of class. Notes typically have embedded extracts (e.g., diagrams, figures) or links to other programs (e.g., MS Project and web sites). The partial note technique is similar to that discussed by others^{1,8} and is thus not further elaborated here.

There is a certain allure, for both instructor and students, to the use of perceived state-of-the-art techniques, such as Tablet PCs, within the classroom. A rational assessment, however, requires assessing the net utility derived from this educational tool. Taking a cue from engineering economy analysis, this suggests that one approach is to determine the net utility by examining the associated benefits and costs associated with using the Tablet PC within the classroom.

The direct dollar costs associated with using a Tablet PC and data projector combination in the classroom are typically nominal, as it involves a single Tablet PC (typically available for less than \$2,000) and a data projector (ubiquitous in a university environment). The more significant costs or disadvantages are indirect and often intangible: associated with incremental time required of the instructor or loss of pedagogical effectiveness. The following costs were found to be associated with using the Tablet PC within the engineering management courses.

- **Increased faculty time.** At first blush, the incremental effort to use Tablet PCs within the classroom seems inconsequential yet in the aggregate the additional overhead imposed was at times significant. This overhead is associated with the need to prepare the e-file notes of a sufficiently professional quality to be effective (i.e., well organized, professionally formatted, and incorporating diagrams and figures), and making material available on the web (e.g., timely uploading to a course web site).
- **Time Critical Pressure.** In an ideal setting, the instructor prepares the material for each class with sufficient anticipation to allow students to a priori print notes for each class session. In practice, both students and faculty often found themselves out of time: the instructor to have the notes on the web with at least 1-2 days lead time or the student to print the material before the class.
- **Loss of Class Flexibility.** Prepared class notes lend a scripted or canned feel to the class: the instructor often feels compelled to faithfully follow the notes (thus not allowing the class to follow unexpected, yet often fruitful directions), and the students feel somehow shortchanged if all of the note material is not covered in the class. Felder and Brent⁹ called this phenomenon ‘death by PowerPoint’.
- **Constrained Instructional Real Estate.** Tablet PC digital ink combined with pre-prepared notes save precious class time and allow for more precisely shown engineering diagrams and figures. However, the use of Tablet PC may also have the unintended consequence of changing the classroom dynamic, particularly in small class sizes: faculty with an energetic teaching style (e.g., moving around the room and using several whiteboards) may find themselves ‘chained’ to the Tablet PC and often partially hidden by an electronic podium; faculty accustomed to using a number of whiteboards (e.g., leaving key points on the board and repeatedly referring to it during the class) may feel frustrated about moving to the next slide or page on the Tablet PC; and, large diagrams or figures may not legibly fit within the constraints of a Tablet PC screen.

- **Student Classroom Attentiveness.** Ideally, students are faithfully attentive throughout the class period. In practice, instructors focus on this issue, with the use of partially completed notes an approach for stimulating student engagement with class material¹. Nevertheless, the availability of even partially completed notes (with fully annotated notes posted on the web a posteriori) anecdotally led to some student loss of attention during class.

The costs and disadvantages associated with Tablet PC use are not insignificant and need to be evaluated with respect to the benefits accrued. The following section describes the benefits resulting from the use of Tablet PCs in the engineering management courses.

Student satisfaction is perhaps the most readily apparent benefit derived from use of the Tablet PC within the engineering management courses. Although preliminary in the present study, this is consistent with reported findings of others^{1,7,8,10}. Student often commented favorably on course evaluations on use of the Tablet PC and the availability of notes on the web. Student satisfaction, however, masks and is perhaps the result of other more fundamentally root benefits:

- **Better Prepared Classes.** The Tablet PC imposes a disciplined approach to each class and allows seamless multi-media presentation of material. Classes frequently include prepared notes annotated during the class, supplemented by videos, web material, and software demonstrations. ‘Chalk and talk lectures’ are thus avoided.
- **Coverage of more material.** Class time is more effectively used, as diagrams, figures and tables are preprinted in the class notes, and key elements are added during the class period. The instructor can focus the class discussion on concepts, interpretation and other key aspects (and not use valuable class time for student transcription from blackboards to notes). The Tablet PC also allows the instructor, as deemed appropriate, to annotate or develop sketches as to facilitate or enhance student understanding.
- **Web availability of annotated notes.** A complete set of notes as annotated in the class is placed on the course web site, usually within 24 hours but always before the next class period. Students use these notes to compare to their own or in case of class absence.
- **Archiving of class notes.** Once developed, class notes are easily organized and archived and serve as basis for future use. The instructor developed two sets of e-notes: one set containing the partial notes made available to the students, the other set complete notes (i.e., filling in the missing aspects of the partial notes) and serving as instructor class notes.

