AC 2011-964: USING TABLET PCS AND ASSOCIATED TECHNOLOGIES TO REVEAL UNDERGRADUATE AND GRADUATE STUDENT THINKING

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Using Tablet PCs and Associated Technologies to Reveal Undergraduate and Graduate Student Thinking

Abstract

The *How People Learn* framework[1, 2] was applied to redesign the courses Food Chemistry (IA-332) and Advanced Food Chemistry (IA-530). Our goal was to improve undergraduate and graduate food chemistry teaching and learning by creating high-quality learning environments that promote an interactive classroom while integrating formative assessments into classroom practices by means of Tablet PCs and associated technologies[3, 4].

We utilized *InkSurvey*, a web-based tool to pose open-ended questions to students during class and receive real-time student responses[5]. Furthermore, we identified classroom assessment techniques appropriate to the course and adapted them into a Tablet PC/*Classroom Presenter* environment to gauge student learning in real time, provide immediate feedback, and make real-time pedagogical adjustments as needed[6].

The redesign of IA-332 and IA-530 increased student participation and formative assessments while instructors utilized the information gained through real-time formative assessment to tailor instruction to meet student needs. This paper highlights what we have learned (through qualitative and quantitative analysis of the information obtained from four semesters) about the potential of Tablet PCs and associated technologies to create classroom tasks and conditions under which student thinking can be revealed.

Context

Universidad de las Américas Puebla (UDLAP) is a Mexican private institution of higher learning committed to first-class teaching, public service, research and learning in a wide range of academic disciplines including business administration, the physical and social sciences, engineering, humanities, and the arts. Since 1959, the Commission on Colleges of the Southern Association of Colleges and Schools (SACS) has accredited UDLAP in the United States.

Course descriptions

The studied courses, Food Chemistry (IA-332) and Advanced Food Chemistry (IA-530) are a junior level, 3 credit required course for food engineering and nutrition BS programs and a first-semester 3 credit required course for the food science MSc program and also an elective for the PhD in food science program at UDLAP, respectively. Approximately 10-25 students are enrolled in IA-332 per semester with 6-17 food engineering students and 4-8 human nutrition students, while approximately 5-10 graduate students are enrolled per semester in IA-530; these graduate students have already a BS in food engineering, food science, biology, agricultural engineering, chemistry, or pharmacy. IA-332 and IA-530 major goal is to help students think about the way a food chemist does. Thus, students are involved in answering two key questions: i) how the composition, structure and properties (especially in terms of quality and safety) of foods are affected by chemical changes the food experiences? And ii) how the understanding of key chemical and biochemical reactions can be applied to many situations encountered during formulation, processing and storage of food?

The fundamental concepts of the studied courses are, therefore, *chemical and biochemical changes* of food and *its effect* on food composition, structure, quality, and safety during formulation, processing and storage, while encouraging students *think about* and *apply* food chemistry in the same ways experienced food scientists and engineers do.

Theoretical background

The studied courses, Food Chemistry and Advanced Food Chemistry, could be improved taking into account technological advances and recent research on human learning and cognitive processes that underlie expert performances.

Using information about How People Learn

During the past 30 years, research on human learning has exploded. Although we have a long way to go to fully uncover the mysteries of learning, we know a considerable amount about the cognitive processes that underlie expert performances and about strategies for helping people increase their expertise in a variety of areas[1-4, 7]. Several committees organized by the US National Academy of Sciences have summarized much of this research in reports published by the National Academy Press. A key publication that informs our current discussion is *How People Learn: Brain, Mind, Experience and School*[1].

An organizing structure used in the *How People Learn* volumes (hereafter HPL) is the HPL framework. It highlights a set of four overlapping lenses that can be used to analyze any learning situation. In particular, it suggests that we ask about the degree to which learning environments are[1-4]:

1. *Knowledge centered*. In the sense of being based on a careful analysis of what we want people to know and be able to do when they finish with our materials or course and providing them with the foundational knowledge, skills, and attitudes needed for successful transfer.
2. *Learner centered*. In the sense of connecting to the strengths, interests, and preconceptions of learners and helping them learn about themselves as learners.
3. *Community centered*. In the sense of providing an environment, both within and outside the classroom, where students feel safe to ask questions, learn to use technology to access resources and work collaboratively, and are helped to develop lifelong learning skills.
4. *Assessment centered*. In the sense of providing multiple opportunities to make students' thinking visible so they can receive feedback and be given chances to revise.

