AC 2009-1933: IMPLEMENTING A TABLET PC REQUIREMENT PROGRAM

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Implementing a Tablet PCs Requirement Program

Abstract

Tablet PCs are one of the newest innovations in the computing and communications world and have the potential for significantly improving the way in which faculty members teach and the processes involved in student learning. The College of Engineering at Virginia Tech decided to require that all incoming freshmen be required to own their own tablet PC starting in the Fall of 2006. This paper describes the process by which the College arrived at this decision as well as the benefits of this initiative seen to this point. We also discuss the various processes involved in implementing the requirement program including faculty and staff training, development of the necessary support infrastructure, establishment of working relationships with hardware and software vendors needed to support this pioneering venture, and the assessment activities needed to measure the effectiveness of the overall process and its demonstrable changes in the way in which faculty teach and students learn.

Tablet PCs consist of a standard notebook PC configured with a screen (tablet/slate) which acts as both a display and an input device. A stylus or pen can be used to input standard mouse-type commands as well as gesture commands and electronic ink drawings. These combined features hold the promise of facilitating dynamic and broadly informed faculty presentations while at the same time allowing students to be more natural in their learning tasks such as note-taking and peer to peer collaboration.

Several software packages are available to support the pedagogical needs of the engineering classroom as well as typical engineering group collaborative environments. These packages also allow for a highly interactive environment with both teacher-student and student-student bi-directional real-time interactions. This paper describes some faculty experiences using tablet-focused tools such as Classroom Presenter and OneNote in fundamental engineering courses

Infrastructure and training needs for an undertaking of this magnitude are broad and diverse. Transitioning faculty from their current teaching techniques to tablet-facilitated instruction, as well as building the necessary organization needed to support the technical use of these devices inside and outside the classroom will be discussed in this paper. Furthermore, mechanisms for scaling and adopting the processes for use at other universities will be suggested to the audience.

The Tablet PC requirement program has undergone extensive assessment to examine the effects of the new technology and the corresponding new pedagogical practices that the technology affords. Data have been collected using quantitative and qualitative methods including faculty and student self-report instruments, focus group discussions and quasi-experimental studies comparing courses taught by the same instructor – one in which interactive tablet exercises are used and one in which they are not. This paper discusses the results of the assessment and attempts to draw conclusions on effective practices afforded by the new technology tool.

Background

Improving the teaching and learning environment through the effective use of educational technology has long been a priority of the faculty and administration of the College of Engineering at Virginia Tech. Many teaching innovations have been initiated and implemented with support from the college administration, alumni, corporate entities, and from various research agencies such as the NSF. Innovations include the incorporation of freshman hands-on mechanical dissection labs, multi-disciplinary projects, and integrated subject material courses to name a few. Most notable among the teaching/learning innovations are the College's efforts in the effective use of computing and communication technology in the curriculum. This effort spans the breadth of digital network communications technology from gigaPOP networking through advanced wireless nets, utilizing a broad spectrum of computing devices from personal digital assistants through multiprocessor super computers. In this paper we describe how personal computing devices are coupled with pedagogical practices and used as educational technology.

In 1984, the Virginia Tech College of Engineering became the first large-scale public institution to require all entering engineering freshmen to own a personal computer. By 1996 the computer requirement program had been scaled up to the so-called "multimedia computer" which at that time incorporated advanced features including a CD ROM reader, a high resolution graphics system and a sound card – all features we take for granted in today's computers [1,2]. In 2002, the College moved to a laptop requirement and many of its academic buildings were outfitted with a wireless communication system that allowed students a reasonable connection to the high-speed Internet at most locations on campus. Laptop technology was selected so that students could perform computing and communication operations in a mobile environment. Ubiquitous use of computers in the students' everyday learning styles and lifestyles is the evidence that these technology requirement programs have at least in part paid off. In 2006, the College once again stepped out on the technology forefront, becoming the first and largest public college of engineering to require all 1,400 incoming freshmen to own a computationally powerful and well-connected Tablet PC.

