AC 2010-1912: INFUSING TABLET PCS AND INTERACTIVE LEARNING TECHNOLOGY INTO COMPUTER SCIENCE EDUCATION TO ENHANCE STUDENT LEARNING

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Infusing Tablet PCs and Interactive Learning Technology into Computer Science Education to Enhance Student Learning

Abstract

Students from the digital age are visual and active learners who prefer strong interaction with their peers and instructors. Traditional lecturing styles are insufficient in grasping the attention of these students and in supporting their learning needs. Tablet PCs and interactive teaching applications have proven to be effective in increasing student engagement and supporting teacher instruction. More importantly, leveraging these technologies, innovative teaching methodologies can be developed to improve lecturing efficiency and facilitate assessment. This paper presents an on-going project in the Computer Science Department at Prairie View A&M University that focuses on revamping the teaching of computer science and engineering courses by incorporating tablet PCs and modern educational technology into the classroom. The goal of the project is to enhance student and teacher interaction, improve teaching effectiveness, and increase students' interests in course content.

In this paper, we describe the development of an advanced learning lab equipped with tablet PCs and a SMART interactive learning system. Our goal is to use the educational infrastructure to promote problem-based learning, collaborative learning, and assessment. We present a novel digital ink based computerized testing system—Real Test, which is used to comprehensively measure student class performance. A supplementary virtual reality learning platform is also discussed for enhancing student learning outcomes. Finally, we discuss our phased implementation plan which ensures that students benefit from the innovated learning technology throughout their degree plan.

Background

To build solid academic programs, we need not only effective management and highly-qualified educators and scholars, but also effective teaching methodologies and educational infrastructure. Our higher-education classrooms today consist of a diverse range of students; many of whom have grown up with computers, video games, and the Internet. Instructors need multiple ways to represent information using interactive text, images, sound and video to engage a broad range of learners. The traditional lecturing style and evaluation methods are often less effective in catering to the classroom needs and stimulating student interests. These issues have more acute consequences for technology and engineering faculty as graduating engineers in the 21st century are encountering increasing competitiveness due to a globalized economy. Thus, it becomes paramount to move our engineering students from passive learners to becoming actively engaged in the learning process, and higher educators must ensure engineering students have access to the state-of-the-art learning facilities.

Tablet PCs and supporting applications have shown great potential for classroom instructions. Research shows that tablet PCs have intrinsic advantages in fostering active and collaborative learning. Many educators and researchers have investigated ways to enhance class interaction using tablet PCs[1,2,3,4]. Commercial and in-house applications supporting class interaction using tablet PCs, such as Classroom Presenter[5], DyKnow[6], and Ubiquitous Presenter[7], have also developed. We initiated related research work by developing a truly comprehensive computerized testing system for assessing student performance and enhancing teaching effectiveness (details will be discussed in section─Real Test). We are now exploring the use of tablet PCs in teaching innovation and assisting the department in an on-going project to improve its lecturing infrastructure and revamp the computer science curriculum.

Mainly composed of underrepresented students, Prairie View A&M University (PVAMU) has established a reputation as one of the nation's top producers of minority engineers and plays a vital role in providing the U.S. with a well-prepared, highly trained, and intelligent workforce. The university recently completed a National Science Foundation Project entitled "STEM Enhancement Program" that focused on extending and establishing new processes and strategies to move the institution to the next level of Science, Technology, Engineering and Mathematics (STEM) program quality. As part of these efforts, the Computer Science Department is actively engaged in working to strengthen its education and research infrastructures and investigating novel teaching approaches.

Project Goal and Objectives

The overarching goal of the project has been to infuse modern educational technology throughout the computer science and engineering curricula to create an active and engaging academic environment for students and to assist faculty in the use of technology to support their instructional needs.

The specific objectives of the project include:
1. Strengthening the educational infrastructure for computer science and engineering by incorporating advanced technology into courses and curricula
2. Improving the delivery of laboratory and lectures
3. Enhancing learning and teaching efficiency using computerized assessment platform
4. Deepening students' understanding of abstract concepts and enhancing students' comprehension skills from theory to practice
5. Promoting active learning and stimulate students' interests in computer science and engineering subjects
6. Developing support materials to assist faculty in the use of technology to support their instructional needs

In the sections below, we describe our effort to achieve these goal and objectives. The project consists of innovative technology that enhances student and teacher interaction, simplifies the process and speeds sharing information, supports comprehensive testing and training, and encourages critical thinking.

