AC 2011-298: USING TABLET PCS IN ELECTRICAL/COMPUTER ENGINEERING CLASSROOMS: LECTURING AND IN-CLASS ACTIVITIES

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Using Tablet PCs in Electrical/Computer Engineering Classrooms: Lecturing and In-class Activities

Abstract

This project has been implemented in our department since Fall 2007. Tablet PC-based teaching materials were developed and implemented in four undergraduate Electrical or Computer Engineering courses. The main goals of our project are to improve the teaching and learning environment, increase the interactivity between the instructor and students in class, promote active learning and critical thinking, and, thus, enhance student learning in our electrical/computer engineering programs. Through collecting and analyzing assessment data, we can see that (1) Tablet PCs allow instructors to make a better preparation and demonstration of the content to be taught in class; (2) the in-class interactivity among the instructor and students is improved, which benefits active learning; and (3) the recording of in-class lecture notes make it easy for instructors to refer to the content taught before and for students to review and catch up. Meanwhile, we have also experienced side effects of introducing technologies to classroom. The class may be delayed or slowed down due to setup time and software running errors. Class attendance may be an issue. Solutions to those side effects are suggested in this paper as well.

1. Introduction

Thanks to its graphic tablet/screen hybrid and digital pen, a Tablet PC offers the function of digital inking along with the basic functionality of a laptop or notepad. As the latest portable computing devices, Tablet PCs attract educators' attention and have been introduced to both K-12 and college classrooms [1][2][3]. Funded by an innovative teaching grant from Hewlett-Packard, we have explored the use of Tablet PCs in Electrical and Computer Engineering classrooms since Fall 2007. This paper is going to present our experience of integrating Tablet PC-based learning materials into our Electrical and Computer Engineering courses and discuss its impact to teaching and student learning. First, we will describe how the attractive features of Tablet PCs were utilized to support lecturing, in-class tutoring and interaction, after-class review, and computer-based electronics labs. In our project, the *computer whiteboard*, consisting of a Tablet PC and a LCD projector, is used to replace the traditional chalkboard or PowerPoint slides for lecturing. Lecture nodes are prepared, annotated while lecturing, and saved for review in Microsoft Office OneNote 2007. Tablet PC-based in-class activities are developed to promote active learning. Then, we will describe the methods of assessment data collection and analyze the assessment data to study the impact of this project to teaching and student learning. Surveys were given to students to get an insight of technology they have been exposed before they come to our classes and their perception to the use of Tablet PCs in the classroom. The same exams taken by the experimental group and the control group are also used to investigate the impact of Tablet PC-based teaching modules to student learning outcomes. Finally, we will discuss the enhancement to teaching and student learning brought by our project as well as the lessons we learned.

2. Design and Implementation

This section presents the background, motivations, and goals of our project, the

technologies used in this project, and the practice changes brought by the new technologies.

2.1 Project Background

This project was initiated in June 2007 and has been implemented in our department since Fall 2007. Tablet PC-based teaching materials were developed and implemented in four undergraduate Electrical or Computer Engineering courses: EGR 102 – Introduction to Structured Programming (freshman level), EGR 213 – Digital Electronics, and ELN 311/312 – Engineering Electronics Lab I/II (junior level). This paper is going to discuss our use of the HP mobile technology in EGR 102 and EGR 213. Our classes are typically small-sized, with up to twenty students. While all the students in junior-level classes and most of the students in freshman and sophomore-level classes major in Electrical or Computer Engineering, a small portion of the students in freshman and sophomore-level classes major in Chemical Engineering, Mathematics, or Music Technology Engineering.

2.2 Motivations and Goals

Through a variety of methods such exit interviews with graduating seniors, employer surveys, and discussion with the engineering board, our department has identified programming and design as areas needing improvement and has plans for more open-ended problem solving in our classroom as a result. Therefore, in this project, we intend to utilize the HP mobile technology to improve the training of students on their programming and design skills as well as their problem solving skills. Meanwhile, the following student learning issues also motivated us to bring mobile wireless Tablet PCs into our electrical/computer engineering classrooms. First of all, it is impractical to have students in the computer lab for every programming class. The setup of a computer lab is not convenient for lecturing. However, there is a need for the instructor to demonstrate program editing, compiling, and debugging and also, for students to have in time hands-on in real software system when the instructor introduces a concept, method or algorithm. Another issue in the traditional classroom is that only a few students have the opportunity to answer in-class questions. Moreover, verbally describing the answer is not feasible if graphic presentations, problem solving steps, or program segments are part of the answer. Thus, encouraging the participation of all students to in-class activities is a challenge. Also, paper based assessments such as quizzes and exams take days for instructors to get the feedback on student learning outcomes and to adapt to students' needs. The instructor cannot promptly identify the difficulties students face and how well students understand the concept or method. Finally, in traditional classrooms, lecture notes written on the whiteboard cannot be saved. Being busy in writing in-class notes might distract students from listening to the lecture and thinking. Students missing the class cannot get complete and accurate lecture notes.

The main goals of the use of the HP mobile technology in EGR 213 and EGR 102 are to improve the teaching and learning environment, increase the interactivity between the instructor and students in class, promote active learning and critical thinking, and, thus, enhance student learning in our electrical/computer engineering programs. Specifically we intend to use the technologies provided by Tablet PCs to overcome the student learning issues discussed above. In this project, the development of Tablet PC-based teaching materials aims to 1) allow instructor to demonstrate programming in real-software environment, 2) give students in time