Each of the above mentioned leaps in the use of technology were motivated by specific pedagogical purposes. Initially, students were required to own computers in order to increase their access to computational and programming capabilities and thus allow them the ability to both drill and practice their computing techniques as well as to support their exploratory needs in this area. Moving to a multimedia computer allowed teachers to provide more graphic materials and students the ability to handle more computationally complex problems with this advancement in computers. Pedagogically this enabled an increase in the performance of visualization and situational simulation. Moving to a more ubiquitous computing environment with notebook computers allowed students better and timelier access to research materials and engendered more asynchronous student-teacher interaction. The move to Tablet PCs is likewise based on an attempt to further improve pedagogical practices. Tablet PCs facilitate better opportunity for several important pedagogical practices including:

- More dynamic classroom presentations by the instructor
- Meaningful and extended classroom interaction
- Improved note-taking and review
- Collaborative group work

While the implementation of these improved practices does not guarantee that students will be "smarter" at the end of a course, educational research does indicate that these practices generally lead to improved learning. As we proceed forward with the initiative, we are performing formative and summative assessment to understand if important pedagogical and learning practices are increased and performed at higher levels, and if so, to identify general learning improvements that are implied to be enhanced.

Tablet PC Hardware and Software

Tablet PCs are basically improved notebook computers that have a digitizing screen that accepts input from a stylus device. The stylus acts as a pointer in the same fashion as a mouse but also allows the user to apply natural gestures and writing strokes that are recorded on the screen as electronic ink (e-ink). To best accommodate electronic inking most Tablet PCs these days have a screen that swivels into a flattened position that allows the user to write on a flattened surface. These are called convertible Tablet PCs since they convert from a notebook to a flat surfaced tablet. Some earlier Tablet PCs were developed as so called "slate" devices, comprised of just a stylus-writable screen which could occasionally be connected to a keyboard. While slate devices are popular for certain applications such as field surveys and data collection, the convertible is much more popular for classroom and general learning environment application.

Software for Tablet PCs is being developed by a number of commercial and non-commercial producers. Windows XP and Vista both have built-in facilities to support Tablet PC application software. Some flavors of Unix/Linux have Tablet device drivers and are somewhat capable of running some Tablet PC applications though fewer are currently being written for this environment.

In choosing a vendor to provide hardware and software for the Tablet PC requirement program, we have been very careful to ensure that potential difficulties with the technology would be minimized so as to not interfere with the teaching and learning process. Therefore, vendor reputation, reliability, and availability of service were very high on our list of priorities when it came time to choose a preferred vendor. Additional selection criteria are enumerated in Table I.

Table I: Vendor selection criteria.

Priority	**Criteria**	**Priority**	**Criteria**
1	Minimum feature set	**8**	Screen size
2	Availability for semester start	**9**	Higher speed wireless
3	Reliability	**10**	Upgrade options
4	Maintenance availability	**11**	1 vs. 2 SIMM memory
5	Pricing	**12**	Ease of purchase
6	Video card/memory	**13**	Vendor market share
7	Weight	**14**	Killer feature

Vendor samples were evaluated over a period of three months. A number of vendor technical briefings related to the procurement were held where we discussed the company's commitment to our program, the type of technical support that could be expected, and other details that ensured us of a sound relationship with the vendor. Fujitsu Computers Inc. was chosen as the vendor and we entered into what we termed the Premier Alliance. As part of the three year alliance, Virginia Tech agreed to inform the students of the fact that the Alliance partner was our preferred vendor and that we had set up a number of support and maintenance facilities as well as a very good pricing structure with our Fujitsu. During the first year roughly 75% of our entering students bought their computers from the Alliance partner. One of the biggest advantages of this type of arrangement, besides the price of the systems, is the fact that we have a large common set of systems for which we can maintain one common set of support practices. We weren't up against the problem of trying to maintain information on multiple different hardware platforms and all of the support nuances that go with those situations.

Table II Minimum hardware requirement.