Advanced Learning Lab and Teaching Innovations

Lab Infrastructure

To encourage active learning, instructors need to explore novel teaching methods to turn students from passive listeners to active learners[8]. For this purpose, many lecturing methodologies have been developed (e.g. using visualized exercises to help students grasp the concepts and principles). However, without support at the infrastructure level, it is still difficult to engage each individual and evaluate lecturing results. Thus, incorporating modern computer and networking technology to upgrade the educational infrastructure to enable students' active participation becomes essential.

After extensive research of innovative solutions that support the project's goal and objectives, we are now upgrading one of our lecturing rooms into an advanced learning lab. The core equipment consists of tablet computers and hardware/software products from SMART Technologies. An important component is the SMART interactive whiteboard and projector. Together with wireless slates and an interactive response system, students are able to interact directly with the instructor's lecturing activities from their seats. As shown in Figure 1, students can "write" electronically on the whiteboard and instructors can explain and comment in a real time manner. Traditional blackboard, chalk, and markers are completely removed. To achieve the best use of the hardware, we adopted SMART Sync Management software which provides the instructor with more control and monitoring of computers in the classroom.

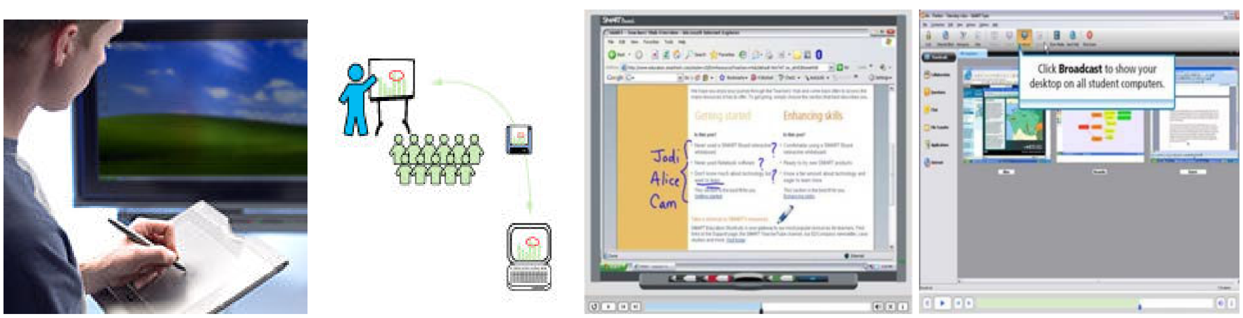

Figure 1. Classroom interactivities with SMART whiteboard, Slate, and SMART Sync

In computer and engineering class teaching, it often requires mathematic deduction, plot drawing, and flow chart analysis. Although keyboard and mouse are fine input devices for pointing and text, for picture drawing and math deduction, they can be awkward. With tablet PCs, the computer processes handwriting as figures and store them in electronic files. It provides an ideal platform for teaching innovation. For example, this lab environment strongly supports problem-based learning, which has proven to be effective in making lectures student-centered and encouraging collaboration[9,10]. Using various closed-form and open-ended assignments, students can actively participate in class activities and show their work by writing every detail (as shown in Figure 2). Meanwhile, since the devices are wireless and portable, it supports collaboration among students and gives instructors opportunities to observe each one's performance. The lab infrastructure builds upon proven results from the literature. It provides a cost-effective and comprehensive technology solution to address our instructional and student learning needs.

Title: Code Analysis–what is the output of the following C/C++ program? Explain how you get it by analyzing function and memories at program running time

Sample Student Solution: see the analysis to the right of the program written in digital ink

```
#include <iostream>
using namespace std;
int A=5;
int fun(int   &A, int  B=3);
int main( )
{
                int B, C;  B=1;
                int &D=B;
                C = fun(B, A);
                cout << A << B << C << D << endl;
                return 0;
}
int fun(int   &A, int  B=3)
{               if (A<B)
                {
                  A++; B--;
                  return       B + fun(A);
                }
                else
                  return       (++A) + (A++) + B;
}
```

