

On the Design of Interactive Classroom Environments based on the Tablet PC Technology

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Abstract - Nowadays, the widespread adoption of the Bologna Process in Spanish universities, is demanding to put into practice innovative proposals. There is no doubt that methodologies must move from traditional style and concept-based teaching to student-centred and competency-based instruction. A novel approach to design interactive classroom environments supported by mobile Tablet PC technology is presented. It is focused on integrating formative assessment into classroom practices and providing students with immediate feedback. We describe the six steps of the proposed approach and how they are implemented in a first-year Computer Engineering course. Initial results have showed that the dropout rate in the experimental group has been reduced more than 50%, while the number of students passing the course has almost doubled over the control group. Our approach has also promoted the students' autonomy and motivation, thereby improving their academic performance and enhancing their self-confidence in the learning process.

Index Terms – Active learning, Digital ink, Instructional design, Tablet PC.

I. INTRODUCTION

The widespread adoption of slides displayed with a digital data projector has supposed an unquestionable technological change in the classroom. However, regarding the model of instruction, these technologies have done little more than reinforce a teacher-centric model of learning. It is well known that it is often difficult to maintain concentration of students for the entire lecture sessions, especially when they last up to two hours and there is no change in the teaching method. Stuart and Rutherford [1] assessed students' concentration during a didactic lecture and they found that “concentration rose to maximum at 10–15 minutes and then fell steadily until the end of the lecture”. Nevertheless, this teaching model is still prevalent in many of our Computer Engineering (CE) undergraduate courses.

Being imminent the widespread adoption of the Bologna Process in Spanish Universities, it is now time to put into practice efficient proposals to follow. In terms of methodologies, there is no doubt that these must move from traditional style and concept-based teaching to student-centered and competency-based instruction. Moreover, there are clear evidences that technology can drive major positive

changes in the classroom addressing problems associated with traditional lecture-based pedagogy [2]. In particular, the flexibility of pen-based devices, such as the Tablet PCs, has the potential to achieve a wide range of educational goals and promote a more participatory classroom environment [3][4].

We may consider Tablet PCs as a hub for personalized learning both from the students' point of view and also from the instructor one. From the students' point of view, Tablet PC-based learning environments allow students: (a) to make changes or add notes on the fly by using the pen and digital ink, (b) to write and sketch out ideas freely as they come to them, (c) to lower barriers to contributing so that more students feel comfortable participating in class, and (d) to share work with teachers and receive individualized, real-time feedback. Tablet PC environments also enable instructors: (a) to use the digital pen to circle important points and call out information on the go, (b) to anonymously display the students work on the lecture room screen, promoting so peer learning, (c) to make instructors more aware of their students' level of understanding, (d) to conduct on-line office hours and (e) to grade papers.

In this paper, we propose an approach to design interactive classroom environments. This approach combines active learning techniques and mobile Tablet PC technology to support bidirectional student to student and student to instructor in-class collaboration.

The approach is built upon six design steps, which provides guidelines to design and develop both lecture materials and active learning exercises in the context of this next-generation technology. Taking as a reference the freshman courses in the Computing Curricula at the Technical University of Valencia, we report the requisites and the steps taken to implement the approach in the Computer Technology course. We consider that the proposed approach has promoted the autonomy, interaction, and motivation of our students, thereby improving their academic performance and enhancing their self-confident in the learning process.

The rest of this paper is organized as follows. Section II presents our Tablet PC-based learning approach. Section III outlines how to implement the proposed approach on a first-year CE course. Section IV summarizes the results of our case study. Finally, section V draws some conclusions and outlines further work.

II. A TABLET PC-BASED LEARNING APPROACH

This section introduces key issues that characterize the needs of our current Computing undergraduate courses. Then, it presents the fundamentals of our proposed learning approach. Finally, it describes the steps to design and implement the proposed approach.

I. Needs analysis

Our proposal builds upon the fundamental issues related to our Computing undergraduate courses: (a) pupils' lack of motivation, (b) low class attendance rates, (c) high course drop-out rates, (d) low participation and student interaction, and (e) eventually, poor students' performance. Although all these evidences are relevant of an unwanted academic situation, we will focus on the final scores to explain the general problem.