The HPL framework provides a convenient way to organize a great deal of information about the nature of competent (expert) performance and about ways to help people develop their own competence[1]. The framework highlights a set of four overlapping lenses that are useful for analyzing the quality of various learning environments. Balance among the four lenses is particularly important to create high-quality learning environments; since for example, some learning environments can be knowledge centered but not learner centered, and vice versa. In addition, many environments lack frequent opportunities for formative assessment and revision, and many fail to promote a sense of community where learning (which includes admissions of "not knowing") is welcomed, and therefore are not aligned with HPL framework four lenses[1, 2].

Tablet PCs

In an increasingly collaborative, mobile and globally inter-connected environment, UDLAP envisions ubiquitous computing as a natural, empowering component of every teaching, learning, and research activity. UDLAP is committed not only to adopting and adapting technologies to all its scholarly endeavors, but also to playing an active role in their development[4, 7]. Tablet PCs combine a standard notebook computer with a digitizing screen and a pen-like stylus device to produce a computer that allows ease of input of natural writing and drawing. Pedagogically, applications for the Tablet PC include lecture/presentation enhancement, problem-solving demonstrations, active learning support, guided brainstorming, reading, commenting, marking-up (providing feedback), and grading of student work. A review of the current literature supports the following advantages in using a Tablet PC: First, digital ink enables instructors to write "on the fly" during class as one would write on a chalkboard or on a transparency. This is especially meaningful for engineering and chemistry courses where examples and explanations are often mathematically and graphically intensive. Second, the freedom of marking-up significantly changes the way students and teachers interact. It facilitates bidirectional sharing of information, moving students beyond merely observing presentations to interacting with the material, the teacher, and each other. In addition, the use of Tablet PCs supports more efficient management of information. Dynamic working notes can be saved in a searchable format, while lecture notes with vivid annotations become available for students' online viewing[3, 7].

Redesign of the courses

A major issue is to help students develop the kinds of connected knowledge, skills, and attitudes that prepare them for effective lifelong learning[3, 4]. This involves the need to seriously rethink not only how to help students learn about particular isolated topics but to rethink the organization of entire courses and curricula. The ability to design courses and corresponding high-quality learning environments require that we move beyond procedural strategies and models. We also need to understand the kinds of skills, attitudes, and knowledge structures that support competent performance. Thus, for the redesigning of the courses IA-332 and IA-530 similarly as previously described[3, 4, 7] we "worked backwards" as suggested by Wiggins and McTighe[8] taking into account Jenkins model[9] as well as the HPL framework[1, 2]. Especially important was knowledge of key concepts and models that provide the kinds of connected, organized knowledge structures and accompanying skills and attitudes that can set the stage for future learning[2]. Our redesigns involved a transformation of IA-332 and IA-530 from a lecture-based format to a challenge-based format. We use the term "challenge-based" as a general term for a variety of approaches to instruction that many have studied, this includes case-based instruction, problem-based learning, learning by design, inquiry learning, anchored instruction, and so forth. There are important differences among these approaches, but important commonalities as well. We used the HPL framework as a set of lenses for guiding the redesign of the lessons, development of our challenges but also the overall instruction that surrounded the challenges[1-4, 7]. Particularly important were opportunities to make students' thinking visible and give them chances to revise. We also noted the importance of provided opportunities for "what if" thinking, given variations on the challenge and for new problems that also involved the lesson's concepts. Attempts to help people reflect on their own processes as learners (to be metacognitive) were also emphasized.

Methodology

Since spring 2009 we implemented the use of Tablet PC in the courses IA-332 and IA-530. These courses are taught alternately during the year. In the spring semester IA-332 is offered while IA-530 is taught in the fall. Therefore, this study was carried out during 2 periods per year since 2009. Data were collected from spring 2008 (before course redesign and Tablet PC implementation) to fall 2010. The studied populations are presented in Table 1.