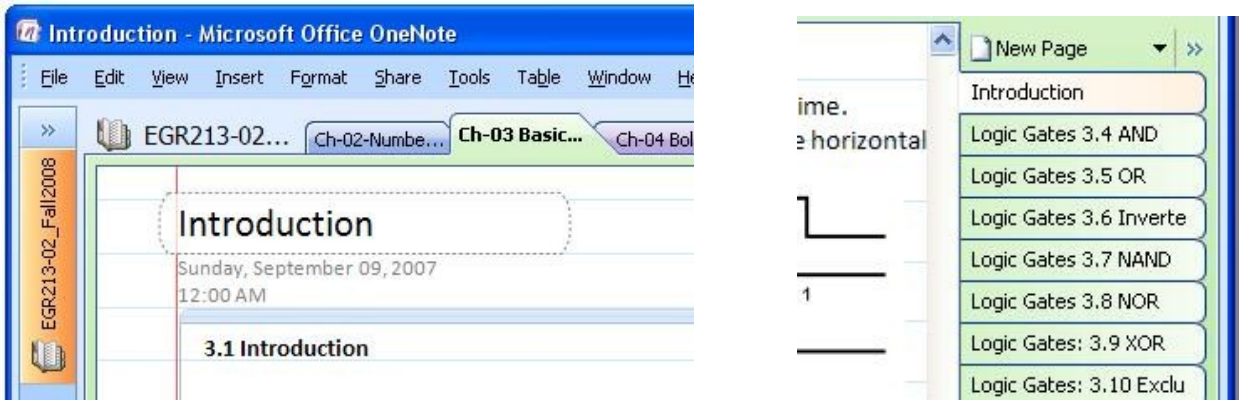
hands-on practice on the topic they just learnt, 3) provide every student the opportunity to answer questions, 4) allow students to give written answers to the questions, 5) enable the instructor identify the content on which students are confused or have difficulty in a timely fashion, and 6) facilitate review on previous topics and after-class review.

2.3 Technology Use

This section presents the new technologies that we implement in our classrooms in this project. These new technologies are inking in Microsoft Office OneNote 2007 and UW Classroom Presenter 3.0, sharing of digital ink in UW Classroom Presenter 3.0, projection of programming in MATLAB® and Borland C++, and e-learning at University's Blackboard® website.

2.3.1 Inking in Microsoft Office OneNote 2007

Microsoft Office OneNote 2007 is an easy-to-use note-taking and information-management system [6]. OneNote provides useful features for use on the Tablet PC with a pen interface and a tablet/screen hybrid.



(a) (b)

Fig. 1. (a) Organizing information into sections in a notebook, (b) Organizing information into pages in a section

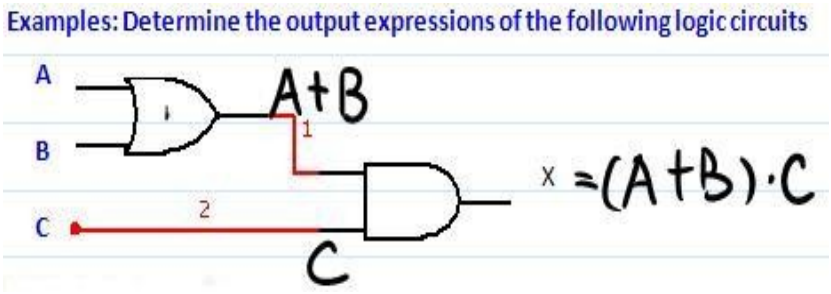


Fig. 2. The mixture of text typing, picture, and handwriting

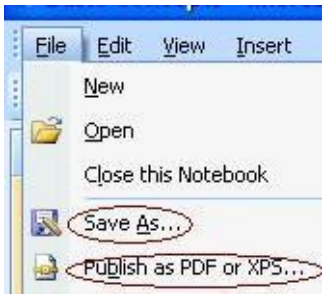


Fig. 3. Publishing

The first feature that is used in this project is the *note organization*. The lecture notes of a course can be organized into a notebook containing pages and sections. For example, as shown in Figure 1, the notebook titled "EGR213-02_Fall2008" records all the lecture notes of the

course EGR213-02 taught in Fall 2008. The lecture notes of every chapter are kept in a section such as "Ch-02-Number System" and "Ch-03 Basic Logic Gates". Each section consists of individual pages, each of which records the lecture notes on a specific topic such as "Logic Gates 3.4 AND" and "Logic Gates 3.5 OR". The instructor can easily copy, paste, add, move, rename, or delete sections and pages, navigate within or across sections and pages, and re-organize the lecture notes.

Another feature we use is the *free-form canvas* offered by OneNote. On this canvas, the instructor types, writes, or draws notes in the form of text, tablet, graphics, and images anywhere and anyway he or she needs. The instructor can also insert pertinent information from other sources such as the picture of a logic device or the flow chart of a well-known algorithm. Figure 2 shows the example of a mixture of text typing, picture, and handwriting. This piece of lecture notes is edited by the instructor through typing the text in blue, inserting the picture of the digital logic circuit that is copied from MultiSIM®, and writing the annotations by hand while giving the lecture in class.

In addition, we also use the *archiving and exporting* feature offered by OneNote. For the purpose of archiving or publishing, the lecture notes edited in OneNote can be *saved as* a variety of file formats including OneNote Sections (*.one), OneNote Single File Package (*.onepkg), Single File Web Page (*.mht), PDF (*.pdf), XPS Document (*.xps), MS Word XML Document (*.docx), and MS Word Document (*.doc). As illustrated in Figure 3, either the command of "Save As…" or the command of "Publish as PDF or XPS…" can be used.

2.3.2 Inking and sharing of digital ink in UW Classroom Presenter 3.0

UW Classroom Presenter 3.0 (CP 3.0) [8] is a Tablet PC-based interaction system that supports the sharing of digital ink on slides between the instructor and students. It can also be used as a presentation tool that integrates digital ink and electronic slides [8]. Developed by University of Washington, UW CP 3.0 is free for downloading at their website [8]. Our project implements three functions offered by CP 3.0, i.e., *digital inking*, *networked presentation*, and *submission of student work*.

To start *inking* in CP 3.0, the instructor either creates a blank whiteboard deck consisting of blank slides or loads slides from a Microsoft PowerPoint file. Using the keyboard or digital pen, the instructor may type, write, draw, or erase notes on these slides. Figure 4 shows an example of digital inking in CP 3.0, where the instructor draws the symbols of several different types of D Flip-Flops and the waveforms of input signals on a blank slide.

Upon starting CP 3.0, the user takes a role of instructor to initiate a *networked presentation* or a role of student to join a networked presentation that is broadcasted by the instructor. Figure 5 gives a snapshot of the dialog box, where the user takes the role of instructor and initiates a TCP Server for a networked presentation. In a networked presentation, the slide and notes that is displayed by the instructor in the "whiteboard" area are seen by all the participants on their own Tablet PCs in a synchronized fashion.

