Facilitating Pedagogical Practices through a Large-Scale Tablet PC Deployment

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The Virginia Tech College of Engineering has begun to explore the use of Tablet PCs in engineering and computer science courses. Using a multifaceted, collaborative approach, the faculty developed an implementation process that includes computer acquisition, faculty training, infrastructure modifications, and multiple evaluation assessments demonstrating positive initial results.

Undoubtedly, when Socrates and Plato met for their many conversations, they discussed ways to improve student learning. Although they didn't have to ponder the effect of using modern computing and communications technology, they must have discussed ways to actively involve students in the learning process.

While today's outstanding teachers still rely on Socrates' techniques of drawing students into the learning process, now many of them are turning to technology to help facilitate these active and collaborative exercises. Mobile computing and communication devices like the Tablet PC, along with a high-bandwidth communication infrastructure, help increase the quantity and quality of teaching/learning interactivity with the expectation of improving student learning.

In the fall of 2006, the Virginia Tech College of Engineering became the first public college of engineering to require all 1,400 incoming students to own a Tablet PC. The purpose of this requirement program is to better facilitate pedagogical practices that are expected to improve learning—practices not readily accomplished in previous teaching/learning environments. This program is expected to support highly interactive classroom presentations, as well as student-student and instructor-student collaborations. It will also foster comprehensive note taking and review and emphasize more process-oriented lectures as opposed to simple information broadcasting.

This large multifaceted deployment requires the enthusiasm and support of numerous stakeholders. Decisions on hardware and software choices require input from across the university. Training of faculty and support personnel is central to the initiative's success. Physical plant challenges include infrastructure improvements such as network connectivity, additional classroom projection systems, and increased availability of power connections. Sound and frequent assessment of the program's successes and failures and identification of potentially rewarding future possibilities have been part of the overriding deployment strategy from the beginning.

BACKGROUND

The Virginia Tech College of Engineering faculty has a long history of continuously seeking ways to improve the teaching and learning environment to effectively provide students with a high-quality engineering education. Many teaching innovations have been implemented with support from the college administration, alumni, and various research agencies such as the National Science Foundation (NSF). Innovations include incorporating freshman hands-on mechanical dissection labs, integrated subject material courses, and multidisciplinary projects. Most notable among the teaching/learning

Published by the IEEE Computer Society
0018-9162/07/$25.00 © 2007 IEEE

innovations are the college's efforts to foster the effective use of computing and communication technology in the curriculum.

In 1984, the Virginia Tech College of Engineering was the first public institution to require all entering engineering freshmen to own a personal computer. In the early 1990s, Virginia Tech participated in the NSF-sponsored Southeastern University and College Coalition for Engineering Education (SUCCEED) and assumed the lead role in the association's effort to conduct research on technology's effects on engineering education. By 1996, the computer requirement had been scaled up to the so-called multimedia computer, which incorporated features that were advanced for the time, including a CD-ROM reader, a high-resolution graphics system, and a sound card—features we take for granted in today's computers.[1]

In 2002, the college moved to a laptop requirement, and many of its academic buildings were outfitted with a wireless communication system that gave students high-speed Internet access from anywhere on campus. Laptop technology was selected so that students could perform computing and communication operations in a completely mobile environment. Today's ubiquitous computer use in students' everyday learning practices and lifestyles provides anecdotal evidence that these technology requirement programs have been fruitful.

> **Collaboration improves desirable learning outcomes in academic programs, including academic achievement, interpersonal interactivity, self-esteem, and learning retention.**

The college once again steps out on the technology forefront by requiring all students to own computationally powerful and well-connected Tablet PCs. In addition, the college is making a stronger effort to assess specific effectiveness measures. The assessment goal is to understand how to improve important pedagogical and learning practices and to identify general learning advancements that occur as a result of these practices.

TABLET PC DEPLOYMENT

In 2002, the faculty began pilot projects seeking ways to take advantage of the Tablet PC's electronic ink (e-ink) capabilities in the engineering education environment. Much like the standard blackboard or whiteboard, the instructor can use this technology to make dynamic and adaptive presentations that are more responsive to student interaction than a simple PowerPoint presentation.

PowerPoint presentations offer advantages over blackboards in that the instructor can easily organize them and they can contain images that help bring real-world situations to the classroom. PowerPoint also aids in broad distribution of classroom notes, which for engineers and scientists can contain complex drawings that would be nearly impossible to copy during a lecture.

