Abstract - Increasing the retention rate of engineering/computer science students and enhancing student design skills are two major challenges in engineering education. This paper presents a team effort to implement Collaborative Project-based Learning (CPBL) using Tablet PC technology in a broad spectrum of engineering and computer science courses from freshman to senior level. Presented here are a number of innovative teaching strategies to create a more friendly and interactive learning environment to address the aforementioned challenges for minority students. Since Fall 2009, eight innovative pilot courses have been designed and conducted. Assessment results revealed that the implementation of Tablet PC based CPBL had brought transformational changes to the traditional engineering classrooms to support student centered-learning. The paper also describes the impact of Tablet PC based teaching strategy on lecture styles, teaching effectiveness and student learning outcomes from both the faculty and students’ perspectives.

Index Terms - Collaborative project-based learning, DyKnow software, interactive lecture, Tablet PC

INTRODUCTION

Increasing the retention rate of engineering students and enhancing student design skills are two major challenges in engineering/computer science education. At California State University, Los Angeles (CSULA), which traditionally serves the underrepresented and educationally disadvantaged minority students in the East Los Angeles area, institutional research revealed that almost 50% students who began their study in College of Engineering, Computer Science and Technology (ECST) eventually dropped out or changed their majors. Some of the students who choose to stay in engineering/computing fields also encounter significant learning barriers. To address these challenges, faculty members at CSULA have been exploring various approaches to provide a more active and friendly learning environment. One innovation that has successfully created such an environment is the Collaborative Project-Based Learning model using Tablet PCs. This model has been developed since 2005 through the support of Hewlett Packard's (HP) Teaching Initiative and HP Leadership Awards [1,2]. In 2009, a HP Collaborative Learning Center was established at CSULA with the support from the HP Innovation in Education Grant. One of the long-term goals of the established center is to extend the CPBL model to a broad spectrum of undergraduate/graduate courses to stimulate the students’ interest in engineering and computer science for better retention and to enhance their hands-on design skills. In this paper, we present our current progress on the implementation of CPBL in a variety of courses from the freshman level to graduate level, as well as our efforts in creating a more interactive learning environment using DyKnow software.

It is worthwhile to mention that Tablet PC-based instructional technology has gained more and more popularity in both K-12 and higher education. Many research and development efforts have been made to create useful teaching/learning tools based on Tablet PC [3,4]. And many educators have devoted significant efforts to develop and evaluate new teaching pedagogy using Tablet PCs [5-8]. In [9], Jamie Cromack presented how the Tablet PC embodies seven principles of good practice to support learning centered education. In 2008, R. Reed, D. Berque and J. Prey published a book [8] to highlight innovative educational practice using Tablet PC as well as its impact on student learning. Many positive findings were reported to show that Tablet PC based teaching technologies including collaborative note-taking, interactive exercise, and realtime assessment helped to create a more engaging learning environment. The existing research work provides good guideline for other educators to incorporate pen-based technology in classroom instruction, however, to develop effective teaching strategies, one must consider the institutional context and the needs of the students.

In our project, seven faculty members have conducted course revision to eight pilot courses across the curriculum in College of ECST. The breath of our project provides an ideal platform to study the impact of Tablet PC based CPBL on student learning from freshman to senior level. We hope that our work can contribute to the knowledge base regarding how to effectively enhance the learning of minority groups via collaborative PBL.
TABLET pc-based Collaborative PBL

Project-based learning has been recognized as an effective approach to enhance student knowledge and skills in engineering design. In recent years, it has been employed in engineering curriculum worldwide to prepare quality engineers with hands-on skills [10]. Furthermore, engineering educators discovered that employment of project-based learning in freshmen courses helped to foster students’ interest and thus led to better retention [11,12].