3. Electrical Engineering Course

In the Digital Signal Processing course, as with the Engineering Management courses discussed in the previous section, partially completed notes form the foundation leveraged by the Tablet PC to enhance the quality of the classroom teaching and learning experience. The notes contain background information, problem statements and figures that frame the class discussion. As

important as the information provided within the notes, are the strategically placed gaps that they contain. This approach allows students to focus on the concepts instead of spend time copying background information and figures. The concepts are further solidified when both the instructor and students work out problems and fill in the gaps in the notes during class. The partially-completed notes can be provided to students in print or electronic form. Students complete their notes in class using the traditional pen and paper approach (print handouts) or via digital ink on the Tablet PCs (electronic handouts).

For the first half of the semester, students were provided with hardcopies of the notes and used the traditional pen and paper approach to complete their notes while the instructor used the Tablet PC and projected the image with an LCD projector. This mode of instruction has been used for several years by the instructor and has been reported¹¹ to facilitate more effective use of class time, help keep students more engaged in class, and provide more organized class notes that facilitate study outside the classroom. Preliminary results showing that this approach can improve student learning outcomes have also been reported¹².

In the second half of the semester, both the students and the instructor used Tablet PCs. The notes were provided to students in electronic form and students completed their notes using the Tablet PCs. The software package, MATLAB was used extensively in this class. Use of Tablet PCs for both note-taking and software applications streamlined presentation of material. Students' ability to import MATLAB graphs into their notes was very beneficial. Incorporating these plots directly into the notes allowed students to create a more complete and organized archive, making it easier for them to study the material outside the classroom. A segment of the skeleton notes including digital ink annotation and a MATLAB plot is shown in Figure 2.

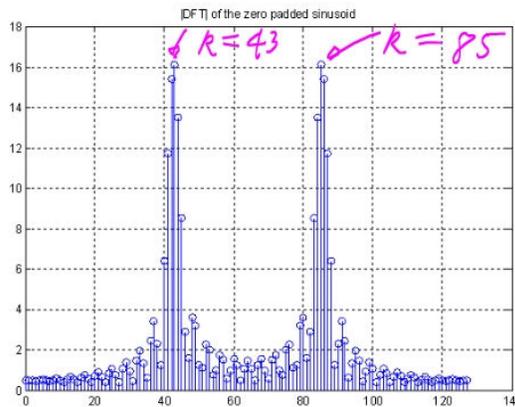
A survey administered at the end of the semester showed that the students preferred this mode of taking notes; all survey respondents recommended that the use of Tablet PCs be continued. Advantages cited by students included higher quality of notes, for example, by using different ink colors and highlighting, more organized notes, and the ability to integrate the output data from simulation tools into the class notes. The only disadvantage identified in the survey was that the computers were slow to startup and open applications. However, the benefits and flexibility derived from using Tablet PCs seemed to far outweigh the logistical disadvantages.

4. Civil Engineering Course

Sustainable Engineering, an upper division multi-disciplinary elective course, was the third course in which both the instructor and students used Tablet PCs in Fall 2007. This course was taught for the first time in Fall 2007 and provided a good opportunity to implement Tablet PCs as a demonstration of use of 'alternative' resources. Partially completed notes, as described previously for the Engineering Management and Electrical and Computer Engineering courses, were prepared in MS Word and posted on the course web site. Students downloaded the notes at the start of each class and used the Tablet PC throughout the period. The time required for the Tablet PCs to boot up was used more effectively by administering a short quiz on the assigned reading during that time.

Example: Use Matlab to sample a 500Hz sinusoid at $F_s = 1500$ samples/sec. Form the 128 point sequence $x(n)$ by taking 32 samples of the sinusoid and zero padding it to length 128. Compute the 128 point DFT $Y(k)$ and plot its magnitude. At what DFT bins do you expect to see peaks? Compare your results with the Matlab plot.

$N = 128$ point DFT
 Have $F = \frac{F_s k}{N}$ \Rightarrow Get $k = 42.67$
 \Rightarrow Peak expected at bin $k = 43$ and $k = 128 - 43$
 $k = 85$



DFT plot
 Shows peaks
 at expected
 locations

Figure 2. Sample notes with digital ink and imported MATLAB plot

Use of the Tablet PC within this course allowed for streamlined transition between resources (notes, internet, models, etc.), and allowed students to develop a complete and organized set of class materials. In addition to advantages noted in previous sections, one particular advantage for this course was the ability to develop active-learning exercises within the notes by inserting hyperlinks directing students to useful web resources related to class material. A question posed in the notes could be followed by an active hyperlink, which students would click to access a web site and answer the question. For example, when the topic of sustainable buildings was being discussed, students were required to access the U.S. Green Building Council web site and identify the different levels of LEED certification available. Similarly, students could link directly via the course notes to a web site where they used a Life Cycle Assessment model, then they copied and pasted model results into their notes in response to a problem statement. (The Tablet PC was used in “regular laptop” mode, as the stylus is rather cumbersome when inputting typed text for an extended period).

One unexpected advantage of having both students and the instructor use Tablet PCs was a flexibility not available to students using hard copies of class handouts. If additional information, graphics, or new questions and ideas became available, the space could easily be adjusted within the Word file and the new information added.