Item	Detail
Platform	Convertible Tablet PC
OS	Windows XP for Tablet 2005
Processor	Core Duo 2.2 GHz or higher
Memory	2 GB min.
Hard Disk	120GB;5400 RPM spindle speed
Video Card	128 MB discrete
Optical Drive	DVD/CD+-RW
Input/Output	USB 2.0
Wireless	802.11 a/g
Ethernet	10/100/1000
Printer	Windows compatible inkjet or laser printer
Warranty	3 years onsite with accidental damage (4yr. recommended)

The entering class of Fall 2008, the third class to be required to own a Tablet PC, was required to own a computer with the specifications shown in Table II. This specification was obtained by performing benchmark testing against the software we expected to be running in the systems. The required software list is contained in Table III. This requirement is the baseline software package and students are notified that there is likely to be additional software required specific to their major once they are selected into a department. The cost of the software bundle is approximately $350. Market price for the software bundle is roughly $1,500. In addition to the software noted in the table, students were provided free of charge access to additional Tablet PC specific software including Classroom Presenter, DyKnow, and the Microsoft Experience Pack, all of which will be discussed below.

Table III Minimum software requirement

Minimum Software Requirement
Matlab
Autodesk Inventor and Mechanical Desktop (ASC free)
Labview simulation and graphing
PDF Annotator
Microsoft Campus Agreement including:
OS upgrades
Office Professional 2007
One Note
Visual Studio
Project
Visio

Exploiting Tablet Features to Improve Pedagogical Practices

In 2002, we began to explore the use of Tablet PCs in the engineering education environment by seeking ways to take advantage of the e-ink capabilities of the device. This preliminary exploration allowed us to become familiar with the technology and the details of making it function. More importantly, we experimented with specific classroom applications of the technology and identified teaching and learning practices that the Tablet could be used to support. At the most fundamental levels we found that much like the standard blackboard or whiteboard, this technology allowed the instructor to make dynamic and adaptive presentations that could be much more responsive to student interaction than a simple PowerPoint presentation. However, PowerPoint presentations do have an important advantage over blackboards in that they are also capable of containing images that help bring real-world situations to the classroom. PowerPoint also allows for broad distribution of classroom notes, which for engineers and scientists can contain rather complex drawings that would be near impossible to copy down during a lecture. Upon searching for Tablet PC presentation tools it was found that software like Classroom Presenter [3] combines the advantageous capabilities of PowerPoint with the flexibility and spontaneity of blackboard lectures. Using Classroom Presenter, an instructor may prepare drawings and graphics in ready-made form and use e-ink to annotate important discussion points on these electronic slides during the lecture. Schematic drawings of problems are normally left partially incomplete and are finished during the presentation. This causes students to pay better attention during class rather than having the student occasionally glance up from their stupor as chock full PowerPoint slides glide by on the screen. Typical student "what-if" questions may be better elicited and answered using the new paradigm that essentially combines PowerPoint and a blackboard. Most importantly, the student may take home a composite of the pre-drawn PowerPoint and the in class annotations for later review and study. Initial use of Classroom Presenter produced very positive responses in polls of students taken after Tablet-based classroom presentations. An example originally static PowerPoint slide that was annotated in class using Classroom Presenter is shown in Figure 1.

In addition to providing annotation capabilities, Classroom Presenter also allows the instructor to accept graphical input from the students. This functionality allows the instructor to pose open ended questions requiring an input from each individual student or from collaborative groups. Once all input is submitted, the instructor may choose a submission or several submissions to openly and anonymously discuss with the class. This is a very powerful mechanism to engage students in classroom discussions. It is well known that engaging students in the classroom leads to improved learning. The caveat is of course that the computer does not create the engagement; rather it better facilitates the interaction. It still requires an instructor to be willing to work to improve the way they teach.

Along the way we identified more discipline specific tools that are Tablet (e-ink) enabled. Examples of these include ChemPad and MS Physics Illustrator. These tools allow teachers and students to use the natural gestures of the e-ink stylus to draw electronic elements and subsequently simulate the behavior of these entities. We also found other commercial Tablet enabled software that could provide good support for teaching and learning. Commercially available DyKnow is a Classroom Presenter- like tool with some enhanced features. Microsoft Office Professional 2007 contains the software package known as OneNote – a note-taking tool that is e-ink capable.