One challenge to implement PBL at CSULA is that many students lack the background knowledge, skills or necessary resources to complete the project by themselves. As a federally designated Title III minority institution, CSULA serves a very diverse student body and more than 50% of the students come from the underrepresented communities in East Los Angeles area. Evidence shows that our students have difficulty adapting themselves in traditional engineering/CS classrooms due to the following reasons:

- As many of the minority students are first generation college students in their families, less guidance from their parents poses an obstacle to persistence in learning.
- Many of our students have a low sense of self-efficacy with respect to scientific and technological careers requiring quantitative skills. They usually do not ask questions or respond to the instructor’s questions to avoid public attention in class, and they frequently struggle with homework/projects due to low competence.
- Many of our students come from low-income families and need to work to support themselves. An estimated 70% of CSULA students work 30 or more hours per week while enrolled in college. They have less time to study and less access to educational resources (books, computers, software, etc.). In computer-related disciplines, this disadvantage is more severe since the students have less opportunity to develop hands-on skills that are critical to their career.

CPBL was developed to address these learning barriers for our students [1,2]. One unique feature of CPBL is the creation of a friendly learning environment that is less intimidating to minority students. Tablet PCs provide an ideal platform to foster collaborative learning, and also allow the professor to provide timely help to the students when they are working on an in-class project. As illustrated in Figure 1, the key components of CPBL are:

- **Small in-class projects / hands-on exercises:** The most important component of CPBL is to incorporate well-defined in-class projects or hands-on exercises to reinforce the student learning and/or to improve the students’ design skills in a progressive way. To ensure that our students can complete the work in limited class time, the scope of each project is small, yet through completing a number of small projects, the students will gain enough knowledge and skills to design more complicated systems or to solve real world problems.

- **Collaborative learning:** Educational research has shown that collaborative learning helps to build students’ confidence to overcome learning barriers. The mobile feature of the Tablet PC facilitates peer collaboration and allows student teams to work closely on in-class projects/exercises.

- **Immediate feedback loop:** For students who lack background knowledge/skills, immediate help from the professor is critical to guide them through the design or implementation process. Tablet PCs allow the instructor to monitor the students’ work and provide timely feedback.

![Collaborative learning](image)

In our previous work, CPBL has been successfully implemented in a few computer engineering courses. Our current work aims to enhance and adapt the CPBL model to a variety of courses across various disciplines. To achieve this ambitious goal, a leadership team consisting of seven faculty members from different departments was established to redesign the courses using Tablet PC based technology. Since Fall 2009, eight pilot courses (from freshman level to graduate level) have been revised and delivered, as shown in Table 1. More than 200 students have been impacted by the new teaching model facilitated by Tablet PC based technology. In the next section, we describe the details of how CPBL has been implemented in various courses, with...
an emphasis on innovative teaching strategies that our students found effective.

INNOVATIVE TEACHING STRATEGY

Before describing the details of course innovation, it is helpful to introduce the classroom settings and software environment first. To facilitate the implementation of CPBL, a new classroom was created with desks/chairs that can be easily moved around to support various lecture styles. A Tablet PC cart with 30 mobile stations is stored nearby (most engineering courses at CSULA have an enrollment cap of 25 students). Each student is assigned a Tablet PC to use in the classroom. Since the Tablet PCs are shared among multiple classes, the students need to check out and check in the Tablet PCs at the beginning and end of the class. For most of the pilot courses, DyKnow Software has been used to make lectures more interactive and dynamic.

I. CPBL implementation and course innovation

Due to the dramatically different educational objectives/contents of different courses, the CPBL model needs to be adjusted to match the content delivery method accordingly. For freshman-level design courses, more focus has been placed on creating a fun and engaging hands-on design experience to foster the students’ interest in engineering/CS fields; for engineering core courses, hands-on projects/exercises are used to visualize the abstract concepts and to enhance the students’ understanding of the design process; for upper division/graduate level courses centered around advanced theories, the emphasis of the course redesign is to embed more active learning components to deepen the students’ understanding and to foster critical thinking; for the course with an existing lab component, the experiments/projects have been redesigned to incorporate collaborative learning and peer interaction. Here we describe the innovative teaching strategies enabled by Tablet PC and DyKnow software that worked well for our students:

