

Using Tablet PCs in Engineering Education

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Abstract

This paper describes the experiences of using Tablet PCs along with associated software, such as Classroom Presenter and OneNote, in a course entitled Introduction to Computer Engineering. Twenty tablet PCs were distributed in a classroom of 40 students. Students used the tablets on a daily basis throughout the semester to take notes, to respond to in-class exercises, and to perform work in small group projects. Active learning exercises, specifically facilitated by the new tablet PC technology, were devised by the instructor for almost every classroom session. Students were able to capture the instructors electronic ink notes made on PowerPoint slides and electronic whiteboards. Along with the instructor's notes, the software also captures student electronic ink notes as well as e-ink input generated by other students. Throughout the course, students kept journals of their experience. Additionally, the performance of the Tablet PC group was monitored and compared to others in the sophomore cohort who took the course without Tablet PCs. In general, students were very satisfied with the use of the tablet PC and their ability to take electronic notes in a format that was natural to them – handwriting. There was also a notably higher level of active participation in classroom exercises through the use of the networked tablet facilities. Overall, students were more engaged in the classroom and were better equipped to review classroom material during their out-of-class study time. This paper will present results and observations from this experiment.

Introduction

Tablet PCs are one of the newest innovations in the computing and communications world. These devices consist of a standard notebook PC configured with a screen (tablet/slate) which acts as both a display device as well as 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. Native tablet operating systems support the use of this new input capability allowing users to input basic commands and drawings, while also facilitating the development of innovative applications by software developers. Typical tablet PCs also include built-in wireless networking hardware that allows the user to relatively easily communicate in localized ad hoc networks or over the broader Internet.

Several tablet PC-specific software packages are available to support the pedagogical needs of the engineering classroom as well as typical engineering group collaborative environments.

Classroom Presenter and MS OneNote are examples of two packages that provide excellent classroom presentation capabilities when used on tablet PCs. These packages also allow for a highly interactive environment with both teacher-student and student-student bi-direction real-time interaction.

Tablet PCs, along with appropriate associated software, inherently contain several features that make them naturally attractive for use in engineering and science teaching and learning environments. The ability to have pre-drawn figures or images over which the teachers may use pen gestures to make annotations, by-hand sketches, comments, notes, etc. is very congruent with most engineering faculty members' teaching styles. Likewise, most engineering and science students favor natural mechanisms such as stylus devices to create their own notes, or ascribe their interpretations to the instructor's handouts. Thus the tablet PC provides a perfect vehicle to perform these basic note-taking functions analogous to the traditional pencil and paper methods.

Electronic ink-based features are specific to tablet PCs. Using these features in combination with typical computer-based capabilities provides a significant advantage over traditional methods of student studying techniques and classroom interaction. For example, using tablet PCs students may perform note taking using electronic ink capabilities while follow up note-reviews may use standard computer search capabilities to locate specific instances of important points or annotations. Search capabilities are highly germane to the mechanisms students are becoming used to using when dealing with information resources.

This paper describes how tablet PC technology was used to enhance the classroom environment of an introductory course in computer engineering. The technology was used to support a more active learning environment in which students were more likely to take notes, participate in classroom discussions, and work on mini-problems solved during class. Although the tablet PC provides great opportunity for enhancing the classroom environment, the use of the technology must be accompanied by fundamental enhancements in the way the class is conducted in order to be effective.

Active Learning

Classroom experience along with a number of education research studies have shown that students generally do better in classrooms that involve the use of *active learning*. Incorporating active learning in a standard classroom can be as simple as asking students to answer a question, plot some data, sketch out a solution, or interpret an observation, predict a behavior, critique a design, explain an experimental result, or troubleshoot an erroneous system or program¹. An extended model of active learning in the classroom includes having students team up on their activities. For example, the *think-pair-share* scenario is one in which the students work on something individually and then pair up to compare and improve their responses before you call on them to present their results to the class. All of these relatively simple practices produce a much higher degree of participation in the classroom activity. Greater degrees of participation generally produce higher levels of learning^{2,3}.