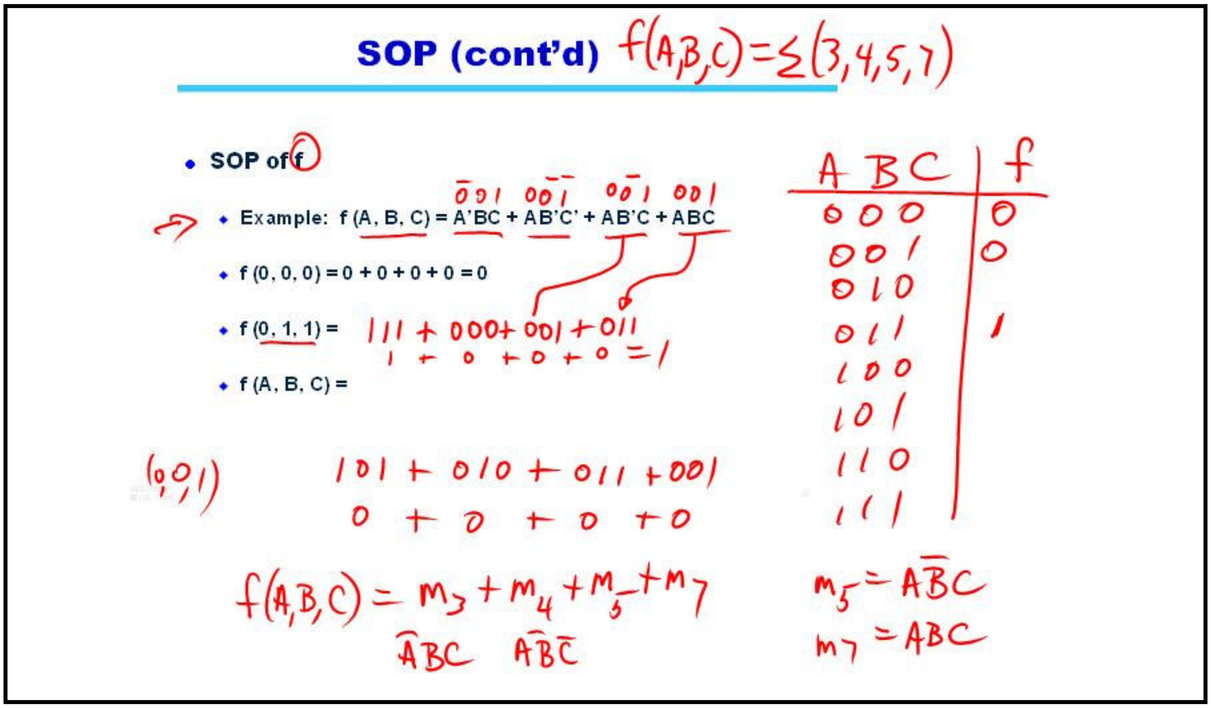

Figure 1. Example of a slide annotated in Classroom Presenter.

Armed with these capabilities we began to broaden our class experiments and identify how other individual teachers would integrate these tools into their classes. In 2005 we ran a few experimental sections of courses using a set of about 50 tablets that were loaned to students either during class or for an entire semester. Student and faculty responses to these experiments were quite positive and compelled us to move to require Tablet PCs beginning in the Fall of 2006.

Infrastructure Challenges

As the Tablet PC program was piloted in larger class, we realized that we had a considerable network challenge on our hands. During the earlier notebook requirement, classroom wireless network bandwidth requirements were mainly driven by the need for email, web browsing, and at the high end, the occasional movie download or streaming. To take advantage of the ability to simultaneously have all students in a classroom have full sets of notes and e-ink sent to them as they evolve in the classroom, it was necessary to upgrade the network capacity in most academic spaces. Particularly challenging are large classrooms where 250 to 300 students are enrolled in freshmen engineering design lectures or introductory chemistry classes. Also challenging is the fact that most classrooms sit physically back to back in buildings which has the potential for interference between wireless access points. Research by our University Communications Network Services digital network design engineers indicated that there had been no published case studies or industry accepted guidelines describing network configurations that can effectively connect 300 users inside of a single high density space. While frequency management of adjacent wireless access points has been studied in the research literature, there was still a good amount of work to be done to apply the theory to our complex situation. Economic considerations were also one of the driving factors in determining how the network would be upgraded to handle the necessary bandwidth.