Figure 1 shows the global academic performance indicators corresponding to the first-year core undergraduate courses, taught at the School of Engineering in Computer Science at the Technical University of Valencia, during the last six academic years. It can be observed that less than a 50% of the enrolled students pass first-year courses and what is worst, some years the drop-out rate is higher than the corresponding success rate.

As stated before, CE instructors frequently use slides to support their lectures. However, in many cases, instead of using them to provide structure for the lectures, slides tend to cover most of the taught contents. This approach gives little chance to students to participate in the class and, besides reducing students' motivation, it seems to be an important factor to explain the low class attendance rates.

Moreover, student assessment is usually based on paper exams that are held at the end of the courses. This approach lacks of the necessary and timely feedback to guide the individual learning achievements.

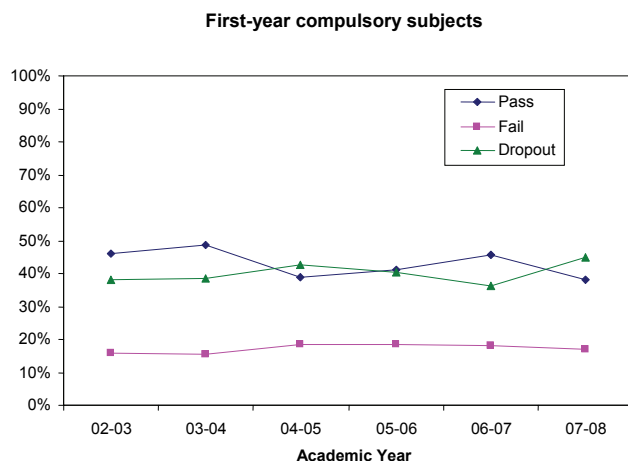


FIGURE 1
ACADEMIC PERFORMANCE INDICATORS

II. Approach fundamentals

Recent research demonstrates obvious advantages of using Tablet PCs in higher education. However, any random implementation of educational technology has a low probability of success and widespread adoption. Thus, we consider that more concrete guidelines are required to develop and deploy such new technology settings.

Our proposal is also inspired on the Seven Principles for Good practice in Undergraduate Education [5] that try to summarize decades of research on the undergraduate student experience.

The approach is based on a teaching methodology that incorporates active learning techniques and supports in-class teacher to student and student to student collaborations. In this context, the instructor role deals with the development of contents and resources, adapted to a Tablet PC environment, the design of interactive activities that take advantage of these devices, as well as the use of quantitative and qualitative tools that enable a continuous student assessment [6].

III. Designing our approach

Next, the six steps that characterize the proposed approach are described in detail.

- **Step #1: To reduce slides content to the essentials in order to permit a dynamic adjustment of delivery and concepts.**

Instructors can connect the Tablet PC to a projector to display slides, while showing their handwritten annotations in real time. This approach combines the benefits of traditional writing (flexibility, ease of providing examples, and adaptation to the audience) with computer projection of slides. These materials can also be shared with students' computers, allowing them to personalize the instructor provided materials. The technology-enabled learning environment promises to appreciably increase active learning. In this context, it's also very important to plan the slide design in such a way that the future adaptation to other devices, as PDAs or mobile phones, be feasible.

- **Step #2: To design and develop specific add-value multimedia resources allowing students to gain a good level of understanding.**

Digital media in the form of still images, audio, video, and animation coupled with hands-on activities can meet the needs of students with visual, auditory, and kinesthetic learning styles.

The instructor's experience on the course will be very valuable to decide the topics to be covered: fundamental concepts but difficult to grasp, most frequent mistakes, complex algorithms and processes, software tools, laboratory equipment, etc. It is expected that these resources help instructors to regain/reset student attention spans during lectures, according to the aforementioned theory.

- **Step #3: To design and develop in-class individual and group activities in order to directly engage learners with the subject matter.**

In general, in class activities might involve: (a) practice of some specific intellectual activity, e.g., analyzing, designing, testing, debugging, interpreting specifications, etc, (b) applying specific knowledge, and (c) having students examine their own knowledge and understanding. In relation to team work, it is well known that collaboration leads to an intense level of information processing that encourages cognitive growth.