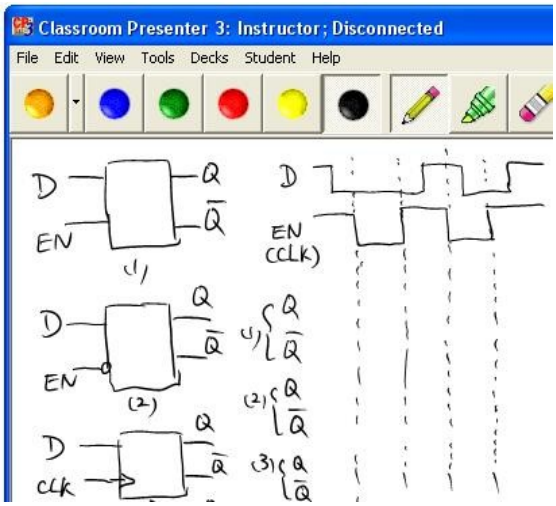


Fig. 4. Digital inking in CP 3.0

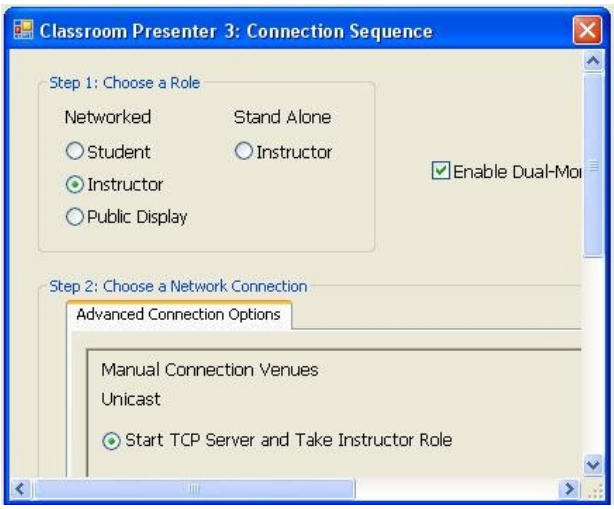


Fig. 5. Initiating or joining a networked presentation

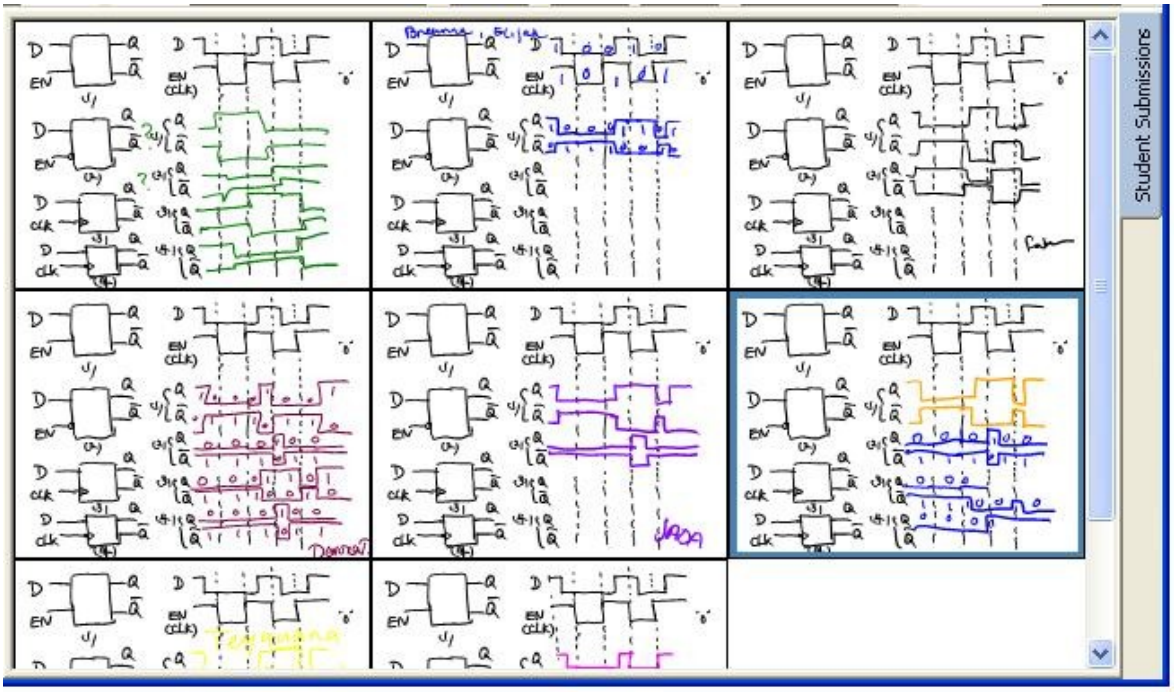


Fig. 6. Student submissions on the instructor's Tablet PC

Once the instructor distributes a written problem statement or gives a quick poll in a networked presentation, every student works on his or her Tablet PC individually and submits the work to the instructor. As shown in Figure 6, the student submissions are only sent to and displayed in the "Student Submissions" area on the instructor's Tablet PC. However, the instructor can select one of the submissions to be displayed in the "whiteboard" area and shared with the whole class.

2.3.3 Programming in MATLAB, gVIM, and Borland C++ Compiler

As two high level programming languages that are commonly used in electrical/computer

engineering industrial, both MATLAB and ANSI C++ are taught in our programming course. MATLAB®, a commercial product of MathWorks™, is an interactive environment for algorithm development, data visualization, data analysis, and numeric computation [7]. MATLAB® is used by the instructor and students to edit, debug, and run script files. Figures 7 and 8 give the snapshots of editing a script file in MATLAB® editor and running a script file in the command window of MATLAB®, respectively.