Over the course of a year, upgrade plans were made and implemented. While most commercial access points have the advertised capability of providing IP addresses to up to 255 users, the reality of the situation is that only a fraction of the 255 IP addresses may be active at one time without severely degrading the access point wireless side bandwidth. Thus the solution for large classrooms became one of providing a sufficient number of access points in the room to provide reasonably good network response. Of course, "reasonably good response" is somewhat subjective and the response expectation rises every year. (In 1999, users were willing to enter a URL and stand and stretch while they waited for the web page to open. In 2008, if the web page isn't opened by the time they take a sip or two of soda, they are likely to click the refresh button several times). We defined reasonable response to mean that initial slides will be distributed to the entire class within the first two minutes and that e-ink will appear on student machines no later than five seconds after being applied to the instructor's machine. An additional factor impacting the system based on our definition of reasonable response is the speed of the instructor's machine. Our benchmark assumption for the instructor machine was a 2 GHz single core processor machine.

Eventually we found that the best strategy was to put in place a baseline system of access points supplemented as need be for larger classroom. For example, in many large classrooms we ended up installing six access points all tuned to non-interfering frequency preferences in either the 802.11a or 802.11g standard. Student machines in the room will thus be automatically spread out over the radio spectrum available in that room and will have less interference collisions, thus increasing the effective bandwidth and improving the response. Adjacent rooms were then tuned to ensure minimal interference between rooms. Overall the initial set up was lengthy, but the maintenance of the systems is relatively minimal. Typically rooms are designed to handle traffic at 110% of room seating capacity. Over 85% of the rooms in the engineering teaching buildings have been certified to be capable of supporting network traffic based on these standards.

In addition to the challenge of having sufficient network capabilities, we were also tested by the need to provide power connections for the more intense use of computers in the classroom. Like so many other campuses, many of the buildings at Virginia Tech were originally built in an era where a plug in the front of the room and one in the back was all the janitorial staff really needed. The solution to this problem has taken many different forms including laying down multi-plug strips fed by original wiring. Perhaps the most effective mechanism is to encourage the students to buy multi-cell, longer lasting batteries, and training them to keep their systems charged and ready to use.

Assessment

Several assessment efforts are underway to determine the effectiveness of the use of Tablet PCs. We have developed survey instruments from well-documented extant measures that allow us to monitor change in student learning practices measure the learning environment based on constructivist learning principles, measure our students' use of learning technology as compared to the national ECAR survey results, and to gather utilization data on the amount and type of faculty and student use of the tablet PCs. A large amount of preliminary data has been collected and is being analyzed. As more complete analyses are completed, detailed assessment data and results will be published.

Examining student survey responses from Tech's freshman engineering class in Spring 2008, students report faculty used the technology well, making the class more interactive, and improving the learning process. Students felt the use of technology helped them better communicate and collaborate with classmates. In class, Tablet use helped to illustrate points with visuals and other materials. Furthermore, when students are reviewing their learning outside of class, they report the Tablet PC functions help them better organize their thinking about course materials, aiding in the gathering of background materials as well as review of course content.

Two examples of response details relate to interactivity and note review. We asked the freshman class of students if the Tablet PC made the lecture presentation more interactive than previous styles of lecturing. The results in Figure 2 show a strong response from the students indicating an increase in classroom interaction when the Tablet PC is used. Of course we should observe that the Tablet does not cause an increased interaction, it only facilitates an increase in interaction. The instructor needs to take advantage of this improved facilitation and change the way she/he operates their classroom in order for this capability to be effective. We call this the *catalyst effect* in which the Tablet PC functions as a vehicle for change and actually in this case even participates in the reaction.