Another reason to consider the use of active learning can be found when the background of young engineering students is examined. Today's students have had less than the desired amount of hands-on experience with problem solving in pre-engineering and basic engineering classes. Therefore, they need more of an introduction to both engineering topics as well as to the typical methods used to solve problems in order to arouse their curiosity and develop their interest in engineering subject matter. Active learning classroom activities have been shown to stimulate student interest and increase attention levels in significant numbers of students and thus produce subject matter interest that increases student retention.

Tablet PCs can greatly facilitate active learning in the classroom. The section below will describe some of the details of how tablet PC systems, including presentation/interaction software, can be used to assist in the implementation of an active learning environment.

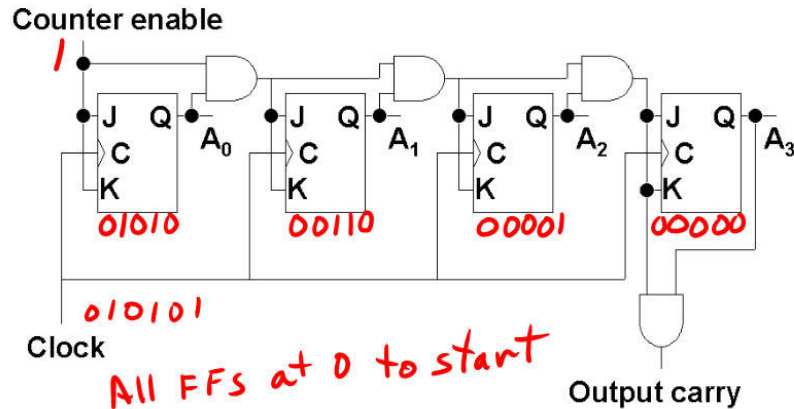
Using Tablet PCs

Several different software packages are available to take advantage of the special features of tablet PCs, tailoring them for use in the classroom. One such package is called Classroom Presenter and was developed by professor Richard Anderson, et al. at the University of Washington^{4,5}. (Classroom Presenter from the University of Washington can be downloaded free at <http://www.cs.washington.edu/education/dl/presenter/>). This program, in its most basic mode, allows you to convert PowerPoint presentation into Classroom Presenter slides, and then to show the slides using a standard computer projector system. The big difference is that the slides can now be written on by the instructor with electronic ink.

Figure 1 is a picture of a typical slide that an instructor might use to explain how hardware counters can be designed. As part of the classroom presentation the instructor would apply inputs to the logic diagram and describe the response of the counter. There may be additional notes written by the instructor that describe the initial state assumptions or special points of interest to the students. Using Classroom Presenter on a tablet PC, the instructor can apply all of these notations by using a pen device and writing on a screen that is in the tablet position. This makes the overall operation very natural and easy to perform. The electronic ink along with the original slide can be saved and made available to students for post class review. Saved ink and notes can be further annotated offline by students during the review process.

In many cases, good discourse in the classroom will lead to extended discussions into areas not anticipated when the original PowerPoint slides were developed. Classroom Presenter has the capability of allowing further drawing area to be available to the instructor by shrinking the original slide and providing whiteboard space adjacent to the original slide as shown in Figure 2. In this figure the instructor has drawn in a waveform at the bottom to describe the behavior of the clock signal applied to this circuit. A table has also been added to more clearly demonstrate to the students that the logic circuit indeed does count up in binary as each full clock period is applied. Again, the emphasis is on making the presentation more spontaneous and tuned to the needs of the class. PowerPoint slides provide the outline and basis for discussion while the instructor reads the reaction of the class and adds notes and points of emphasis to the presentation as it progresses.

Binary Counter (cont'd)



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Figure 1 Classroom Presenter slide showing instructor annotations.

Classroom Presenter has a second mode of operation which is meant to be used when all of the students in the classroom have a tablet PC at their desk. In this mode the contents of the instructor's screen is broadcast to the class in real-time -- this includes the electronic ink that the instructor adds during the presentation. Students may add their own electronic ink on their tablet PC. By participating in the note-taking process and adding their own interpretation of the class discussion to the notes they take, students increase their ability to quickly (in-class) identify portions of the material they have difficulty in understanding. Active participation in note-taking also increase student retention of the material by a significant amount. Figure 3 shows a Classroom Presenter slide taken from a student tablet that includes the student's notations as taken during the presentation. These slides may be saved in a file by each individual student so that they can be reviewed and further annotated outside of the classroom.