Table 1. Participants.

	Class	Total students	Gender	
			Male	Female
Undergraduate	2008	25	16.0%	84.0%
	2009	23	34.8%	65.2%
	2010	10	10.0%	90.0%
Graduate	2008	5	20.0%	80.0%
	2009	7	0.0%	100.0%
	2010	7	42.8%	57.2%

The instructor utilized one of the Tablets and the students utilized each one a Tablet PC. The courses are taught in a large classroom designed for cooperative learning with 20 tables, each one for 4 students. The classroom has six white boards, two LCD-projectors and two screens. The instructor Tablet PC was wirelessly connected to the projectors, so the instructor was able to move within the classroom with his Tablet PC. The classroom is also equipped with a sound system with a tie clip microphone for the instructor and two wireless microphones for the students (Figure 1).

Figure 1. The classroom. Students are using Tablet PCs during a summative quiz.

Vast amounts of educational and psychological research support the efficacy of both active learning and frequent real-time formative assessment in improving learning[4]. In IA-332 and IA-530 we utilized *InkSurvey* (http://ticc.mines.edu/csm/survey.php), a web-based tool developed specifically to allow an instructor to pose open-ended questions to students during class and receive real-time student responses. Students utilized Tablet PCs to respond to these questions with their own words/sentences/paragraphs entered manually via the keyboard, or with digital ink that allows handwriting, sketches, equations, graphs, derivations, etc. Confidence level can be included if desired (as was our case). The instructor received an instantaneous compilation of web-based student responses[4, 5].

A variety of Tablet PC compatible tools are being utilized to facilitate communication within the classroom, such as *Classroom Presenter* (http://classroompresenter.cs.washington.edu). Using the work of Angelo and Cross[10], we identified classroom assessment techniques (CATs) appropriate to each section of the course and then adapted them into the Tablet PC/*Classroom Presenter* environment. The instructor also made use of CATs that are already features within *Classroom Presenter*, like the polling features[6]. Instructor utilized CATs to gauge student learning in real time and made real-time pedagogical adjustments as needed. *Classroom Presenter* can broadcast the presenter's screen content to the entire class using wireless networking[6]. In this mode, students were able to receive the application output and instructor's annotations as well as add their own notes to every course presentation[3, 4, 6, 7].

The sequence of the activities realized by the students using the Tablet PC for this study was that the teacher using *InkSurvey* or *Classroom Presenter* posted a question (from a previous semester quiz or exam) about a particular topic. The questions were asked mainly: i) before class began, in order to reveal the students' prior knowledge about a specific topic and/or ii) at the end of the class, to know how much they learned about a topic.

Once students received the questions on their Tablet PCs; they wrote their answers and then send them back to the professor Tablet PC, students utilized Tablet PCs to respond to the challenging questions (posed by the instructor) with their own words/sentences/paragraphs entered manually via the keyboard, or with digital ink that allows handwriting, as well as input of sketches, equations, graphs, chemical structures, etc. (Figures 2 and 3).