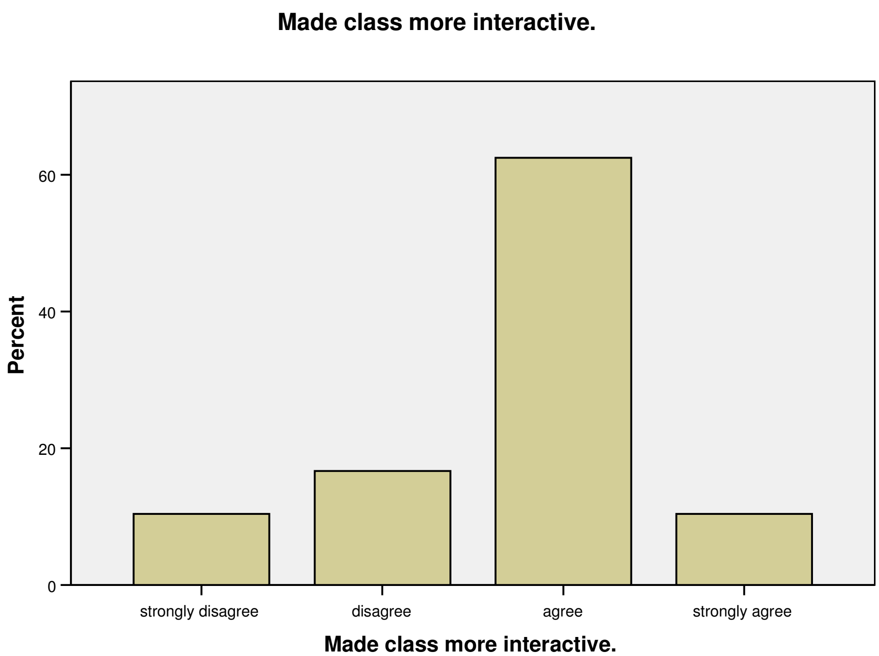

Figure 2. Student response related to a question asking if the Tablet made the lecture more interactive.

We also asked the students if the Tablet PC helped them to review their course notes and other materials, either as they performed a daily review or as they prepared for tests. Figure 3 has the results from this question indicating a total positive response 80% of the students agreeing that the Tablet did indeed help them review their course materials. Educational research findings suggest student concept development and retention is increased when students review course materials, specifically their own notes, more frequently. Admittedly, a gap exists in the relationship connecting Tablet PC use and better learning. In the next round of assessment we will attempt to determine not only if the note-review is of better quality, but we will also investigate other factors such as frequency of review. We plan to correlate data from both the self-assessment survey of the students and a survey of the faculty, as well as gather information from objective classroom observers and from focus groups.