- **Step #4: To introduce the use of discipline specific software and resources to tackle problems and/or projects in more realistic scenarios.**

The idea is to provide learners with the opportunity to employ tools such as *Matlab*, *PSPice*, *LabView*, etc, in a similar way to what practicing engineers in industry might have access to in their real environments. Sketching is also an important activity in the early stages of project-based approaches. Digital ink possibilities can also support each step of the idea generation process and thus, improving the efficiency of collaborative learning and teaching.

- **Step #5: To design and develop one-minute papers that help instructors to gain knowledge about students understanding.**

Quick polls are very useful to gather formative information and allow instructors to provide immediate feedback on students' misconceptions. In the context of networked classrooms, presentation tools support these strategies in a very efficient way. Instructors raise the corresponding question to the audience and can immediately show the corresponding results in graphical form.

- **Step #6: To design and develop assessment items in such a way that the overall content of the course be covered.**

These items should be designed with different difficulty levels and approaches including, at least, questions devoted to recall of knowledge and application of knowledge (understanding). Tests will then be assembled from the appropriate assessment items and will facilitate instructors a quantitative continuous assessment. A networked classroom allows authenticated students to access to any test stored on the typical virtual learning environments and also facilitate the feedback process.

III. IMPLEMENTING THE APPROACH

In order to apply the proposed approach, both specific materials and committed faculty members are essential. In relation to equipment, a networked Tablet-PC classroom together with the corresponding teaching platform is required. In our case, a wireless classroom equipped with 20 Tablet PCs for students and one additional for the instructor has been configured. The classroom also includes a special

Mobile Net Education Center to store and easily move the Tablet PCs. All this material has been funded by Hewlett Packard as part of the award granted to our group, in the framework of the *2008 HP Technology for Teaching Grant Initiative, Transforming Teaching and Learning through Technology* [7].

Once the Tablet-PC classroom was setup, a teaching platform has to be chosen in order to boost the technology possibilities. Nowadays, we can find both commercial and free available pen-based teaching platforms. We have decided to use free platforms as they incorporate enough capabilities to support our approach. Moreover, it is easier to tailor them to the specific needs of the educational setting. In particular, we have selected the *Classroom Presenter* (CP) tool [8] [9] because it suits very well the different steps of the previously described approach. CP, developed at University of Washington, is a Tablet PC-based classroom interaction system that supports the sharing of digital ink on slides between instructors and students to increase the teacher's flexibility while lecturing. These features facilitate introducing active learning into the classroom and enhance in-class teacher to student and student to student collaborations.

Concerning to human resources, we want to point out that besides the instructors giving the classes, experienced faculty are needed to design and develop the new educational resources described in steps #2 and #3. Ideally, project teams should also include other participants, such as staff with pedagogy, educational technology and/or instructional design expertise.

I. Case Study

In this section we describe in detail how the approach has been being applied to Computer Technology (5554), a core course in our CE Bachelor. It is given in the first academic year, by the Computer Engineering Dept. It has 7.5 credits (75 teaching hours), distributed in lectures, recitation classes and laboratory sessions. 10 faculty members were involved in the course during the 2008-09 academic year, having 322 students. They are distributed in 5 lecture groups, 9 recitation groups and 15 lab groups.

According to the syllabus, the course includes a two-hour lecture and a two-hour recitation session per week. In both cases, instructors used to have a prevalent role whether exposing the contents, supported by a slide presentation, or solving the problems on the blackboard. Several strategies were essayed to increase in-class student participation during the three previous academic years. However, many students were reluctant to present their solutions on the blackboard and what is worst, some declared to drop the course due to the participation requirements. As a consequence, these attempts have not significantly improved the overall scores [10].

In order to test our approach, an additional group of 20 students has been defined. Although this figure could seem very low, it often represents the actual number of students regularly attending recitation sessions. We have applied the

six steps of our approach in order to move forward into an interactive classroom scenario.

The first change proposed to implement our approach has been to eliminate the distinction between lectures and recitation classes. Thus, we define a typical classroom session where the instructor spends at least a 75% of class time engaged in high levels of teacher-student interaction. It means that students, either individually or in groups, are devoted to tackle questions, solve exercises, discuss solutions or answer quizzes. The idea is to make good use of the possibilities of the mobile technology environment.