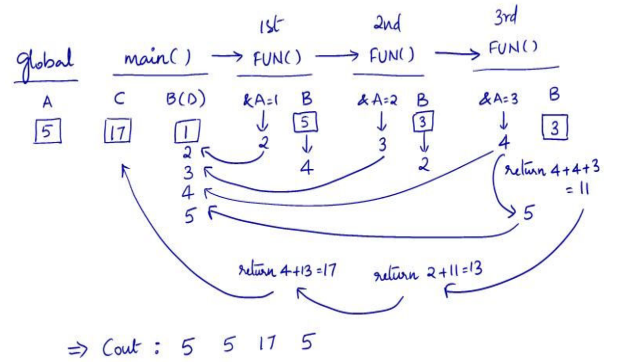

Figure 2. Question and answer ─ an example of problem-based learning using digital ink

Real Test – A Comprehensive On-line Testing and Assessment System

Computerized testing and assessment (CTA) system is getting prevalent. Although there are doubts about how it may impact different people (e.g. female and male), recent research keeps showing that computerized testing is equivalent in effect with paper-and-pencil based testing[11,12,13]. Compared with paper-and-pencil based tests, computerized testing has its inherent advantages such as quick scoring, adaptive testing, cost saving, and support of distance learning[14](as shown in Figure 3). Moreover, following scientific teaching methodologies, CTA can be used to enhance student learning effectiveness. For example, educators and scholars have consistently found that one way to improve teaching efficiency is to increase the frequency of tests [15,16,17]. However, as classes meet following a preplanned schedule, giving more tests typically means that students have less time for learning activities. To solve this dilemma, CTA proved to be an ideal solution by allowing students to take examinations more frequently outside class meetings[18].

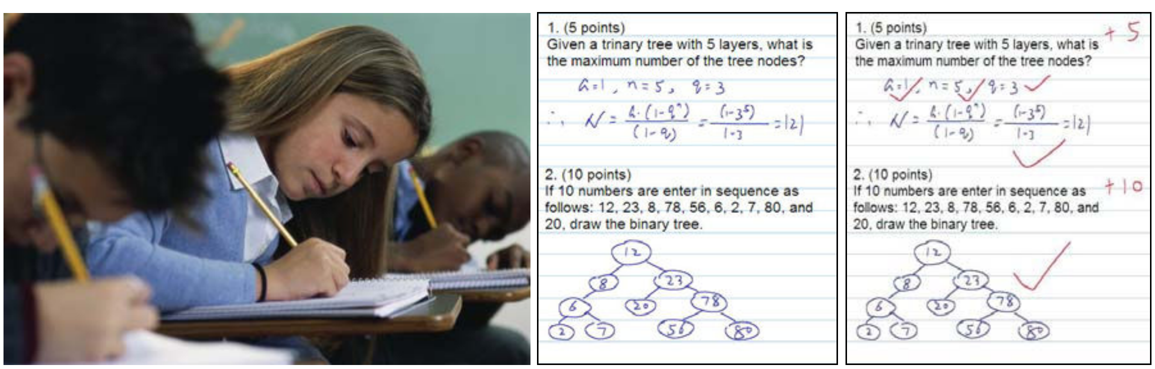

Figure 3. Paper-and-Pencil based test vs. digital ink testing

Currently, many computerized assessment systems focus only on objective questions such as true/false, multiple choices, matching, short answer, etc. A common feature for these questions is that the students do not need to “write” down the details of how they obtain the answers. Due to this, the tests cannot guarantee a comprehensive evaluation of students’ class performance[19], especially for those from STEM programs where math deduction and flowchart drawing are always required. To deal with this problem, we have developed a novel tablet PC based testing and assessment system─Real Test (as shown in Figure 4), which supports true comprehensive problems such as equations, plots, and diagram drawing using digital ink. In this system, students can “write” and “draw” on the electronic tests as doing traditional paper-and-pencil tests; and instructors can “grade” tests and leave remarks or comments directly on the electronic “paper”.