Free software like Classroom Presenter,[2] a Tablet PC presentation tool, combines PowerPoint's advantages with the flexibility and spontaneity of traditional blackboard lectures. Using Classroom Presenter, an instructor can prepare drawings and graphics in ready-made form and then annotate discussion points on the electronic slides during the lecture.

Instructors normally leave schematic drawings of problems incomplete and finish them during the presentation. This causes students to pay better attention during class instead of occasionally glancing up from their stupor as chock-full PowerPoint slides glide by on the screen. Using this new paradigm that essentially combines PowerPoint and a blackboard can better elicit and answer typical student "what-if" questions. Most importantly, students can take home a composite of the predrawn PowerPoint presentation supplemented by the in-class annotations for review and study.

Initial use of Classroom Presenter produced positive responses in student polls taken after the tablet-based classroom presentations. Attendance increased as students found the lectures more interesting. Given the early success of using Tablet PCs in simple presentations, the faculty began to identify other opportunities for using this technology to facilitate pedagogical practices that are known to improve learning.

TARGETED PEDAGOGICAL IMPROVEMENTS

Engaging students in the learning process by having them participate in an active discussion or problem-solving session with the instructor and with their peers has been shown to improve learning. According to Michael J. Prince and Richard M. Felder,[3,4] "The core elements of active learning are student activity and engagement in the learning process. Active learning is often contrasted to the traditional lecture where students passively receive information from the instructor." Richard Hake[5] used pre/post test data to examine more than 6,000 students in introductory physics courses and reported significantly improved performance for students in classes with substantial use of interactive engagement methods.

Collaborative learning consists of two or more students working together to solve a problem or understand a concept as opposed to individual work on a topic.[6] Studies show that collaboration improves desirable learning outcomes in academic programs, including academic achievement, interpersonal interactivity, self-esteem, and learning retention.[7-9]

When used appropriately, the Tablet PC's rich communications and multimodal input capabilities can increase learning interaction in the classroom. This technology can facilitate intense collaborative

Table 1. Tablet PC hardware requirements.

Item	Detail
Platform	Tablet PC convertible
OS	Windows XP Pro Tablet Edition
Processor	Pentium Core 2 Duo 1.8 GHz
Memory (RAM)	2 Gbyte
Hard disk	100 Gbyte; 5,400 RPM
Video card	128 Mbytes
Optical drive	DVD/CD+-R writeable DVD
Input/output	USB 2.0
Wireless	802.11 a/g
NIC/Ethernet	10/100/1000 Ethernet
Warranty	3 years for accidental damage
External backup	USB external backup drive, 160 Gbytes

activities using software that is either currently available or under development.

The characteristic that differentiates between notebook and tablet technology is the user's ability to more naturally jot down ideas and sketch drawings that can be communicated with other collaborators on shared electronic surfaces. Meaningful tablet-based collaborations can take place either locally or over distances separated by the Internet.

Comprehensive, organized, and easy-to-review note taking is an effective learning behavior that increases subject cognition.[10-12] Keiichi Kobayashi's research on the impact of note taking and reviewing on student learning revealed that properly performed note taking substantially improves learning outcomes and demonstrated that assisting students in improving their note-taking skills can produce additional positive benefits.[13] Tablet PCs can improve student learning by allowing note taking in a natural manner and by improving the ability to review notes either through ease of search or increased organizational capabilities.

Achieving the expected outcome of enhanced student learning is based on improving three key pedagogical practices:

- increased active learning,
- incorporating collaborative exercises into the learning process, and
- improved note collection and note searching/review.

To support these practices, the hardware and software selected for student and faculty use must be sufficiently capable, faculty must be trained in the use of the technology as well as in appropriate pedagogical practices, students must have a baseline understanding of the technology and its expected use, and sufficient infrastructure and support personnel must be available. The overarching umbrella to all of this effort must be an assessment operation that formatively measures the accomplishments of the program, identifying the most likely avenues for success as the initiative progresses.

COMPUTER SPECIFICATIONS

In the fall of 2007, incoming Virginia Tech engineering students will purchase their Tablet PCs on the open market using a set of specifications that the college issued in mid April. As Table 1 shows, the minimum computer specifications are a compromise among price, capability, longevity, and reliability.

For example, specifying the Pentium Core 2 Duo processor and the associated 2 Gbytes of RAM means that the computers will be capable of running all of the required software at reasonable speeds, while remaining affordable to the majority of the entering class.