Taking into account the number of students in the experimental group, as well as the fact that first-year CE students use to have positive attitudes toward ICT, a one-to-one Tablet PC approach has been adopted in the experimental group.

Concerning step #1, we have reduced the slide contents to the essentials in order to promote the student activity. By using the digital pens, both instructors and students can annotate on the slides, or draw as naturally as they do on paper.

In step #2 specific course materials have been designed and developed to help students in understanding the fundamentals of electronic devices. Among them, we have produced some short multimedia videos focused on those aspects of the topic that are more difficult to understand. For instance, Figure 2 refers to a short video produced to explain the fundamentals about DC biasing of Bipolar Junction Transistors (BJTs). In the same way, some Java applets have been developed to simulate, in a simple manner, the working of the main semiconductor devices. Figure 3 shows the main screen of the MOSFET biasing applet.

In step #3, we take advantage from one of the main strengths of the Tablet PC, which is its ability to support collaboration. Using Tablet PC, students can anonymously submit content to the instructor that can be then incorporated into the classroom discussion. We have designed a wide set of learning activities that allows instructors to complement the topics covered into the different units. Most of them are circuit analysis exercises; although some design exercises are also proposed. At the end of the different units, some more complex problems are set out. Sometimes, students take the instructor role (a CP feature) in order to present how they have addressed the exercises. We have realized that this fact enhances self-confidence of students and, at the same time, it allows instructors gaining knowledge about their achievements.

Concerning step #4, in order to help students having special difficulties to solve the proposed activities, we take advantage of our inter-connected class to incorporate the *Orcad PSpice* software [11] to tackle some realistic examples.

In steps #5 and #6, several item banks have been developed. They incorporate selected questions of previous exams that were statistically analyzed in terms of difficulty and discrimination levels. These item banks are a rich information source to dynamically create learning activities

(exercises, problems, one-minute papers, quizzes...) that are mainly solved into the classroom by using the Tablet PCs.

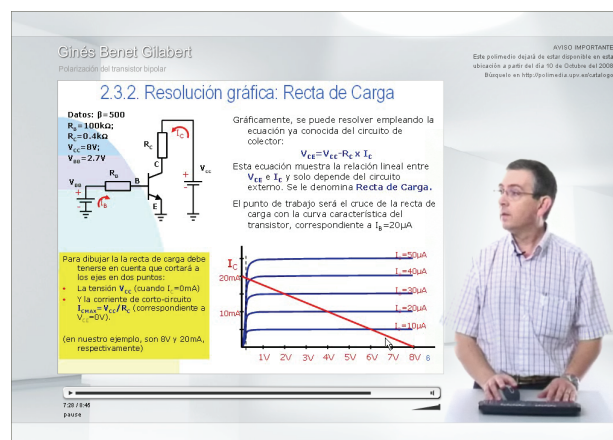


FIGURE 2
VIDEO TO EXPLAIN BJT DC BIASING

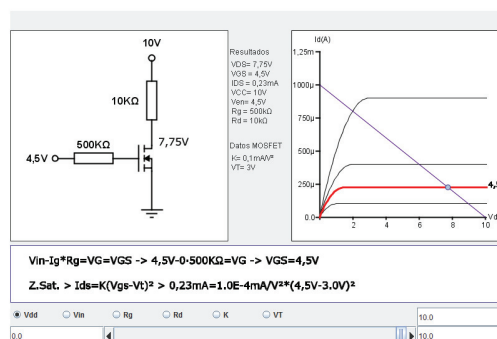


FIGURE 3
JAVA APPLET TO SIMULATE MOSFET BIASING

IV. RESULTS AND DISCUSSION

To measure the effectiveness of the proposed approach, we have compared the academic performance of the treatment group using the Tablet PCs (20 students using a one-to-one approach), and a control group (34 students), following the traditional delivery method. In order to reduce teacher-level differences, lectures and recitations in both groups were taught by the same instructor. We report here some quantitative measures of effectiveness.