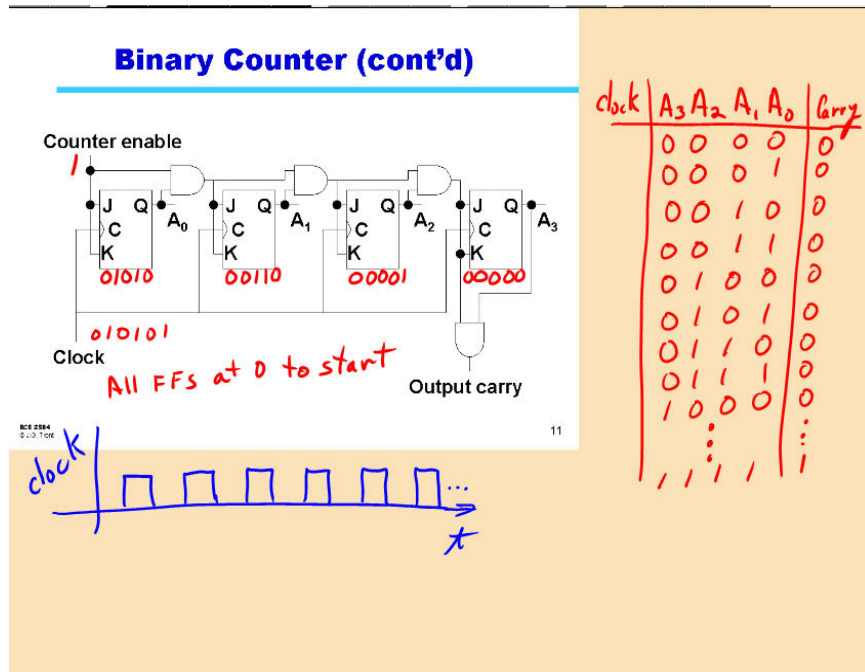


Figure 2 Classroom Presenter slide with additional drawing area.

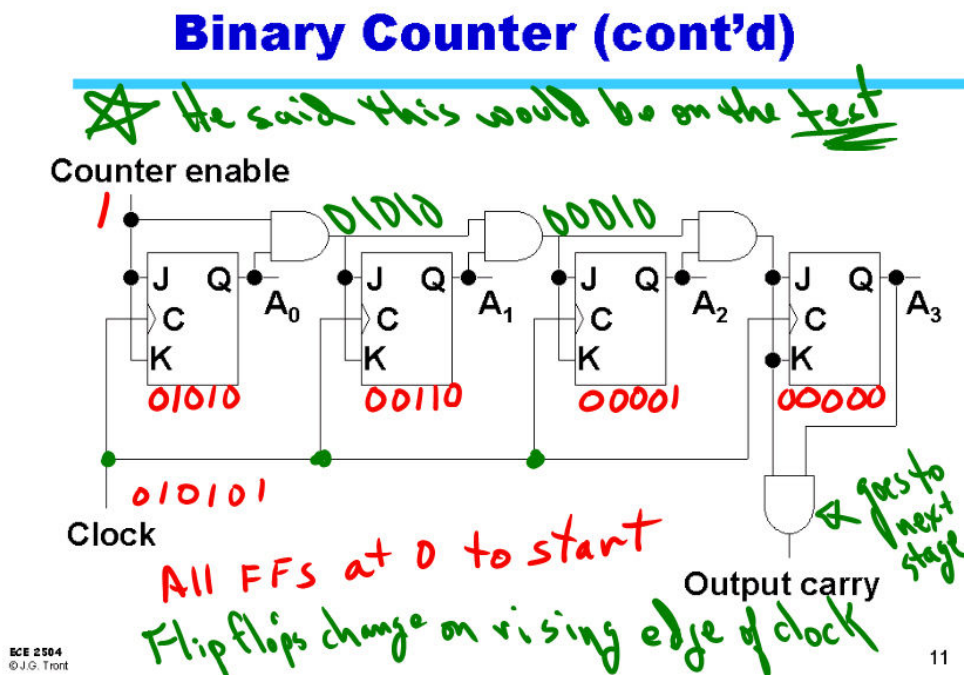


Figure 3 Classroom Presenter slide from student tablet with student notes added.