Including wireless access cards capable of 802.11a, b, and g formats ensures the best opportunity to avoid overlapping broadband communications in the classroom and dormitory wireless infrastructure. While these minimum specifications might seem high initially, they are intended to ensure that the computer will be usable four years later, when the senior student will likely be performing computationally intense calculations and simulations.

Historically, about 40 percent of the entering students purchase the minimum hardware package, while the remaining 60 percent add higher-level capabilities to their systems such as a flat-panel monitor, increased RAM, more disk drive space, or extra video RAM.

An often-overlooked consideration is the Tablet PC's weight. The tablet cannot be too cumbersome because the student is expected to bring it to class every day. This leads to a conflict between the desire to have a large display screen and the additional weight of the upsized screen.

Typically, the 12-inch screen machines weigh about 4.5 pounds, which is considerably less than the 14-inch screen machines, which can weigh 8.5 pounds. The smaller devices are generally encouraged not only because of their lighter weight, but also because of their form factor, which lends itself to easier use on a typical classroom desktop.

Students also must purchase the engineering software bundle, which complements the hardware by providing the computing capability necessary in typical engineering learning environments. The minimal software suite for the student's Tablet PC is similar to what practicing engineers in industry might have access to in their design environments, including

- Matlab,
- Autodesk Inventor and Mechanical Desktop,
- PDF Annotator,
- Labview, and
- Microsoft Campus Agreement including: Office Professional, OS upgrades, OneNote, Visual Project, Visual Studio, and Client Access Licenses.

The process of selecting hardware and software considered both the educational program's needs and the hardware vendors' expected offerings. Discussions took place in nondisclosure meetings conducted early in the year, taking into account whether vendors could deliver the hardware in the July/August timeframe. A vendor's unfulfilled promise can be disastrous if students are left without a computer to start the semester. To avoid these difficulties, the college established working relationships with reputable vendors and provided pertinent information to students and their families.

TRANSFORMING CLASSROOM PRESENTATIONS

To effectively use Tablet PC technology, instructors must transform their teaching style and modify their instructional materials. They are using several e-ink-enabled software tools, including Classroom Presenter[2] and Dyknow Vision (www.dyknow.com), two mainstay tools that support more dynamic presentations and increase student interactivity.

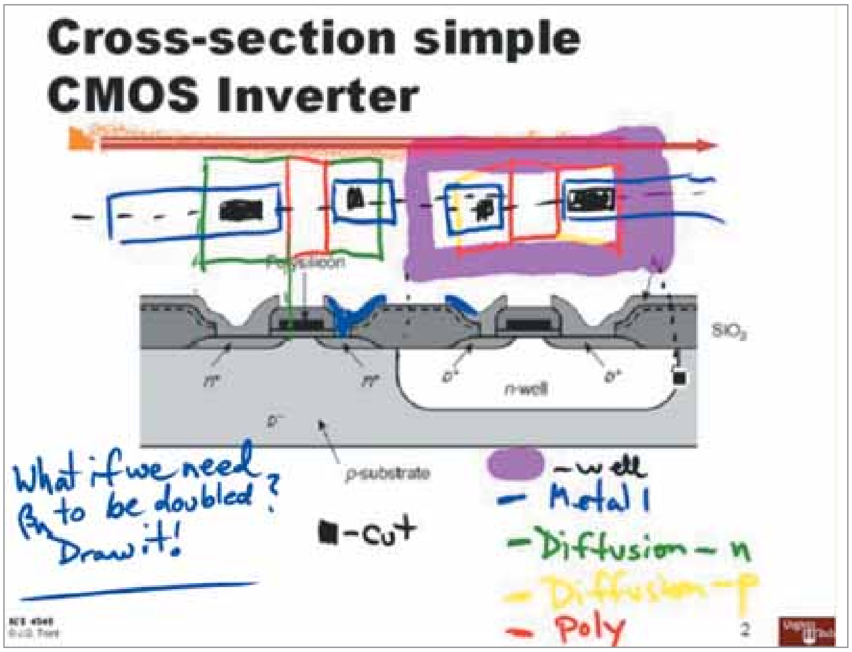

Figure 1. Annotated presentation. The instructor's slide accommodates dynamic annotations and challenge questions. The presentation is no longer limited to static, preplanned information.