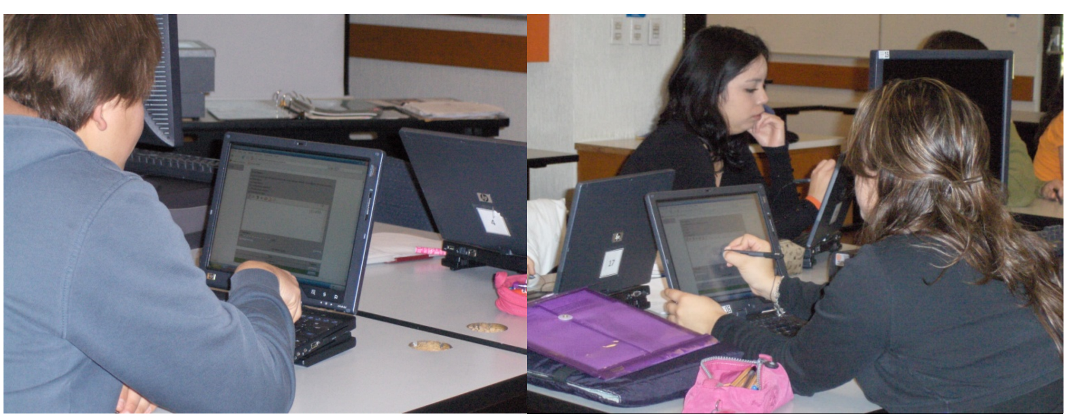

Figure 2. Students working with *InkSurvey* on Tablet PCs

The instructor received an instantaneous compilation of web-based student responses. Then he displayed selected responses to the rest of the class on the classroom presentation screen to make students' thinking visible and give them chances to revise, as well as to provide opportunities for "what if" thinking, given variations on the challenging question (Figure 3). Further, in response to students' answers (and sometimes students' questions), the instructor and/or the students would provide feedback, comments, and/or change instruction accordingly.

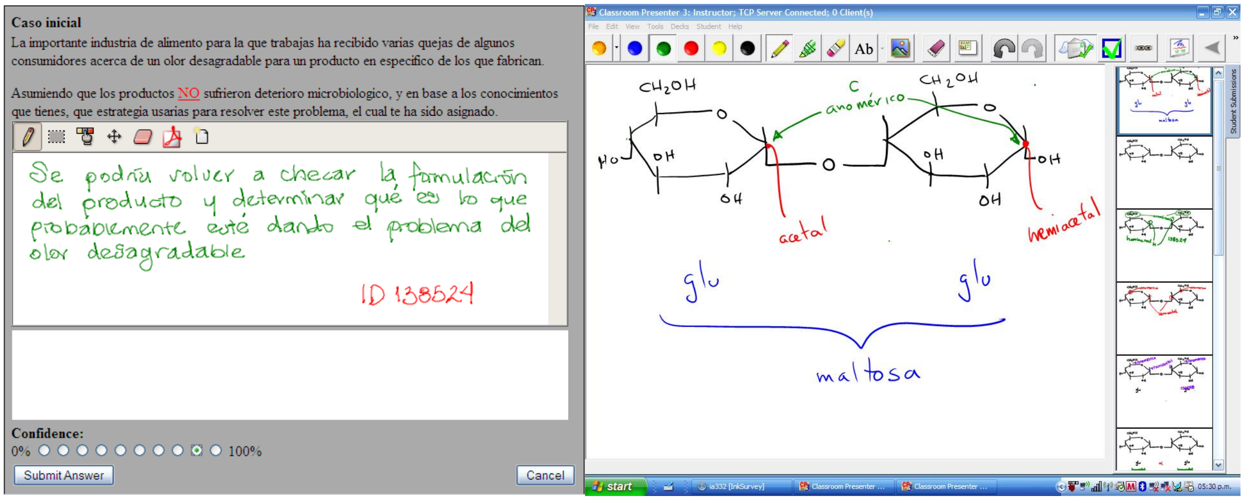

Figure 3. Screenshots of selected student answers using *InkSurvey* and *Classroom Presenter*

The objective of such exercises with *InkSurvey* and *Classroom Presenter* was to (by means of these formative assessments) enable students to acquire skills and knowledge that would be useful for their formal summative assessments, because finally, the questions asked in these exercises were very similar to those that would appear in quizzes and exams during the semester, which have a direct effect on their final grade. For this study, were analyzed the scores of quizzes applied during the semester and compared them with the scores (assessed only for this study and not part of the final grade of the course) of the formative assessment exercises that utilized *InkSurvey* or *Classroom Presenter* during the classes.

Furthermore, beginning in the spring 2009 we applied two online surveys for each studied course. The first survey was applied at the beginning of the semester and the second one at the end. The first survey has the purpose of knowing students' expectations regarding the use of Tablet PCs. The second survey was designed to understand the academic experience that the students had with the use of Tablet PCs and associated technologies.

Results and Discussion

In Table 2 the means of grades (out of 10) of undergraduate and graduate students in the two studied courses' three quizzes for 2008, 2009, and 2010 classes can be observed. With the use of Tablet PCs and associated technologies (*InkSurvey* and *Classroom Presenter*) during several formative assessments prior to the quiz, students improved their results (2009 and 2010 grades) in these summative assessments (quizzes) with respect to students' grades before course redesign and Tablet PC implementation (2008).