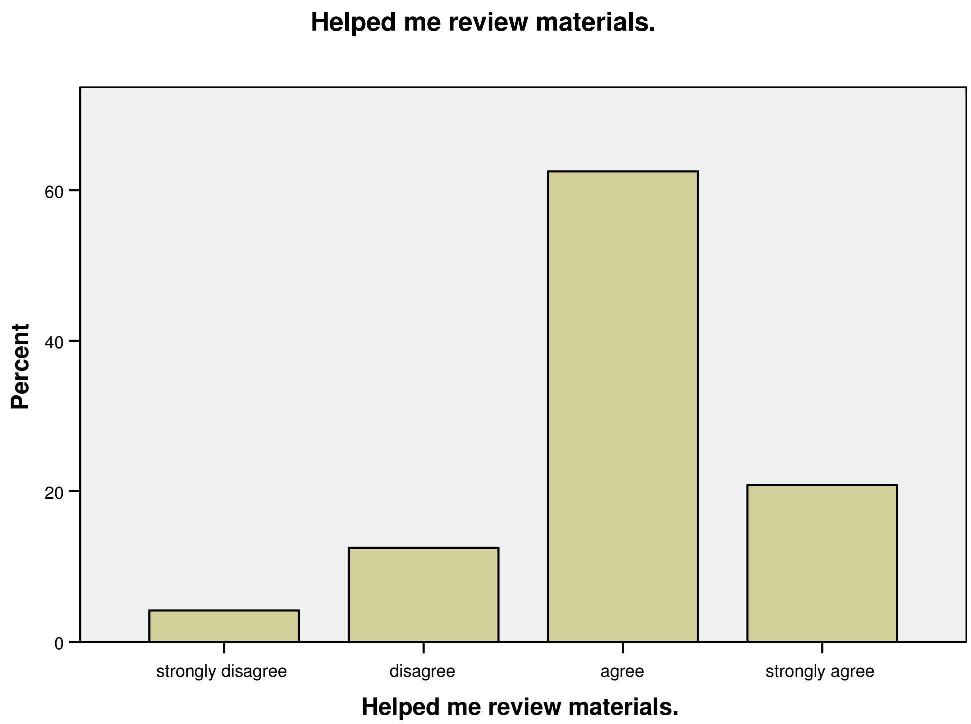

Figure 3. Student response related to a question asking if the Tablet helped them review class notes and other study materials.

In spring 2008, teaching two sections of the same course provided the unique opportunity to study the impact of the Tablet PC on the engineering classroom. Classroom interventions incorporated the Tablet PC technology and were measured using constructivist principles. Using a quasi-experimental design, one section was taught with the instructor and students using the Tablet PCs. The second section was used for comparison and was taught in a more traditional way using PowerPoint slides and only the interaction and student queries that are in a typical reasonably good course. Note that elements of the course remained constant across the two sections: presentation slides were essentially the same, the instructor was the same, and the course was given in the same classroom. To ensure appropriate protection of human subjects, the students could not be randomly assigned to sections; however, after examination of prior GPA as well as final grades in the course, the class samples demonstrated similar academic capabilities.

A post course survey was completed by the students. The mean differences on reflection questions specific to technology were tested. Students in the Tablet PC section report significantly higher engagement ($t = 2.15, p < 0.05$) in class using technology ($\bar{X} = 2.93$) than students in the control section ($\bar{X} = 2.38$). Reported scores are in response to the statement "I was more engaged in courses that required me to use technology than in courses that did not use technology", where the responses were weighted as: strongly disagree≡1; disagree≡2; agree≡3; strongly agree≡4. Descriptive statistics from the two class sections are shown in Table IV.

Table IV. Statistics for Paired-Sampled T-test

	Time of course	N	Mean ($\overline{X}$)	Std. Deviation	Std. Error Mean
Self-Report of engagement in courses using technology for instruction*	9:05AM-tablet	27	2.93	.829	.159
	10:10AM-control	21	2.38	.921	.201

While the results of this quasi-experimental study are interesting, they must be recognized as preliminary in nature, providing support for one indicator of the usefulness of the Tablet PC in the engineering classroom. Similar studies are planned for the future.

We hypothesize the addition of the Tablet PC use by students in the experimental section will lead to a constructivist learning environment in which learners construct knowledge for themselves – each learner individually (and socially) constructs meaning. It is anticipated that the use of the Tablet PC functions will allow for greater student control of the learning environment with increased interaction between student and instructor, student and classmates, as well as student and course content.

We have refined the assessment into two different instruments to be used in a self-reporting scheme, one for students and one for tablet-using faculty. Report responses will be compared to determine if the attempted practices reported by specific faculty are also reported by the students in their specific classes. This study will allow us to take corrective action to ensure best practices are being followed by both faculty and students.

The data from the assessments described above are being archived annually for the purpose of studying the impacts of the Tablet PC longitudinally. Assessment instruments are freely available to others working on similar initiatives.

Summary

The effective implementation of enhanced pedagogical practices in conjunction with the use of Tablet PCs has transformed classrooms into active learning environments improving class participation and student creativity, and encouraging types of collaborations expected in an industry environment. Assessment data indicates that the initial effort of the deployment have produced a positive result to this point. Some data has indicated a need for adjustments in the way in which the technology is applied by individual instructors and appropriate corrections have been made. Infrastructure upgrades must be included as budgetary items in order to assure they are properly carried out. Much of what has been accomplished at Virginia Tech is scalable and extensible to other institutions and to other disciplines outside of engineering. Cooperative efforts with departments teaching pre-engineering courses can be very beneficial since they will likely encounter engineering students before they are in the mainstream courses of their specific engineering discipline.

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