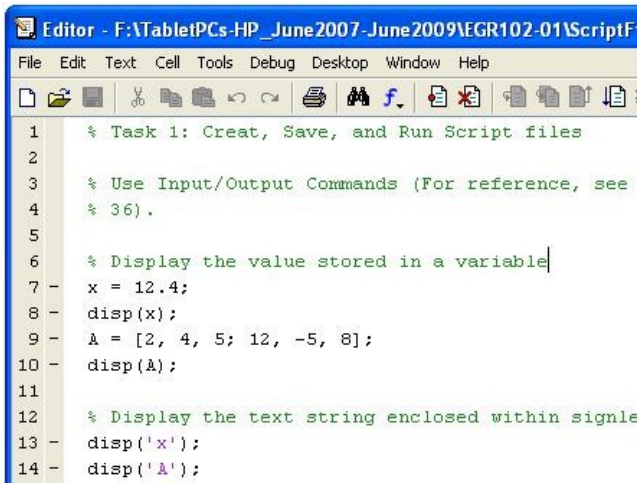


Fig. 7 Editing a script file in MATLAB Editor

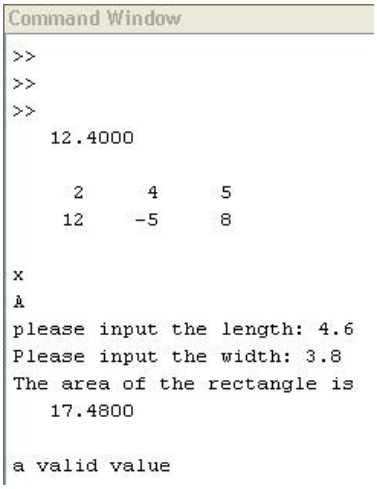


Fig. 8. Running a script file

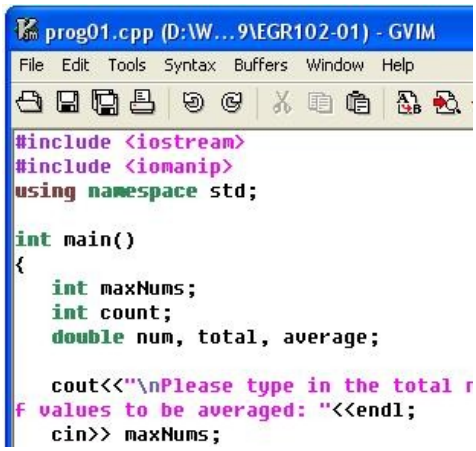


Fig. 9. Editing a C++ source code file in gVIM

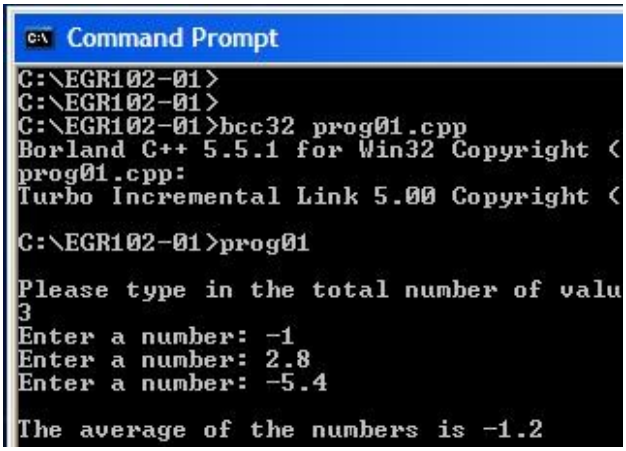


Fig. 10. Compiling and running a C++ program

VIM, often called a "programmer's editor", is a highly configurable text editor built to enable efficient text editing [9]. As a GUI version of VIM, gVIM is used by the instructor and students to edit C++ source code files. Borland C++ Compiler 5.5 [5], a free command line ANSI C++ compiler, is used for compiling source codes. A snapshot of editing source codes in gVIM is shown in Figure 9. Figure 10 shows a snapshot of compiling the C++ source file using a command of "bcc32" and running the executable file named "prog01".

2.3.4 e-learning at University's Blackboard® website

In this project, Blackboard®, a Web-based course-management system [4], is used by the

instructor to post syllabus, lecture notes, handouts, and homework assignments on-line as well as to communicate with the class out of the classroom through emails and on-line announcements. Figure 11 shows the on-line classroom of EGR213-02 on the Blackboard® at our University. The instructor and all the students registered in a course have the access to the on-line classroom of that course.

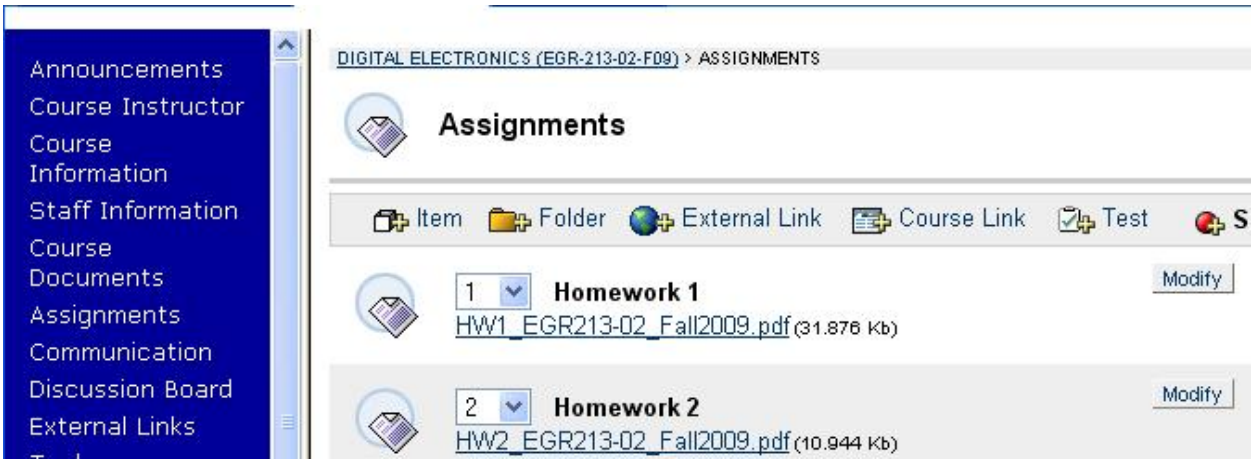


Fig. 11. Homework assignments posted at the on-line classroom of EGR213-02

2.4 Practice Changes

In this section, we discuss the changes that are brought to our classes by the technologies presented in Section 2.3.