Table 2. Mean grades of undergraduate and graduate students in course's quizzes for 2008 (before course redesign and Tablet PC implementation), 2009, and 2010 classes (redesigned courses that utilized Tablet PCs and associated technologies).

	Year	Quiz-1	Quiz-2	Quiz-3
Undergraduate	2008	7.8	7.4	8.9
	2009	8.0	8.0	9.8
	2010	9.8	7.9	9.3
Graduate	2008	7.7	7.5	9.0
	2009	8.0	8.0	9.1
	2010	9.0	8.0	9.6

Furthermore, Figure 4 exhibits the grades of undergraduate and graduate students in formative assessments (assessed only for this study and not part of the final grade of the course) using *InkSurvey* and those obtained at the corresponding summative quiz (final in the figure, which have a direct effect on students' final grade). In both cases, undergraduate and graduate courses, the formative assessment exercises performed with the Tablet PC and *InkSurvey* had a positive impact on the grades of the summative quizzes.

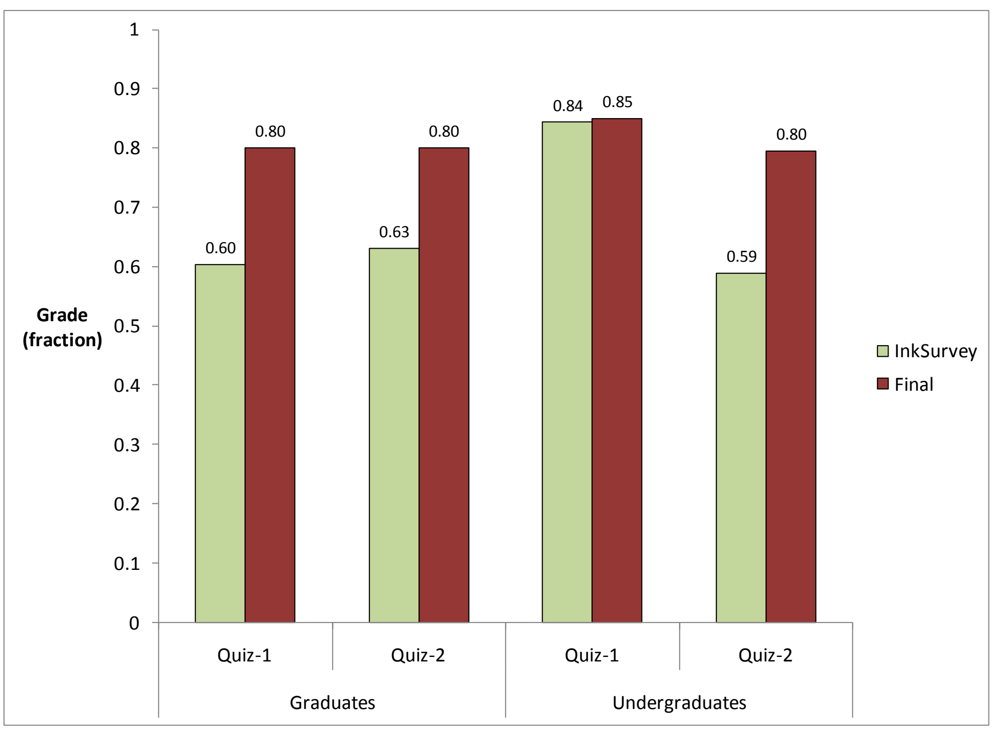

Figure 4. Mean grades (as a fraction) of undergraduate and graduate students in formative assessment (*InkSurvey*) and summative assessment (final) two first quizzes.

Figure 5 exhibits the mean grades (out of 10) of quizzes taken by undergraduate and graduate students in the quizzes applied four years before implementing the use of the Tablet PCs (2005 to 2008) that were compared with results (after) obtained during the next two years (2009 to 2010) when the courses were redesigned and Tablet PC and associated technologies were utilized.