Although the student mode for the program works best on a tablet PC, it is also somewhat functional on a standard notebook PC as well. The major difference is the lack of electronic ink

on the notebook. Notebooks can be readily used to capture the presenter's in-class slides and ink, and can be used to review notes after class.

Another very valuable tool contained in Classroom Presenter is one which allows students to send their screen input to the instructor's screen. By using this type of interaction capability, the instructor is able to pose questions to the class during the normal flow of the class based on the material being discussed in the presentation. The instructor may present a partially completed logic diagram and ask the students to complete the design. Or the students may be asked to write the program to drive a particular hardware interface device to perform specific operations. Once the students solve the problem, they transmit their solution to the instructor's computer. The instructor may then choose from among the student responses and display them anonymously on the projector for further discussion by the class. This feature is a major step in facilitating active learning. Again, the students may use electronic ink applied by stylus (pen) devices to enter their designs, or code, etc. in a natural way; much as they would do in a pen and paper or chalkboard exercise.

One final feature of Classroom Presenter that assists the instructor is the ability for the student to provide short feedback information to the instructor on-the-fly during the lecture. Feedback consists of a type of popup note that appears on the instructor's machine and is generated by one or more students' input from their tablet PC. For example, a student may feel that the instructor is going to fast and that the presentation needs to slow down in order for him/her to keep up. By clicking on a feedback option on the student tablet, a note will pop up on the instructor's screen with an appropriate message. Examples of feedback from three different students are shown in Figure 4. Feedback marks are located adjacent to areas on the slide where the student is having problems, or where the material has been well explained. Obviously, the instructor needs to be able to control feedback in order to maintain control of the class. Classroom Presenter allows feedback to be turned either on or off throughout the presentation.