Using these tools, a teacher generates instructional material by producing a set of PowerPoint-based slides to act as a framework for the lecture. The slides consist of pictures, diagrams, equations, Web page clippings, and other electronic materials to support the lecture.

The instructor then modifies the slides, hiding portions of diagrams or sections of equations to be filled in during the classroom discussion. Hidden portions are visible on the instructor's screen, but not in the public view or on the students' screens. The instructor uses e-ink to fill in the missing material dynamically in class. This encourages students to reflect on the material during the lecture rather than simply listening to a verbal reiteration of what is already shown on the screen or a reading of preprinted notes.

E-ink's power lies in its ability to show dynamically the process of developing a schematic or inking an equation's terms just as a practicing engineer does. The instructor's value-added factor is in showing the personalized process of development; without this personalization, the students might as well just read the book and skip the lecture.

Students become more engaged in the natural discussions in class because now they can view and participate in the design process rather than simply receiving a solution. In addition, they are not overwhelmed by the perceived need to mechanically copy notes.

Integrating interactivity is a second-level effect that the new tools facilitate. During the lecture, the instructor poses an open-ended question and asks the students to respond with a solution that is typically graphical in nature. Students write a solution on their tablet and submit it electronically to the instructor, who then chooses submissions to display anonymously and discuss with the class. Students become particularly engaged when instructors use this technique—they look forward to responding and are disappointed if the class doesn't discuss their solution.

Figure 1 shows an example of an annotated presentation screen in which the instructor spontaneously generates a question and asks the students to respond with answers to be displayed and discussed. The key to success here is the use of e-ink and the high-speed communication that facilitates the interactivity. Using this technique accommodates various student personality traits, ranging from those who are outgoing and are the first to volunteer an answer to those who are shy and rarely proffer a comment. The faculty has observed a more even distribution of students paying attention in class and more active discussion both during and after the lecture.

Another advantage to this presentation paradigm is the student's ability to generate a local, personalized electronic version of class notes. Both Classroom Presenter and DyKnow can broadcast notes and the instructor's e-ink in real time to students in the classroom. Students can then add their own e-ink and save the composite notes on their machines for later review.

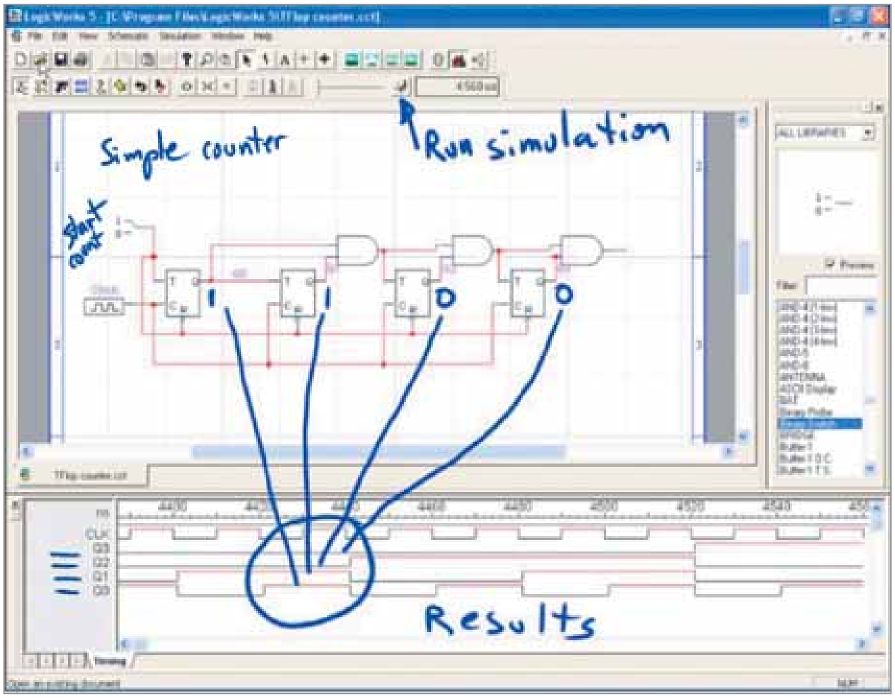

Figure 2. WriteOn tablet-based tool. The instructor can annotate directly on the operating simulator's output window, and students can save annotations and simulator output for later review.

pencil and paper paradigm but has several advanced capabilities. For example, with OneNote the user can rapidly search the entire notebook and locate handwritten words that relate to a concept. The built-in handwriting recognition facility does this with a high level of correctness.