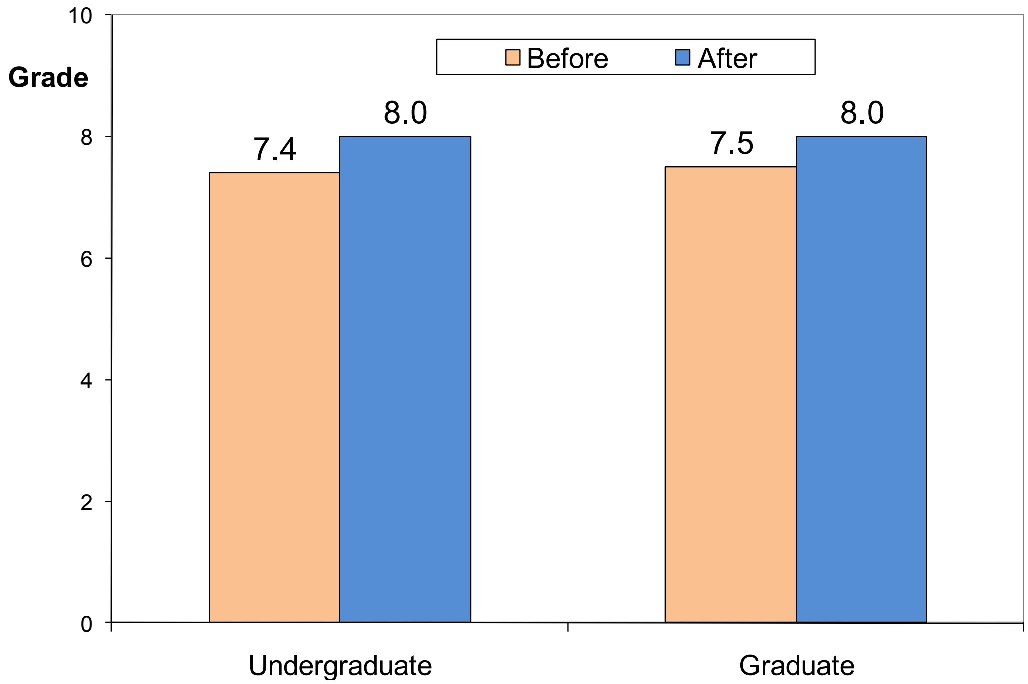

Figure 5. Mean grades (out of 10) of quizzes taken by undergraduate and graduate students before (2005-2008) and after (2009 and 2010) course redesign and Tablet PC and associated technologies implementation.

Because of the anonymity afforded by Tablet PC technologies, students felt comfortable sharing their ideas with classmates, which enabled instructors to assess student understanding frequently during the processes of instruction, problem solving, and peer evaluations to quickly identify the most common difficulties, provide immediate feedback, redirect classroom activities, and/or refine instruction based on feedback received. Particularly important were opportunities to make students' thinking visible, give them chances to revise, and for "what if" thinking, as well as to help students reflect on their own processes as learners (to be metacognitive).

Tablet PC associated technologies generated possibilities for self-assessment, making it possible for students to anonymously analyze their own and classmates' results. Another positive result of Tablet PC use was a visible increase in student motivation to participate in class discussions and problem-solving activities mediated through technologies (*InkSurvey* and *Classroom Presenter*) associated with Tablet PCs. Further, the redesigned IA-332 and IA-530 courses enhanced student understanding of the engineering design approach to problem solving as well as students' abilities to solve practical food chemistry problems and complete real world food engineering projects as directly assessed in several other student work products such as problem-based learning projects, assignments, exams, and journals.

Students' initial conceptions provided the foundation on which more formal understanding of the subject matter was built. Further, frequent formative assessment helped make students' thinking visible to themselves, their peers, and their instructor. Facilitated by Tablet PC technologies, feedback (in both courses) that guided modification/refinement in thinking increased. Additionally, the project has had several other important impacts, particularly on instructor identifying the most common difficulties in undergraduate and graduate food chemistry courses while providing immediate feedback of both written work products and oral presentations from students; helping students reflect on their own processes as learners; and instructor understanding of how through the use of Tablet PC associated technologies, student thinking can be revealed, and therefore the student learning experience in the classroom can be enhanced resulting in improvements in both instruction and student academic success[3, 4, 7, 11, 12].