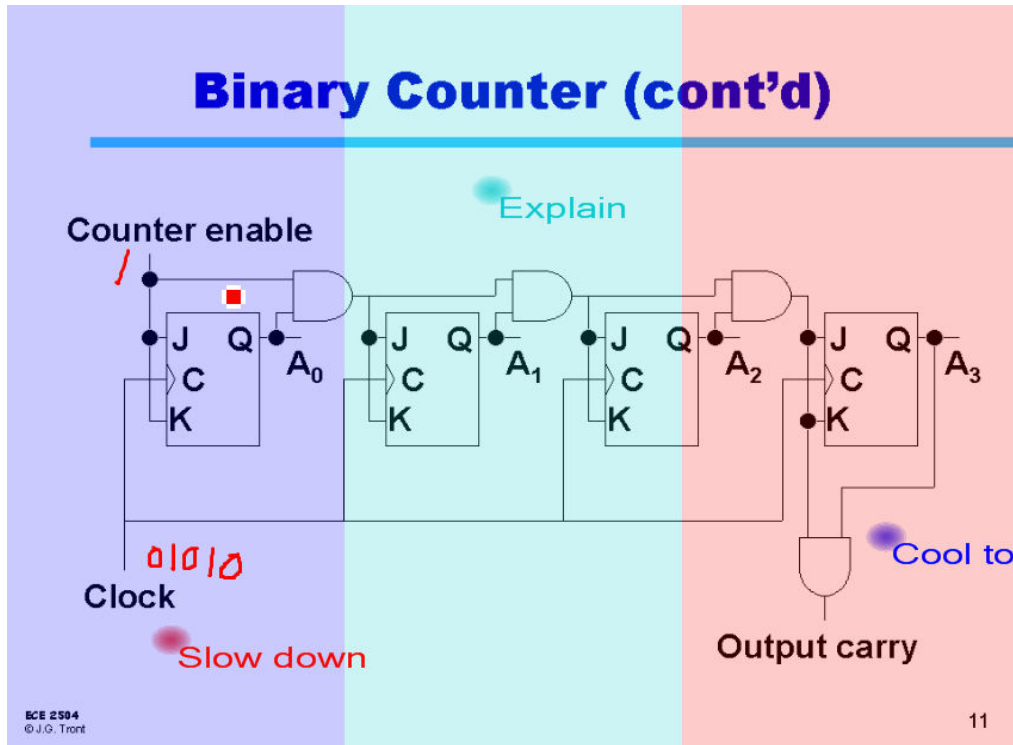


Figure 4 Instructor screen with examples of student feedback messages

Classroom Experience

Tablet PCs configured with Classroom Presenter and Microsoft OneNote were used in a course entitled Introduction to Computer Engineering. At Virginia Tech, this course is required of EE, CpE, and CS students with most students taking the course in their sophomore year. Twenty tablet PCs were distributed in a classroom of 40 students in both the spring of 2004 and the spring of 2005. Students used the tablets on a daily basis throughout the semester to take notes, to respond to in-class exercises, and to perform work in small group projects. Students were able to capture the instructors electronic ink notes. Throughout the course, students kept journals of their experience and documented their satisfaction and concerns with the use of the tablet PCs. Additionally, the performance of the Tablet PC group was monitored and compared to others in the sophomore cohort who took the same course, but without Tablet PCs.

To set up the class, it was necessary for the instructor to convert his PowerPoint slides over to the file format acceptable by Classroom Presenter which is called the CSV format. This was a rather mechanical operation and took little effort. However, in order to truly take advantage of the new technology-based tools, the need to perform a more involved transformation soon became apparent. First, slides were adjusted so that the instructor would fill in more blanks on the fly. Diagrams were left partially completed so that they could be finished during class with students collaborating on the details of completion.

To take advantage of the improved interaction possibilities, new slides were added to incorporate more active learning opportunities in the presentation. *Exercise slides* were included wherein

students were required to participate in some problem solving work. Most of these exercises were set up so that students working on their tablets would be able to share their solution with the class by submitting it to the instructor system. The instructor then solicited comments on designs, on coding solutions, or on any aspect of the student submission in order to increase the interactivity in the learning environment. Since not all students had tablet PCs, many of the exercises were set up to be group exercises or think-pair-share exercises. An example of an exercise slide along with a student submitted solution response is shown in Figure 5. On the left side is the original slide with the problem statement. On the right, the student (or group of students) has drawn a possible solution for the question.

Exercise

- Design an 8 word by 4-bit ROM with the following values stored in it:

Address	D3	D2	D1	D0
0	0	1	0	1
1	1	1	1	1
2	1	0	0	0
3	0	0	0	0
4	1	0	1	0
5	0	1	1	1
6	1	1	1	1
7	1	1	1	0

Figure 5 Exercise slide with student solution.

After receiving student submissions, the instructor quickly reviews them and chooses one or two, or more to review with the entire class. Proposed solutions were projected on the public projection screen and students are invited to discuss and critique the solutions. Exchanges were generally quite engaging with a large majority of the class participating.

The other tablet PC-oriented tool that we used in this class was Microsoft's OneNote. This tool allowed students to produce notes consisting of electronic ink, graphics, still images, sound, and any other entity that can be cut and pasted in a Windows environment. Students used One Note as an ancillary tool in the introduction to computer engineering course as well as in the other courses the students were taking that semester.

Assessment

Several different measures were taken in order to assess the effectiveness of the use of tablet PCs in this class. First, students were asked to keep a journal chronicling their experience with the tablet PCs. Several basic questions were suggested for discussion in the journals. These included indicators of student satisfaction with the hardware and software itself as well as indicators of satisfaction with the instructional approach. The entire class was also surveyed at the end of the semester to gauge their satisfaction with new tools and techniques.