This was the first exposure to Tablet PC technology for all ten students enrolled in the course. Tablet PC use was implemented from the first day of class, where inevitably, there were technological and logistical issues such as wireless connectivity problems, inaccessible student accounts, lost passwords, etc. By the second class period, most of these issues were resolved, but students were still in the process of adapting to the technology and new course format. The students and instructor agreed to use the technology for three weeks, then to assess and discuss their experiences, and determine whether to continue use of the Tablet PCs. Student feedback was gathered using the Tablet PC use survey (Figure 1), and by that point, while several expressed frustration with slow start-up times, all agreed that the Tablet PCs should continue to be used for the remainder of the semester. A second survey administered at the end of the semester showed that students' experiences improved as they became more familiar with the technology and logistical issues were resolved, and they identified many advantages to using the Tablet PCs.

For this particular course, all homework assignments and projects required completion of written memos or project reports that could be submitted online or in hardcopy format in Fall 2007. Thus, the Tablet PC was also used by the instructor to grade and provide feedback on assignments submitted electronically, which were then returned to the students in electronic format. In the current semester (Spring 2008), students are required to submit all assignments online, allowing students to compile an electronic archive comprising almost all the course materials (excluding quizzes and exams).

One disadvantage noted is the ability to write neatly and legibly on the Tablet screen, depending on the sensitivity of the stylus. This semester, the course instructor is using a Tablet PC manufactured by a different manufacturer, and the stylus is less sensitive than the HP stylus. This problem has been resolved for the most part by using extensive writing practice, but must be considered by the instructor using the Tablet PC.

Student Perspectives

In addition to student feedback presented in previous sections, students noted several advantages and disadvantages that were not necessarily apparent to the instructors, or whose importance may have been deemphasized. Almost all students noted the added ability to organize course notes and the ability to use multiple resources (notes, internet, other software) as a principal advantage of Tablet PCs. A second principal advantage noted was the ability to use different colors, line widths, and even digital ink highlighters when taking notes. The principal disadvantage related to reliability of wireless connections. A few students noted the tendency of computers to periodically freeze and require rebooting, which could cause the student to lose a file and miss information.

Several survey respondents appreciated the ability to learn new technology and to master it quickly. One student appreciated not having to carry too many binders for the different classes, and another noted that if Tablet PCs were used in more classes or if students had their own Tablet PCs, they could store all their files and course materials electronically, have access to them from different locations, and not be a victim of the "I brought the wrong notebook to class"

syndrome. Students who preferred course materials in hard copy format could print their files and organize them in a binder. Other advantages noted were:

- Students who missed a class could download the annotated notes or obtain them from another student.
- If students had a question regarding the class material, they could annotate or highlight the item and email the file to the instructor, who could then provide an annotated explanation directly on the same document, and email it back to the student.
- Notes from completed courses can be easily archived onto floppy drives or flash-drives, which take up much less space than binders and notebooks “which are always likely to be ritualistically burned when the semester is ends” (Student comment).
- Students and professors can easily network together for in-class exercises.
- During class, instructors can demonstrate and students can use tools and multimedia materials that are often included with the purchase of hard-cover textbooks.
- On the other hand, if online textbooks are available, students can purchase them for use in class with far less associated weight and cost. They can digitally highlight and bookmark these files without worrying about preserving textbook condition or missing pages.

Other disadvantages noted by students were:

- Students usually utilize small blocks of time between classes to quickly review and study notes, which may be difficult if all materials are stored electronically, and the student must find an available computer or boot up a personal laptop.
- Power outlet access in classrooms is needed for maximum functionality of a Tablet PC, as the battery life can easily be drained if using multiple applications.
- The lure of the internet and computer games may be distracting during class.

Assessing Impact Upon Student Learning

This preliminary comparison of the advantages and disadvantages suggests that the Tablet PC can serve as a useful tool for teaching and learning. Yet to be assessed, however, is the impact of using the Tablet PC upon the fundamental objective: student learning. Adhering to ABET guidelines, each of the engineering courses has a defined set of desired student learning outcomes. Achievement of the respective course outcomes is assessed by a traditional set of course metrics (e.g., tests, homework, quizzes, and term projects). Examining the pedagogic worth of the Tablet PC approach to classroom instruction requires not only determining the associated cost and benefits, but more fundamentally its impact upon the defined student learning outcomes.

To simplify analysis, final course grades may be considered as a crude surrogate for aggregated student learning outcomes. A number of studies report anecdotal or preliminary evidence that the Tablet PC/data projector combination has little or no impact upon student course grades^{1,8,10,13}. Student feedback obtained from this experience seems to indicate that, although there may not yet be a tangible impact on learning, students found the Tablet PC to help in organization of their course materials, and therefore may help students to use their time more efficiently. Determining the impact of this technology upon specific course learning outcomes is a challenging and open research question, the answer to which will provide insight into the future new pedagogic directions of the for technological tools within the undergraduate engineering classroom.

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