Online surveys

Students were asked if they knew and had utilized a Tablet PC before the course. The responses are presented in Figure 6. Less than 50 percent of students in each of the courses had previous contact with a Tablet PC.

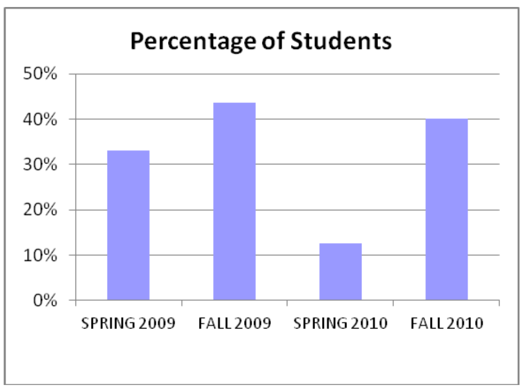

Figure 6. Percentage of students who utilized a Tablet PC before the course.

Students who responded to have utilized a Tablet PC before the course shared their experiences. Box 1 displays some of their responses.

- The experience was good because it is a different way to learn digitally and avoid printing slides to write in class. Further, it can take all kinds of notes and information that you could review after
- I think they are helpful tools to better learn, because digitally you may have all information, further you can consult it anytime

Box 1. Responses of the students about their prior experience with a Tablet PC.

Students were also asked to rate on a scale from 1 to 10 (where 1 was the minimum) how useful was for them the use of a Tablet PC and associated technologies to enhance their learning. Figure 7 exhibits the scores obtained for each studied course.

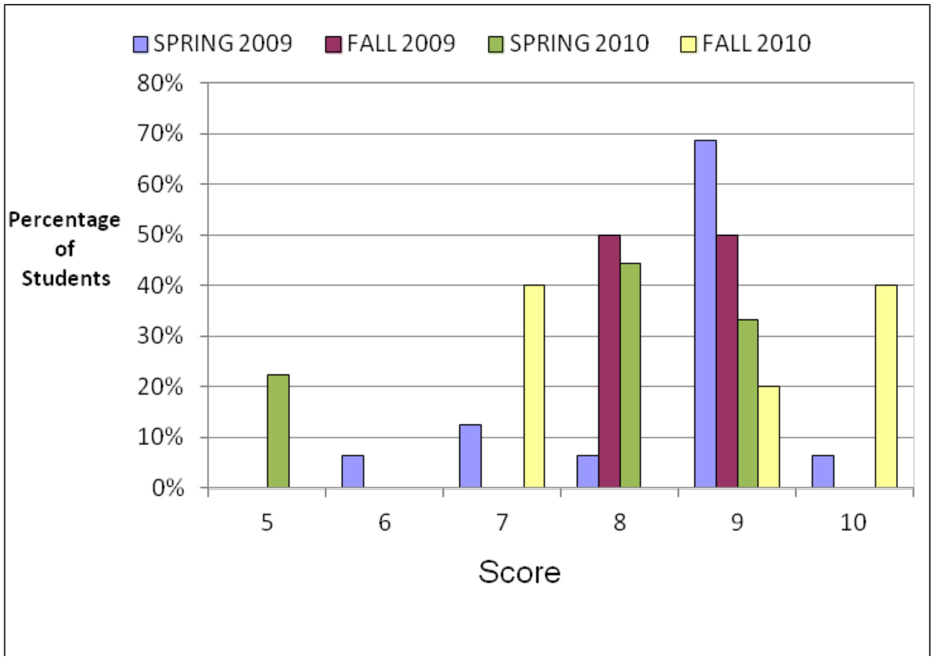

Figure 7. How useful (scored on a scale from 1 to 10, where 1 is the minimum) was for students the use of a Tablet PC and associated technologies on their learning.

After three weeks using the Tablet PC and associated technologies in the redesigned courses, students were asked if they considered that a Tablet PC had advantages or disadvantages with respect to a regular laptop. Their perceptions are presented in Box 2.