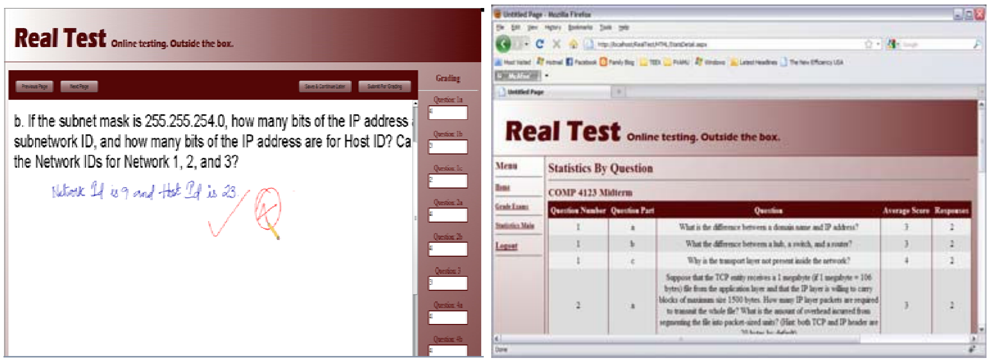

Figure 4. Snapshots of test taking, grading, and class statistics in Real Test

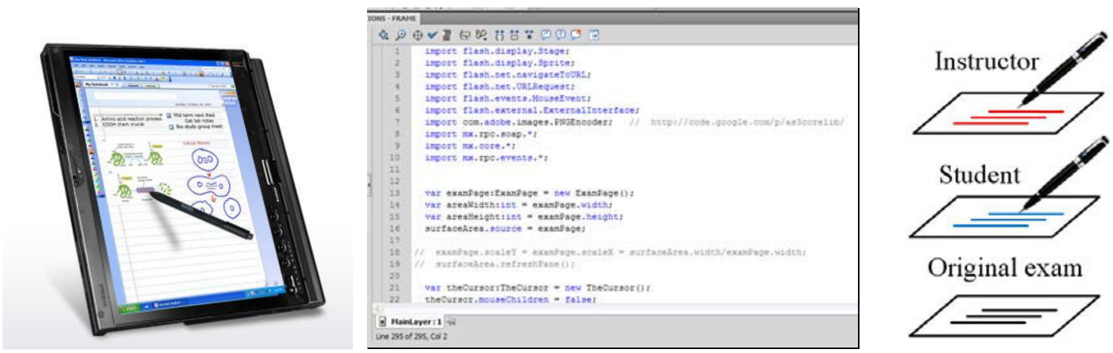

Figure 5. Action Scripting and Layered Designs of Real Test

To emulate traditional paper-and-pencil based testing, we designed and implemented Real Test following a layered architecture. Through account management system, different users are given different privileges to work on the tests. This design ensures that no one can modify the original exam or other’s work intentionally or by mistake. Each one can only work on his own layer. For example, the original exam is written in black color at the bottom layer; student users can write or erase in blue color on the intermediate layer; and instructors will grade in red color on the top layer. An illustration is shown in Figure 5.

Besides the above merits, Real Test also supports various statistical data generation. The Real Test was recently demonstrated at the first PVAMU STEAM (STEM and Agriculture) research symposium 2010. A survey conducted shows that 100% of students and faculty would like to try this software at their classes, and 80% students believe this system will increase their study interests. Similar to other CTA systems, one key advantage of the systems is: once the testing and training materials are set up, they can be easily adapted and reused for many semesters. We plan to apply this testing system to a series of pilot courses. The main purpose is to provide students with extensive training and assessment opportunities outside class meetings, have students experience latest technology, and give instructors more time in lecturing.

Virtual Reality Learning Platform

Leveraging a current department project in math education[20], we also plan to develop a virtual reality teaching environment to stimulate student interests and enhance learning effectiveness. By converting abstract concepts into vivid animation and providing game-like interactivities, such a teaching environment possesses the unique power that traditional classroom teaching does not have: *first*, it helps learners understand complex and non-intuitive subjects. For computer science courses, the ability to work with abstract and strong-logic phenomena that students usually have difficulty comprehending is critical. Traditional methods of displaying and visualizing these concepts on computer screens or in books are static and two-dimensional. The proposed virtual reality teaching and learning system uses 3D graphics and animation technologies to allow the creation, simulation, and visualization of abstract data, events, and concepts that are hard to observer in the real world. *Second*, it enhances the learning by making the learning experience fun, while still retaining the underlying content. Virtual reality teaching and learning environment is engaging, entertaining, attractive, interactive, and flexible. Because of their rich experiences with videogames, students today are able to master and retain knowledge when they are actively involved in constructing the knowledge through learning-by-doing. *Finally*, this environment also enables us to create better learning environments for those students who have difficulty in learning from the traditional classroom instruction.

Figure 6. Snapshots of an interactive game lecturing software for math courses

Implementation Plan

We plan to take the following steps to achieve the project goals and objectives.