Class attendance has considerably increased: 60% attended at least 67% of the classes in the experimental group while only 32% in the control group. To better understand these data it is important to state that class attendance was not mandatory. 25% in the treatment group dropped out of the course during the semester while 59% in the control group. Drop-out in the experimental group is considerably less than might have been expected based on the control group figures, and also on knowledge of the proportion of the three previous academic years, always above 50%. Figure 4 summarizes data about attendance and drop-out in the two sections under analysis.

We used final scores as the overall performance indicator, since they were a direct summative evaluation of the different activities included in the semester. Student performance in this course is assessed by means of two paper exams and a final exam (70%), a hands-out exam at the lab (20%) and class participation in recitations (10%).

30% of the Tablet-PC students passed the course (grade above 5) vs only 18% of the control group. Although the ratio of students passing the course in the experimental group could seem very low as it is in fact, we should state that this ratio was always below 20%, during the last three academic years. Moreover, in the experimental group, grades of those students passing the course were higher than the corresponding in the control group. In a 10-point scale, the mean score was 7.8 for the Tablet group while for the traditional group was 7.3.

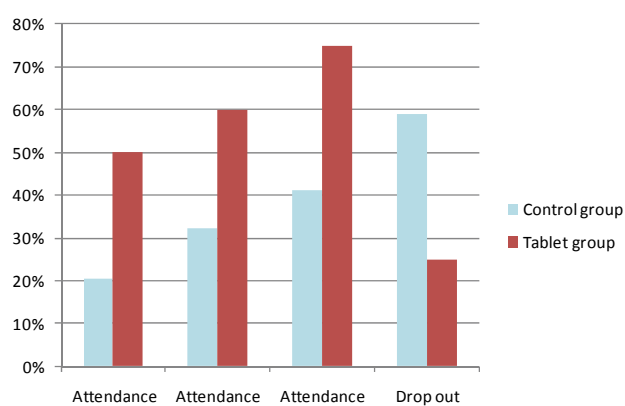


FIGURE 4
COMPARISON OF CLASS ATTENDANCE AND DROP-OUT

Other remarkable evidence is that the percentage of students taking the final exam in the experimental group was a 70% while in the control group was only a 29%. This ratio was always below 45% in the last three academic years, even considering the second call to be held in September. In spite of the high fail percentage ratio among students using Tablet-PCs (40%), we consider very positive the fact that students take the exams as an evidence of their engagement into the course. Figures 5 and 6 highlight the attained improvements.

However, we also should state that a few students often used the Tablet PC to surf the net instead to be focused on the course activities. They eventually dropped-out the course.

Furthermore, a qualitative analysis of the experience has provided a very good perception from student and faculty participating on it.

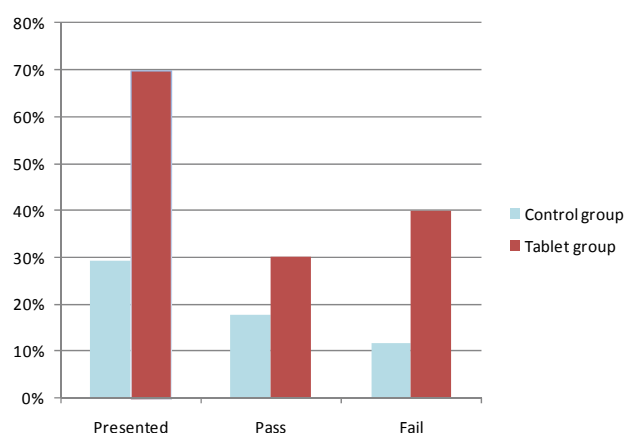


FIGURE 5
COMPARISON OF OVERALL PERFORMANCE AND PRESENTED RATIOS IN THE FIRST CALL (JUNE 2009)