- **Dynamic and interactive presentation**: Employment of Tablet PC technology brought significant changes to the lecturing style of all eight pilot courses. DyKnow software has many nice features to which support effective presentation. Existing PowerPoint slides can be loaded and projected to the students as DyKnow panels. The instructor can highlight important concepts and show the design process or flow charts via ink annotation, while the students can work on top of the projected slides to add their own private notes. Furthermore, the replay feature of DyKnow notes allows the students to review the lecture easily, which really benefits the students who need more time to understand the course materials. An effective strategy to engage students in learning is to create interactive in-class exercise using DyKnow panels. Students can work in groups on the exercises using Tablet PCs and submit their answer to the instructor. The instructor can then display selected student submissions anonymously to demonstrate to the class how the particular response could be corrected or to give an example of a good solution. Figure 2 depicts an example of in-class exercise used in CS422, an upper division CS class on Database systems, where the instructor explained the solution via ink annotation.

- **Real-time classroom assessment**: DyKnow software supports real-time polling that allows the instructor to create short questions to assess the student learning progress. This feature is especially helpful to solicit feedback from minority students since most of them do not like to respond to the instructor’s questions in public. Figure 3 shows how polling is used in EE454 (Biomedical Instrumentation) to check the student understanding on how a blood pressure measurement device works. The students can also indicate their confidence levels when submitting their answers. Evidently, frequent use of direct assessment allows the instructor to adjust the teaching pace and make the learning more effective.

- **Collaborative learning**: DyKnow software further enhances peer collaboration in the CPBL model. Through DyKnow monitor, the instructor can group students together to work collaboratively on in-class exercise or project (as shown in Figure 2). Students in a group can share their ideas, sketch their design diagrams, or work on programming flowchart through shared screen even though they are not sitting next to each other. Joint submission of the group work is also supported. This feature has been utilized to facilitate team work in EE244, EE454, CS422 and CS537.

Figure 2: An example of interactive in-class exercise in CS422.

Figure 3: An example of real-time classroom assessment using polling.
Inquiry-based learning: The original CPBL mainly focused on providing hands-on practice to reinforce student learning. Recently, it was discovered that inquiry-based projects are very helpful to stimulate the students’ interest and to foster critical thinking. In the redesign of EE244 (a freshman digital engineering course), more inquiry-based projects were developed. For example, instead of introducing the function of FPGA board through lecture, a small game was created to allow students to explore the board and “guess” the functions of each hardware component. Student feedback verified that the inquiry-based projects made the learning not only more engaging but also more effective.

II. Improvement in teaching and learning

The implementation of Tablet PC based CPBL has brought transformational changes to how teaching and learning is conducted in participating engineering and CS courses. The traditional way to teach these classes is through blackboard or PowerPoint (Microsoft, Inc.; Redmond, WA) presentations, and the dominant student learning activities are listening and note-taking. Professor-student interaction is limited, usually through oral question/answer. It is very likely that only a few students will respond to the questions while most of the students are disengaged.

Figure 4 shows the distribution of teaching and learning strategies adopted by the CSULA faculty in their pilot Tablet PC based courses. Clearly, the teaching strategies have been significantly enriched and include a diversified set of active learning components. Have these changes helped the students to achieve their learning outcomes? In the next section, we will present assessment results which show the impact of the course innovation on student learning and teaching effectiveness.

ASSESSING THE IMPACT

The course innovation experience provided an excellent opportunity to study the impact of CPBL as well as the interactive learning environment facilitated by Tablet PC based technology on teaching effectiveness and student learning outcomes. Since many of the faculty and students were first time users of Tablet PCs, the study also gives insight into the students’ perspective on the introduction of innovative technologies in the classroom and the instructors’ perspective on the overhead required to utilize a new teaching strategy. To evaluate the impact, the following assessment instruments were employed:

- Student survey with both quantitative and qualitative questions to collect students’ feedback on the effectiveness of the new teaching strategy, their experience/comments on the learning experience, and their self-assessment of learning outcomes.
- Faculty survey with both quantitative and qualitative questions to collect their feedback on how various teaching strategies were used, the impact on their teaching style /effectiveness, as well as the incurred overhead/difficulty.
- Student performance evaluation and classroom observation to provide direct assessment of the impact on student learning outcomes.

The following subsection presents the assessment findings from the data collected in Fall 2009 and Winter 2010.