- You can take important points or notes about each showed slide, instead on the laptop, you only can see slides without the possibility to take notes
- On a laptop you can't take notes as easily as you want, because you have to add text boxes or something, and on a Tablet PC you can "do" and "undo" it directly on the slides
- There is a greater interaction between students and instructor
- I think it has advantages by using *Classroom Presenter* and also because you can write and make graphs or pictures, and with a laptop you can't
- You can interact with other people who are using the Tablet PC, and thus exchange ideas and/or information
- On a Tablet PC you can quickly make "drawings"
- Using a Tablet PC you have direct contact with the instructor
- With a Tablet PC you spend less time making notes
- A Tablet PC optimizes the learning process

Box 2. Advantages/disadvantages of using a Tablet PC instead of a laptop.

The second survey that was applied at the end of the semester revealed interesting student's experiences using the Tablet PC. Box 3 presents several of their responses. Every student felt that the use of Tablet PCs and associated technologies in the redesigned course improved their learning experience. Box 4 presents several of their arguments.

- It was a new experience, and I think for good, because it is more illustrative
- It was really a new experience but I feel that helped me a lot, because you keep out of the ordinary classes, further it had more features that could be used
- The experience was very good, it was the first time I used it, and although everything was very simple, it was easy
- For me it was a new experience, the learning was very fast, but didn't allow me to make notes. I didn't know whether to write or listen, and then I saw the advantage: I could listen and after class recover the information.
- In the beginning was difficult using the Tablet PC, however I liked this tool, I believe that my learning was better
- I liked it because there is an interaction between teacher-student, and also because the Tablet PC is a tool to take notes, to do quizzes and exercises
- I liked the teacher's classes with the tablet PC, because I understood better and the notes we made were saved and served to us when studying

Box 3. Students' experiences with the use of the Tablet PC and associated technologies.

- Because it is more visual and there is more interaction
- You have all material in your hands, and you could advance as you want
- These are my notes and help me to remember what the instructor said in class…it is a new tool for my growth
- The "extra" notes helped me when I studied the concepts again
- It helps to study earlier for the quizzes or exams, and when we take notes, because sometimes you can remember what color utilized the instructor, it improves the learning
- My learning experience improved, because it was more attractive to write on the Tablet PC, instead of a notebook, further you could draw whatever you wanted to understand better all the concepts
- I could follow better the class, having the presentation and at the same time enabling us to answer some questions. I also liked that we could make our own observations in the presentation
- Not having to be copying the themes and notes in my notebook, let me pay more attention to the class, writing on the same screen only the most important things
- You can be in contact with others and send the questions, you can view animations, videos and presentations of different things that make change your usual routine and it helps to be more alert in class
- On the Tablet PC I could do many notes that after helped me to remember the most important things that were discussed in class. It was also very helpful because if I didn't understand a presentation I could go back to see it in the Tablet, and this helped me to answer my own doubts
- Tablet PCs made the class more interactive and fun, the possibility to make annotations was excellent and we could see with more detail on the presentations, returning to the information if we wanted without having to always go with the teacher

Box 4. Enhanced learning experiences by means of Tablet PCs and associated technologies.

At the end of the semester students were asked if they would like to utilize a Tablet PC in other courses. Their arguments are presented in Box 5.

- Yes, because it is a good tool for class work
- I would like to learn more about its functions, to have more practice
- I think there are more applications for learning
- It gave me the benefits of achieving and assurance of what I learned, only if you can use it well you will achieve an integrated learning
- Definitively yes, it could accelerate and encourage the educational process
- Indeed, to share information among students and teachers
- Yes, since you can make quick notes on presentations and it is easy to work with

Box 5. Using a Tablet PC and associated technologies in more courses.

Students made suggestions to expand the benefits while using Tablet PC and associated technologies in IA-332 and IA-530 courses. Some suggestions are exhibited in Box 6.

- To have more interaction with the instructor and students, not only in the quizzes and exams
- Maybe in a certain topic the instructor could ask questions or ask us something that we have to illustrate or write
- It could be used to do practices with all students in the class (as a competition) in teams or pairs to assess the knowledge acquired after each topic
- Individually, in order to enable each person to take notes on the slides
- To do practices where we could state points of view and/or opinions

Box 6. Some suggestions to further utilize Tablet PCs and associated technologies.

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