2.4.1 Classroom Presentations on the Computer Whiteboard

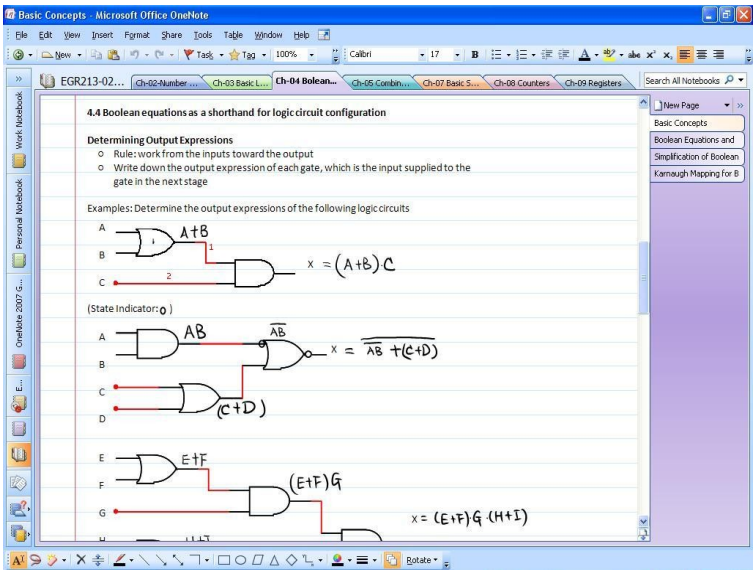


Fig. 12. Classroom presentation on the Computer Whiteboard

The *computer whiteboard*, consisting of a Tablet PC and a LCD projector, is used to replace the traditional chalkboard or PowerPoint slides. Prior to the class, the instructor prepares teaching materials such as outlines, figures, concepts and definitions, and problem statements in OneNote. During the lecture, the *pen interface* and *handwriting function* jointly offered by Tablet PC and OneNote allow the instructor to write and display in-class notes to demonstrate the problem solving process step by step, highlight key points, and record in-class discussions. Saved lecture notes can be used repeatedly to demonstrate connections between current and previous topics, or review topics covered before.

2.4.2 Saving and Publishing Lecture Notes

The lecture notes, including the teaching materials prepared before the class and the in-class notes are saved and posted on the HU Blackboard.

2.4.3 Tablet PC-based Interactive In-class Activities

Thanks to its additional feedback channels, CP 3.0 is used to support the tablet PC-based interactive in-class activities. The instructor initiates a networked presentation on the instructor's Tablet PC to deliver the in-class assignment, which could be a problem prepared before the class or a quiz written in class. With Tablet PCs in hand, students, individually or in a group of two people, connect to the presentation, retrieve the assignment, write down the solution on their tablet PCs, and submit their work to the instructor's Tablet PC. The instructor may quickly review the submitted work and share the right solution with the whole class. Figure 13 shows the work submitted by a student in class, and Figure 14 shows students working on an in-class assignment.

Another scenario of Tablet PC-based interactive in-class activities was implemented in the Introduction to Structured Programming course. Boland C++ Builder and MATLAB are installed on every Tablet PC to support coding, compiling, debugging, and running. Students work on hands-on activities individually or in small groups to practice the concepts and methods they just learned in real software environment and get the instant feedback from the instructor.

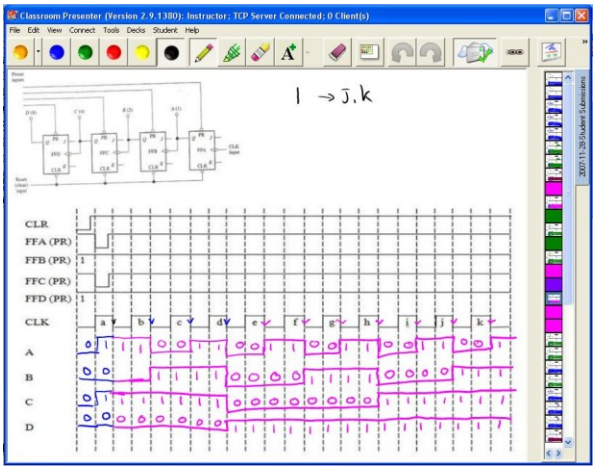


Fig. 13. Student work during an in-class activity

Fig. 14. Students working on an in-class assignment

3. Data and Analysis

The data and learning outcomes have been collected in the following ways:

- *Prelim-Surveys* were taken in the second week of the semester to get an insight of technology they have been exposed in other collegiate courses they have taken.
- *Post-Surveys* were taken in all classes where Tablet PCs were used in the last week of the semester to get an insight of student perception to the use of Tablet PCs in the classroom. Based on how technologies are implemented in a class, questions are carefully designed to get students' perception to the comparison of "computer whiteboard" and traditional whiteboard, the recording and posting of lecture nodes, and the use Tablet PCs for in-class activities.
- The same set of *mid-term and final exams* were given to the classes with/without the implementation of technologies to compare the impact of the implementation of technologies to learning outcomes.

3.1 Preliminary surveys on technologies in classrooms

Preliminary surveys have been given to freshmen and sophomore students in the second week of the semester to get an insight of the technologies that they have been exposed to other collegiate courses and are currently experiencing in this semester. Survey questions are listed in Table 1.

Table 1: Questions on the use of Tablet PCs in the preliminary survey

Q1: Have you ever heard about a Tablet PC?	Q2: Have you ever used a Tablet PC?
Q3: Have you ever taken a course where the Tablet PC was used?	Q4: Would you prefer to have lecture notes written by instructors during the class be recorded and posted?