1. Impact on teaching effectiveness

In general, the feedback from the faculty members based on their teaching experience in pilot courses has been very positive. All faculty members who taught the pilot classes reported that the new teaching strategy helped them to achieve their overall educational objectives. As shown in Figure 5, 100% of the faculty members strongly agreed that Tablet PC enhanced class presentation, 100% of the faculty agreed or strongly agreed that Tablet PC based technology helped to enhance in-class interaction and made the hands-on projects more effective. The positive impact of Tablet PC based technology on lecture presentation is also reinforced by student feedback. As shown in Figure 7 (a), more than 70% of the students agreed or strongly agreed that “Tablet PC helped the instructor to present the course material”.

Figure 4

DISTRIBUTION OF TABLET PC BASED TEACHING (TOP) AND LEARNING TECHNOLOGIES (BOTTOM) USED IN PILOT COURSES
The faculty feedback also indicated some overhead of using Tablet PC with DyKnow software. So far the biggest overhead reported is the Tablet PC check-in/ check-out time needed in each class session. Unfortunately, this overhead is imposed by the limited resource and there is no short term solution. However, its affect can be reduced by a good management of Tablet PC check-in/check-out procedure. Despite the overhead, all participating faculty members are willing to use Tablet PC continuously in future courses since it offers a lot of opportunities to try different teaching strategies to address student learning issues.

II. Impact on student learning

The impact of CPBL and Tablet PC based teaching strategies on student learning outcomes were evaluated by both the faculty observation and student self-assessment. According to the classroom observation results and student performance comparison, 100% of the faculty agreed that the Tablet PC based teaching strategy helped to make students more engaged in learning and develop a better understanding of the lecture (indicated in Figure 6), 80% of the faculty think that the students gained better hands-on skills through CPBL and 60% of the faculty reported better student performance after course innovation. Overall, all faculty agreed that the friendly and interactive learning environment helped students to achieve their learning outcomes.

The student feedback on their learning experience is also encouraging. Figure 7 shows that the majority students agreed or strongly agreed that Tablet PC based teaching strategies helped them to gain better design skills, to make note-taking more effective and to learn the course better in general.

In summary, the course innovation experience has been successful so far. However, more assessment data needs to be collected in the future to provide concrete measurement of the impact on teaching and learning.

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Figure 5

Faculty survey results: how Tablet PC based technology affect the teaching effectiveness (5—strongly agree, 4—agree, 3—neutral, 2—disagree, 1—strongly disagree).

Figure 6

Faculty survey results: how Tablet PC based technology and CPBL affect the student learning (Percentage of Faculty Agreement with the statement).

Conclusions

This paper discusses our work to employ Tablet PC based collaborative project-based learning in eight pilot courses in engineering, computer science and technology departments. Although the CPBL model was adjusted to fit into individual course content, all revised courses do share some common features as: 1) Enhanced lecture presentation; 2) More interaction between instructor and students; 3) Frequent classroom assessments; and 4) Enhanced collaborative learning. These innovative teaching strategies have brought transformational change to the traditional engineering classrooms. To evaluate the impact of the new teaching strategies, quantitative and qualitative assessment data have been collected from both the faculty members and the students involved in the pilot classes. The feedback from both constituents were very positive, showing that the implementation of Tablet PC based CPBL has been successful in general. Nevertheless, due to the short implementation period, the assessment data collected so far is not sufficient to provide a solid study to show which teaching strategy works best in different courses at different levels in undergraduate/graduate education. In the future, continuous assessment effort will be made to answer the
above question as well as to further improve the implementation. And we hope that with more collected data, a longitudinal study can be performed to evaluate the long-term impact of Tablet PC based CPBL on student learning and retention.

(a) Helped the instructor to present the material
(b) Helped me gain better design skills
(c) Made the note-taking more effective
(d) Helped me learn better overall

FIGURE 7
STUDENT SURVEY RESULTS: HOW TABLET PC BASED TECHNOLOGY AND CPBL AFFECT VARIOUS LEARNING ASPECTS.

ACKNOWLEDGMENT

The work is supported through HP Innovation in Education Grant and NSF CCLI Grant (#0737130). Special thanks go to all colleagues who worked hard to enable a better learning experience for the students.

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