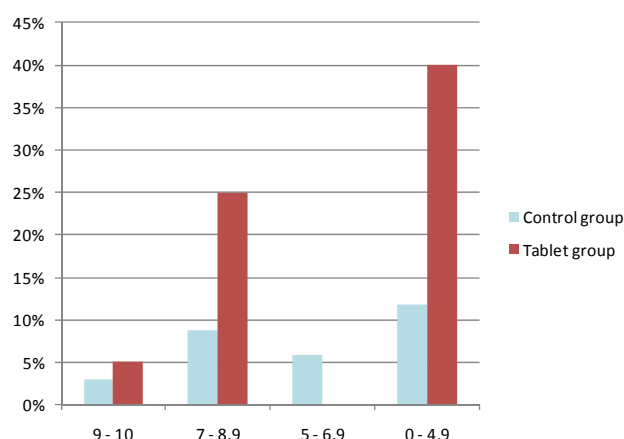


FIGURE 6
COMPARISON OF GRADE DISTRIBUTIONS IN THE FIRST CALL

V. CONCLUSIONS

In this paper we have presented an approach to develop interactive classroom environments supported by mobile Tablet PC technology, which integrates formative assessment into classroom practices and provides immediate feedback to students. This approach provides some guidelines that we have implemented in a first-year CE undergraduate course. The initial results show that the proposed approach has promoted students' autonomy and motivation, thereby improving their academic performance and enhancing their self-confidence in the learning process.

During the current academic year we are implementing the approach in other courses, such as *Operating Systems* and *Data Structure and Algorithms*, in order to test its suitability in different areas. Initial results seem encouraging. Current work is also devoted to organize and structure the knowledge about both instructional domain and technology domain. The goal is to introduce conceptual maps to model the particular educational settings and thus, obtaining information that helps in the teaching guidelines generation [12].

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REFERENCES

- [1] J. Stuart and R.J. Rutherford, "Medical student concentration during lectures", *Lancet* 2 (8088), 1978, pp. 514-516
- [2] J.D. Bransford, A. L. Brown and R.R. Cocking eds., *How People Learn: Brain, Mind, Experience, and School*, National Academy Press, Washington, D.C., USA, 1999.
- [3] J. Sneller, "The Tablet PC classroom: Erasing borders, stimulating activity, enhancing communication", in 37th ASEE/IEEE Frontiers in Education Conference, 2007 © IEEE. doi: 10.1109/FIE.2007.4417929.
- [4] K. Koile, D. Singer, "Assessing the Impact of a Tablet-PC-based Classroom Interaction System", Monograph of the 3rd Workshop on the Impact of Tablet PCs and Pen-based Technology on Education. Evidence and Outcomes, Purdue Univ., West Lafayette, Indiana, USA, 2008, pp. 73-80.
- [5] A. Chickering and Z. Gamson, "Seven principles of good practice in undergraduate education", *AAHE Bulletin*, 39, 1987, pp. 3-7.
- [6] K. Koile, K. Chevalier, M. Rbeiz, A. Rogal, D. Singer, J. Sorensen, A. Smith, K. Seng Tay, K. Wu, "Supporting Feedback and Assessment of Digital Ink Answers to In-Class Exercises", *Proc. of the 22nd AAAI Conference on Artificial Intelligence*, AAAI Press, Vancouver, British Columbia, Canada, July 22-26, 2007, pp 1787-1794.
- [7] Higher Education HP Technology for Teaching Grant Initiative Recipients (2004-2008). http://www.hp.com/hpinfo/grants/us/programs/tech_teaching/hied_global_emea.html
- [8] Classroom Presenter website, available at: <http://www.cs.washington.edu/education/dl/presenter/>.
- [9] R. Anderson, R. Anderson, P. Davis, N. Linnell, C. Prince, V. Razmov, F. Videon, "Classroom Presenter: Enhancing Interactive Education with Digital Ink". *Computer*, 40(9), 2007, pp. 56-61.
- [10] J.V. Benlloch, S. Blanc, "Adapting teaching and assessment strategies to enhance competence-based learning in the framework of the European convergence process", *Frontiers in Education Conference*, 2007. FIE '07. 37th annual, IEEE, Milwaukee, WI, USA, 10-13 Oct. 2007, pp S3B-1-S3B-6.
- [11] Orcad PSpice site, available at: <http://www.cadence.com/products/orcad/pages/default.aspx>
- [12] J.V. Benlloch, F. Buendía, J.C. Cano, "A Tablet PC-Based Teaching Approach using Conceptual Maps", *IEEE Engineering Education 2010: The Future of Global Learning in Engineering Education (EDUCON)*, Madrid, Spain, 14-16 April 2010 (in press).