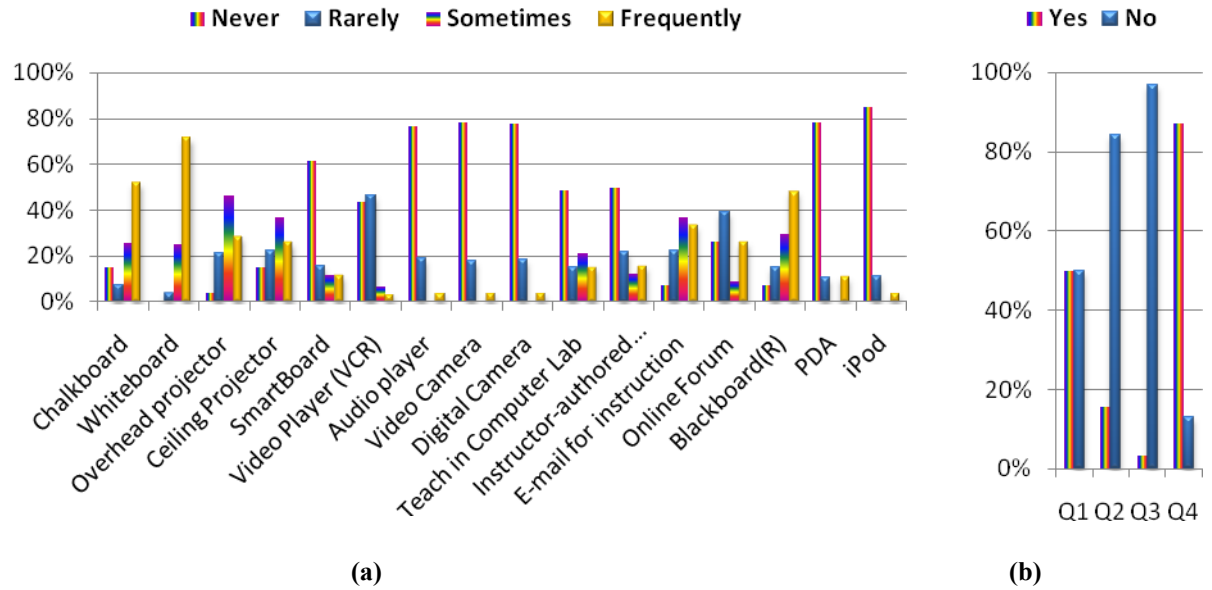


Fig. 15. Results of Preliminary Surveys among Freshmen

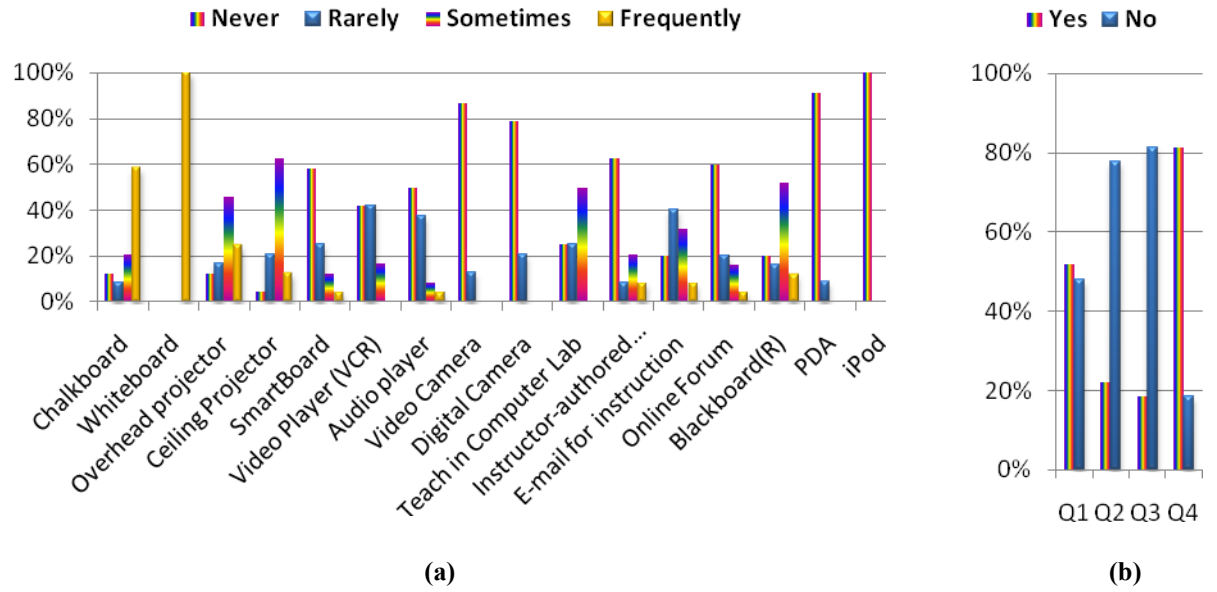


Fig. 16. Results of Preliminary Surveys among Sophomore

Figures 15 and 16 give the results of preliminary surveys among freshmen and sophomores. We can see that Chalkboard and Whiteboard are most frequently used in teaching. Projectors, E-mails, Blackboard®, and computer labs are used sometimes. Other technologies are very rarely used. While most of the students neither used a Tablet PC nor took a course where Tablet PCs were used, they indicated their interest of having lecture notes written by instructors during the class be recorded and posted.

3.2. Comparison between classes with or without Tablet PC-based activities

In Fall 2007, Tablet PC-based in-class activities were given to the class of EGR 213 on a few topics that are tested by Problem 9 in Exam 3 and Problems 9 and 10 in Final Exams. In Fall 2008 Tablet PC-based in-class activities were not given to the class of EGR 213. To make a clear and fair comparison, the normalized average grades of four pairs of exams: Exam 3, Problem 9 in Exam 3 (Exam 3: P 9), Final Exam, Problems 9 and 10 in Final Exam (Final Exam: P 9&10) are calculated as below:

- *Converting all the full marks into 100*: The full marks of all exams are already 100; however, the full mark of problems in an exam is the total points assigned to them. So
  the grade of a student achieving in Exam 3: P 9 (or Final Exam: P 9&10) =
  100 × the points of a student achieving in that problem(s) ÷
  the total points assigned to Exam 3: P 9 (or Final Exam: P 9&10)
- *Normalizing the average grades*: To eliminate the impact caused by two difference student groups, the average grade of the class in Exam 2, which was the most recent exam before the Tablet PC-based activities were introduced, is used to normalize each average grade. So
  the normalized average grade of the class achieving in Exam 3 (Exam 3: P9, Final Exam, or Final Exam: P 9&10) =
  the average grade of the class achieving in Exam 3 (Exam 3: P9, Final Exam, or Final Exam: P 9&10) ÷ the average grade of the class achieving in Exam 2

Figure 17 compares the normalized average grade in identical exams between the class in Fall 2007 and the class in Fall 2008. It is clearly indicated that the normalized average grades of the class when Tablet PC-based activities were given are all higher than that of the class when there were no such kind of activities, especially on the problems directly relevant to the topics of those Tablet PC-based in-class activities.