Over 85% of the students commented in their journals that they were very pleased with the tablet PCs and their use in the class. They liked the ability to easily track the lecture and to make notes while still being able to keep up with the pace of the class – they didn't feel as though they had to write down every last thing that the instructor said. Out of the 20 students who were loaned the tablet PCs for the semester, three said they were immediately going to buy a tablet, eight said that they were going to buy a tablet when came time to replace their current notebook, and four said they would likely eventually buy a tablet PC because it had the capabilities that engineers were highly likely to need as they practiced their profession. Two students said they found the tablet to be distracting since they used it in class to browse the web or check their email. This may in fact have occurred with other students, but they didn't complain of distraction; rather they found it to be a good readily available feature. It may be that the instructor needs to work a little harder to retain the attention of the class.

The active learning exercises were very popular with the students. During the active learning exercise the instructor observed a high degree of class energy and participation. The class was a buzz with discussions of different ways in which to solve the problems. Students were quite eager to have their solution shown to the rest of the class and many took pride in defending their solution strategy. Ninety percent of the survey and journal respondents indicated that the exercises helped to clarify and solidify the concepts being demonstrated during the presentations.

The follow-on course for Introduction to Computer Engineering is a course titled Digital Circuit Design I. For the past five years, we have administered a pre-test on the first day of class in this course. The purpose of these tests is to determine the preparedness of the students and to identify how well individual instructors prepared the students in the introductory course. We plan to use information from this pre-test to help us understand whether students who participate in tablet-enabled section of the introductory course appear to have absorbed the material better.

Although it is difficult to provide a numerical value to indicate the amount of improvement brought to the learning environment by these new tools and techniques, the instructor did notice a much higher degree of interest in the course material, a much higher level of class participation, and a lower absentee rate. Another indicator of improvement was a modest increase in the overall teaching rating for the instructor – no small feat when teaching sophomore level classes.

Conclusions

Tablet PCs can be used to help improve the delivery of lecture material by allowing the instructor to combine somewhat static PowerPoint slides with the dynamic delivery mechanism of electronic ink. Instructors can annotate and draw in a more natural manner and allow students to download composite slides consisting of the original PowerPoint along with the electronic ink for post-class review.

Classroom activity is greatly enhanced in an environment where all students have a tablet PC and are able to receive the instructor's annotated presentation and add their own electronic ink to these notes. Students were particularly energized by the ability to work on exercises on their own tablets and subsequently discuss their solutions that were uploaded and projected through the instructor's computer. Students also found it useful to be able to provide on-the-fly electronic feedback to the instructor regarding the pacing of the class and the clarity of the topic being discussed. However, this feature would likely be much more valuable in larger classes where some students find it difficult to ask questions or give the instructor a verbal signal of their level of comprehension.

New computing and communication technology cannot by itself improve teaching and learning. Faculty need to work on integrating technology into their teaching scheme much like they did when desktop computers first became affordable to all students. In order for the technology to make a difference, faculty must re-think the way in which they teach and the way in which students best learn. Tablet PCs provide a great mechanism for allowing instructors to incorporate active learning methods into their presentations.

Future Work

A significant number of students have been involved in the tablet PC trial study to this point. However, in order to better show the viability of this new tool, we are planning to use the tablets in several more courses in the upcoming semester. Additionally, we will broaden our experiment to include other engineering courses outside of the current study in the introduction to computer engineering course.

As part of our future work, we plan to improve our assessment techniques so that we will be able to more precisely identify the features of the new tools and techniques that provide the most benefits for all students. We are developing new survey instruments and an automated mechanism for students to keep their journals. We are also developing a modification to the Classroom Presenter code to monitor the amount of electronic ink activity performed by each student in order to get a better understanding of the correlation between note-taking and comprehension.

Given the power and versatility of the tool, we plan to put more emphasis on the use of OneNote in the future. We are developing note templates for use with OneNote and we are investigating the strategic use of sharing strategies to perform multi-way think-share-compare scenarios.

Finally, we are developing a set of guidelines and support tools for faculty who want to create their own sets of in-class active learning exercises for their discipline

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Biography

Joseph G. Tront is professor of Electrical and Computer Engineering at the Bradley Department of Electrical and Computer Engineering at Virginia Tech. He teaches courses in computer architecture and in VLSI design. He is also very active in developing and using e-technology in engineering education and provides workshops to universities on the use of personal computing devices and educational digital libraries as they relate to teaching and learning.