Phase 1: Set up the proposed infrastructure, install and test the comprehensive computer testing and assessment system, develop training tutorials and the virtual reality learning environment

An existing lecturing room in the Computer Science Department is used to establish the proposed Advanced Learning Lab. The SMART interactive whiteboard, wireless slates, and tablet PCs will be used by students in the lab for learning and training activities; the SMART Sync software will be used to manage the interaction between students' input and instructor's presentation; and the SMART Senteo interactive response system is for students to do in class quizzes (e.g., quick objective question based assessment). The in-house Real Test system will be installed on the department server. Lab manuals will be created for students to learn how to use lab equipment and software correctly. Meanwhile, we will develop the virtual reality learning environment based on other project results and integrate with computing examples and principles. To fully utilize the proposed infrastructure and engage students in class activities, we will also revamp the course materials. More interactive exercises and quizzes will be designed to stimulate students' interests and assist collaboration (e.g. Jeopardy Game)

Phase 2: Incorporate the new learning infrastructure into two pilot Computer Science courses: COMP2013 Data Structures and COMP3113 Object Oriented Design & Analysis

As a core course, COMP2013 covers most fundamental programming and algorithm topics and their applications. Upon completion of the course, students are expected to gain advanced programming skills and have a deep understanding of computer memory operation and frequently used algorithms. COMP3113 is a core software engineering course in the computer science curriculum. Upon completion of the course, students are expected to obtain enhanced software design experience and be familiar with modern software tools and languages such as the unified modeling language (UML) and C++. Both courses require intensive exercises and strong logic analysis which needs to be explained using pictures, diagrams, flow charts, and mathematic deduction. As a result, we choose these two courses to test the effectiveness of the SMART system, tablet PCs, and Real Test in student engagement, learning enhancement, and collaborative learning stimulation. The role of the instructor will be both a teacher and a class manager. Course performance results will be compared with those in the past. At the same time, we will also test the virtual reality learning environment in these courses and improve it based on student feedback.

Phase 3: Incorporate the proposed infrastructure and interactive learning into other targeted courses (GNEG1121 Engineering Application Lab for Math, COMP1223 Computer Science II; COMP3223 Software Engineering; and COMP4123 Computer Networks) to enhance active learning; promote the new learning and teaching pedagogy

The selected courses sample all computer science curriculum levels, and cover a variety of topics from hardware to software and from systems to applications. All courses require significant mathematic and computing logic analyses which are usually difficult for undergraduate students. At this stage, we broadly adopt all proposed learning and training system to reinforce teaching effectiveness by providing students with more interactive examples and outside class exercises. The project discovery and results will be presented to college and university levels. Outreach activities will be conducted to disseminate project outcomes to neighbor schools and community. At the same time, leveraging the proposed infrastructure and equipment, we will further investigate education innovation and measure the effectiveness and impact of modern computer technology in computer science and engineering education.

Formative and summative evaluation will be implemented during the proceeding of the project. We will collect and compare course assessment data before and after applying the educational innovation to show the differences in teaching effectiveness. These data serve as the objective evaluation of the project results. Subjective feedback will be collected from administered student surveys on each targeted course to demonstrate the improvement in student learning and class engagement.

Conclusions and Future Work

To summarize this ongoing project, we are developing an advanced learning lab using tablet PCs and supporting applications. Utilizing the lab infrastructure, we can investigate innovative teaching methodologies, such as problem-based learning and collaborative learning, at the Computer Science Department at PVAMU to engage students and enhance active learning. A novel computer-aided testing and assessment system, Real Test, has been developed to enhance teaching efficiency. A virtual reality learning environment is being implemented to assist instruction needs. We defined a phased implementation plan to ensure the attainment of the project goal and objectives. Upon the completion of the project, we expect to have the following outcomes: (1) the proposed lab infrastructure is established; the Real Test system and virtual reality learning environment are applied to a number of computer courses. The teaching/learning pedagogy using tablet PCs is deposited into the current courses and curricula; (2) Class teaching and learning effectiveness are strengthened. Students gain hands-on experience of modern equipment and technology, and have better understanding in breadth and depth of the targeted courses. The motivations and retentions of students in computer science and engineering are increased. (3) New teaching methodology is investigated and advocated to other STEM disciplines.

Started in spring 2010, the project is now at the first phase. We are testing the equipment and software of the advanced learning lab, enriching the functions of the Real Test system, and developing virtual reality learning modules. The effectiveness and impact of the lab infrastructure and applications in student learning will be evaluated in the forthcoming phases.

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