Students also can use OneNote to record the audio portion of lectures while they take notes. In postclassroom sessions, students can click on e-ink objects in OneNote and playback the relevant audio clip, allowing very specific review of classroom information.

Collaboration is a powerful mechanism for reinforcing learning and preparing students for real-world design and development activities. OneNote's built-in collaboration facility lets participants share the electronic notebook's common sections.

This is a powerful mechanism that encourages in-depth thinking and enables reflections that are key to understanding complex concepts.

Engineering and computer science classes typically use dynamic simulators or other visualization tools. Instructors usually show the simulation's visual aspects in class and ask students to operate the simulator outside class, requiring them to remember the material presented during the lecture. With WriteOn, a new tablet-based software tool, the instructor can make notes on top of a dynamically running program and capture the annotations along with the simulation display as either a set of still images or as a movie of all onscreen activity.[14]

Figure 2 shows logic simulator on which the instructor has made notes about the behavior shown in the simulator-generated waveform. WriteOn lets the instructor provide value-added information that previously might have been presented in a rather dry and difficult-to-remember demonstration.

Several other similar Tablet tools are under development or are currently available to support classroom interaction in the Microsoft Tablet PC Education Pack (www.microsoft.com/windowsxp/downloads/tabletpc/educationpack/default.mspx).

Note taking and collaboration

Microsoft OneNote, a software tool for general note taking, provides an electronic notebook that mimics a pencil and paper paradigm but has several advanced capabilities.

Figure 3 shows a typical exercise in which several students work together to solve a problem. When they join a shared session, they can see the e-ink that other participants generate. The students can contribute their own e-ink, typed information, or any other electronic object they can extract from the electronic clipboard. A collaborator can modify or erase any object on the screen. Participants can be local or remote—with Internet access being the only requirement.

Initial classroom collaboration experiences indicate that most students are willing to participate in this type of interaction, but they do not have the refined skills required to derive maximum benefit from the exchange of ideas. However, after exposure, students quickly learn the basic requisites for effective electronic collaboration such as personal identification, appropriate sequencing, and idea formulation.

Electronic homework submission

Electronic homework submission has typically been difficult for engineering students since much of what is submitted consists of not just text as in a typical English or history class, but sketches intermingled with text along with the occasional picture. Several tablet-based tools offer students more flexibility in producing submissions. Word, OneNote, PDF Annotator, and Adobe Acrobat all allow applying e-ink annotations to typed documents, making it easier for students to produce electronic homework submissions.

For instructors, electronic homework submissions generally are easier to handle and grade. For example, upon receiving a submission either through e-mail or a classroom management system, the instructor can mark it up and return it to the student without having to use class time for paper collection or distribution. This also more readily preserves student privacy. Several faculty members who have used this scheme for a few semesters are pleased with the way it has streamlined the process and identify this practice as significantly increasing their efficiency.

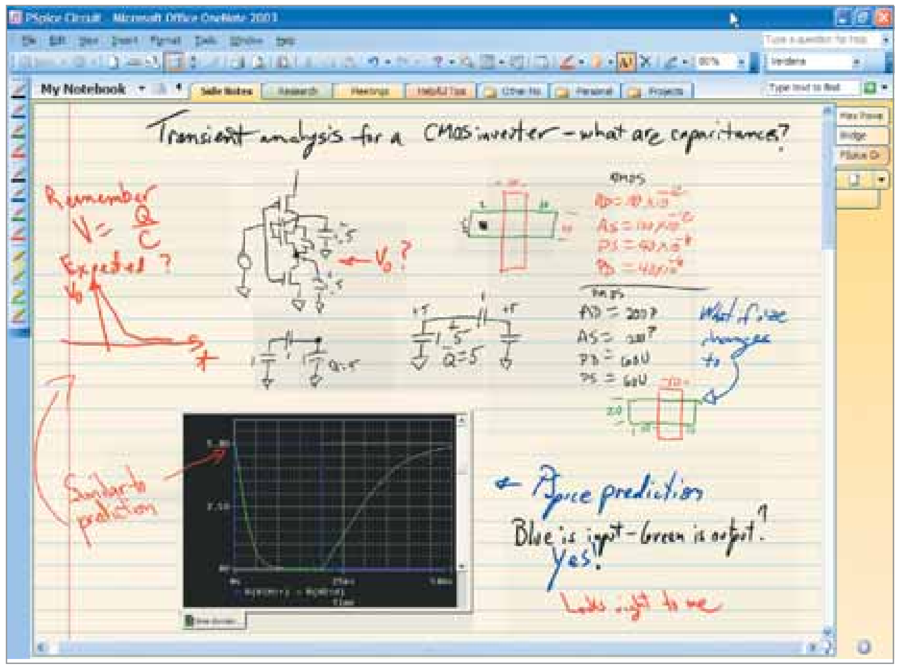

Figure 3. OneNote. Students can use the software tool to collaborate when solving a problem. Multiple participants in distributed locations can participate in the visual conversation.