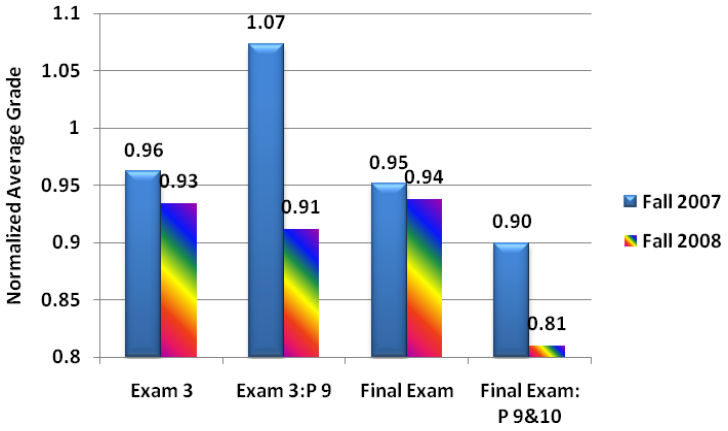


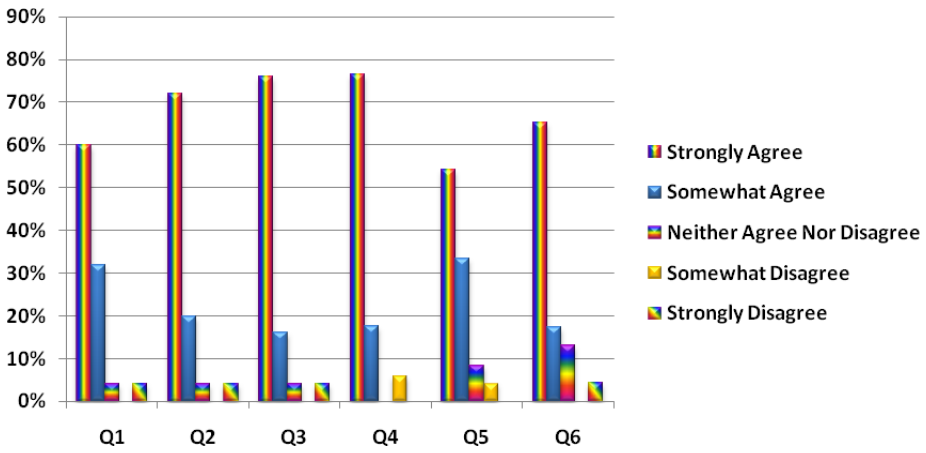
Fig. 17. Comparison of identical exams between the class WITH Tablet PC-based activities (Fall 2007) and the class WITHOUT Tablet PC-based activities (Fall 2008) in EGR 213 – Digital Electronics

3.3. Results of the surveys on student perception

In the last week of the semester, the instructor gave a *post-survey* to the class where Tablet PCs were used to get an insight of student perception to the use of Tablet PCs in the class. Questions were specifically customized for each class according to how technologies are implemented in that class. Generally speaking, those questions can be classified into three categories: the use of "computer whiteboard" for lecturing, the use of the lecture nodes that are recorded in class and posted on the University Blackboard®, and the use of Tablet PCs for in-class activities.

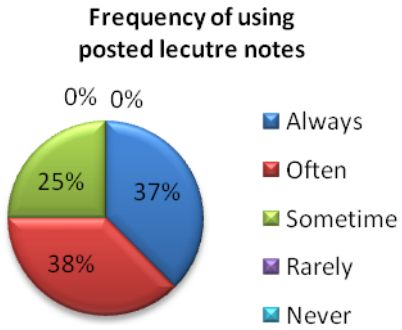
The results of the post-surveys on those three categories of questions that were given in the classes of EGR 213 – digital electronics are shown in Figures 18, 19, and 20, respectively. To avoid redundancy, only the results of the post-surveys on the use of Tablet PCs for in-class activities are included in this paper for EGR 102 – Intro to Structured Programming as shown in Figure 21. This is due to the fact that the way of using Tablet PCs for in-class activities in EGR 102 is quite different from the way how they were used in EGR 213.

These survey results clearly demonstrated that most of the students strongly agreed or agreed that using Tablet PCs is beneficial to their learning. Most of them preferred the use of Tablet PCs for lecturing and in-class activities. All the students always, often, or sometime used the lecture notes that were recorded in class and posted on the university Blackboard®. Most of them strongly agreed or agreed that those lecture notes are useful and those in-class activities are helpful to attract their attentions in class.