FACULTY TRAINING AND SUPPORT

To take advantage of the new technology, faculty members are encouraged to participate in the Faculty Development Institute (FDI), a series of workshops where faculty are trained on pedagogical practices as well as details of the technology's operation. Early adopters of the new technology with knowledge of the difficulties and solutions teach the tablet workshops. Approximately 25 percent of the faculty receive training from the FDI each year.

Five or six times throughout the semester, faculty study groups meet to discuss progress and exchange tips and tricks for success. The faculty receives additional technical support at the beginning of the semester to help resolve in-class issues such as projector settings and network connectivity. Thus far, the faculty response has been positive, with participants enthusiastically working on developing and modifying materials as they participate in workshop sessions.

ASSESSMENT—PLANS AND PROGRESS

Assessing the tablet requirement program's effectiveness is paramount in ensuring that it produces the targeted pedagogical improvements. The assessment process is built around a core set of measures that are gauged each semester by having students respond to three surveys. A student-learning strategies instrument was adapted from the Motivated Strategies for Learning Questionnaire.[15]

The adapted MSLQ is used in a pre/post test design to measure changes in students' learning strategies using the Tablet PC during each semester. Adding a subset of questions from the national Educause Center for Applied Research study helps determine how students will self-report on their use of technology compared to other engineering students nationally. A second utilization questionnaire is distributed midsemester to measure the frequency and nature of technology use.

A survey administered longitudinally to a sample of the engineering faculty assesses faculty response to the use of the Tablet PC. Developed from extant teaching measures in the literature, the survey addresses not only the faculty's use of instructional technology but also their more general teaching practices and pedagogical beliefs. Responses will help determine if the faculty's philosophy and practice change over time and, in particular, if they become more attuned to active learning and the need to increase student engagement and collaboration in their teaching.

As the assessment program ramps up, school officials will use other measures to determine the Tablet PC's impact on how students organize and think about course materials, collaborate with other students, and participate in class.

Data collected and analyzed so far has focused on the impact on student note taking and whether using Tablet PCs encourages metacognitive strategies and critical thinking skills in individual studying and note taking. While confirming the Tablet PC's value in collegiate instruction, the results also have raised some technical and instructional issues related to its use.

Using the MSLQ data, the faculty painted a picture of an incoming freshman engineering student's learning strategies and technology use and assessed the changes after a semester in the program. In September 2006, 61 percent of freshman engineering students reported they did not have access to computers in their high school classes; by midsemester nearly all students reported using their PCs on a daily basis.

In the preliminary phases of data analysis, we see some significant changes in student learning habits as they apply to note taking and studying, and we will continue to measure and analyze changes as students progress though their degree program. As we collect and analyze data, we will report on results related to the measurement instruments' validity.

Using a multifaceted, collaborative approach, the Virginia Tech College of Engineering has developed an implementation process for using Tablet PCs that includes computer acquisition, faculty training, infrastructure modifications, and multiple assessments for program evaluation. Initial results of this groundbreaking program are positive, showing measurable improvements in pedagogical practices that are ultimately expected to lead to learning improvements. Various aspects of the program's processes are scalable and extensible to other institutions and to the science, technology, and mathematics disciplines. As we proceed, we imagine the types of Tablet PC-based dialogues Socrates and Plato might have had and how useful it would be to have searchable e-ink archives of those conversations.

Acknowledgments

The author acknowledges Glenda Scales, associate dean for engineering computing, for her leadership in this effort and Deborah Olsen and Kimberly Filer for their work on the program's assessment aspects. This endeavor's success is due mainly to the broad participation of our innovative engineering faculty and students. Thanks also to Microsoft Research and Fujitsu Computers, who, along with the Virginia Tech College of Engineering, have formed the Premier Alliance, which supports the efforts to effectively use Tablet PCs.

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