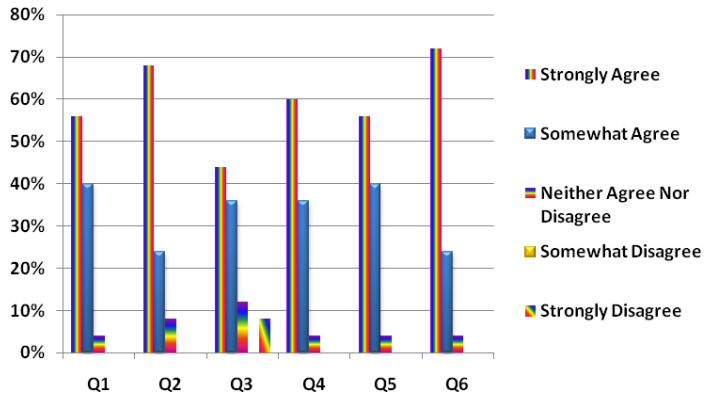


Q1	The use of computer “Whiteboard” can save more in-class time for lecturing and discussion by allowing the instructor to write part of the lecture notes prior to the class.
Q2	Using computer “Whiteboard” provided by the tablet PC, the instructor can demonstrate how to solve the problem step-by-step in class instead of just projecting the whole solution written before the class, which is helpful for students to understand the problem solving procedure.
Q3	Using the tablet PC, the instructor can easily show figures and add notes on them, which is helpful for students to understand the lecturing.
Q4	The content shown on the computer “Whiteboard” is clear to be seen.
Q5	Overall, I prefer the computer “Whiteboard” to a traditional whiteboard/Chalkboard.
Q6	Overall, I prefer the computer “Whiteboard” to an overhead projector.

Fig. 18. Computer "Whiteboard" for lecturing in EGR213, Fall 2007 & 2008



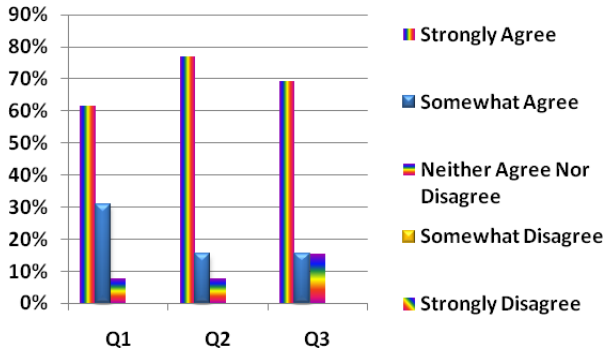
(a) How often do you use the posted lecture notes?



(b) survey on the following six questions.

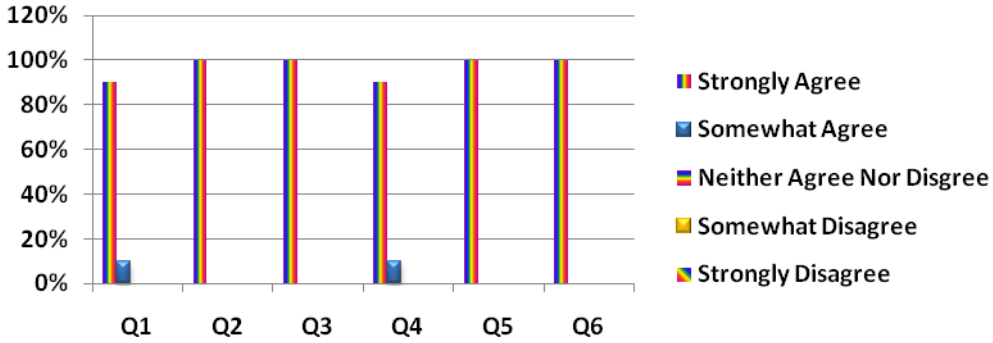
Q1	Those lecture notes are useful for me to review the content taught in class a second time.
Q2	Those lecture notes are useful for me to see what was covered if I am unable to come to class.
Q3	Because lecture notes are recorded and posted automatically, I don’t need to worry about missing important notes.
Q4	Because lecture notes are recorded and posted automatically, I can focus on listening to the lecture and thinking, instead of writing notes.
Q5	Those lecture notes are clear and complete.
Q6	Overall, I found those lecture notes are useful.

Fig. 19. Recording and posting lecture notes in EGR213, Fall 2007 & 2008



Q1	The software and tablet PCs for in-class activities are easy to be used.
Q2	In-class activities are helpful to attract my attentions on the learning material covered in class.
Q3	Overall, I like tablet PCs to be used to in-class activities.

Fig. 20. Using tablet PCs for in-class activities in EGR213, Fall 2007



Q1	Using tablet PCs allows me to practice what I learn from the lecturing in-class, which is helpful for me to grasp the main ideas in lecture.
Q2	Using tablet PCs allows me to work on hands-on programming tasks with the instructor's help, which improves my skill to write a program.
Q3	Using tablet PCs allows me to edit, compile, and run a program in the real software environment with the instructor's help, which is helpful for me to learn the whole procedure of programming.
Q4	The software and tablet PCs for in-class activities are easy to use.
Q5	Tablet-PC based in-class activities are helpful to attract my attentions on the learning material covered in class.
Q6	Overall, I like tablet PCs to be used for in-class activities.

Fig. 21. Using tablet PCs for in-class activities in EGR102, Spring 2008

4. Conclusions

In this paper, we presented the motivations and goals of this project, the technologies that were used, the changes brought to the ways of teaching and learning, and the analysis of survey and exam data. As a result, we summarized the benefits as well as the lessons we learnt.

The main benefits of using Tablet PCs in a class include: (1) Tablet PCs allow instructors to make a better preparation and demonstration of the content to be taught in class; (2) the in-

class interactivity among the instructor and students is improved, which benefits active learning; (3) automatically recording in-class lecture notes makes it easy for instructors to refer to the content taught before and for students to review and catch up.

Meanwhile, the following lessons were leant in the implementation of this project. For each lesson, the solution is suggested.

- *Lesson 1*: Class may be slowed down due to software running errors. We have experienced all kinds of software failures such as network failure, the failure of license server, oversized images/files, and system incompatibility.
  - *Solution*: The functionality and capability of software must be thoroughly tested before new software or a new feature is used in class.
- *Lesson 2*: The start of class may be delayed due to the setup time. Although software has been thoroughly tested, some unexpected situations may happen and the initialization of software takes some time.
  - *Solution*: The instructor needs to go to the classroom about 5 ~ 10 minutes ahead of time to make sure that everything is ready before class starts.
- *Lesson 3*: Class attendance may be impacted since some students may think the lecture notes saved and posted on Blackboard are good enough to cover the content taught in class.
  - *Solution*: Attendance policy must be announced at the beginning of semester and be strictly enforced. Interesting in-class activities are also useful to attract students to come to class. Once students realize the importance and gain of coming to class and build up a good routine, attendance will not be an issue.

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