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# Helping Teachers Create a Dynamic Learning Environment Using Pen-Based Technology

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*Abstract: There is evidence that Pen-based Technologies (PBTs) can facilitate radical changes that would make it possible to address problems typically associated with lecture-based pedagogical models. In the context of university-level Computer Science studies, there is widespread consensus that PBTs—and tablet PCs, in particular—are tools that have great potential for encouraging interaction in the classroom and promoting a far more dynamic learning environment. In view of the complexity of these types of technology and their explosive evolution, it would be advisable to assist teachers who wish to utilize them by developing strategies based on a conceptualization of their educational capabilities. With this objective in mind, this article analyzes the use of concept maps as tools for modeling both the instructional domain and the PBTs domain. To validate the proposed approach, a number of workshops were conducted, in which professors of Engineering were given a presentation on the educational capabilities of these technologies and then had the opportunity to experiment with tablet PCs and other digital ink devices. Participants completed a pre-questionnaire at the start of the workshop; its questions were generated from a generic concept map for the instructional domain, and its purpose was to list each professor's instructional requirements. Next, recommendations for use were developed, based on the PBTs concept map, and converted to the questions on a post-questionnaire completed at the end of the workshop, on which the teachers indicated the degree to which they agreed with the recommendations. More than 70 professors from different departments participated in these workshops, and their overall evaluation was quite favorable.*

*Keywords: Digital Ink, Tablet PC, Pen-based Technology, Concept Maps, Instructional Design*

## Introduction

Some years ago, when the use of digital presentations to support lecture-based instruction became widespread, it represented a technological advance over transparencies and the blackboard, which had been the conventional methods used. In many cases, however, this meant only a consolidation of the didactic model centered on the teacher's role as transmitter of knowledge.

With reference to the teaching and learning model, a recently published report (Fundación Telefónica, 2011: pp. 47) states, "A trend toward a participatory and collaborative model has been noted, in which learning takes place as the student performs activities and acquires knowledge through interaction with the environment." The report goes so far as to state, "It is anticipated, for example, that in the year 2015, 80% of university professors will be using new, ICT-supported didactic models in their classes." Another report (Fundación de la Innovación Bankinter, 2011: pp. 10-17), produced in connection with the *Future Trends Forum* project, proposes a set of ten principles for contributing to profound reforms in the field of education. One of these principles calls it Education 2.0, referring to the use of ICTs for improving the quality of teaching and learning and the support for both students and teachers as innovative methods are introduced that make education more attractive and effective.

Numerous studies show that ICTs can bring about major changes in the classroom, thereby easing some of the problems associated with the traditional, teacher-centered model of instruction (Sneller, 2007). Simply incorporating technology does not guarantee improved learning achievement, however; successful intervention requires a technology-supported

environment designed and deployed under explicit criteria. Based on the well-known “*Seven Principles for Good Practice in Undergraduate Education*” (Chickering and Gamson, 1987), we found various articles offering general recommendations on how to utilize technology to enrich and expand student-teacher contact, cooperation between students, active learning, and timely feedback (Ehrmann, 2008), among other things.

The personal computer’s already numerous and unquestionable capabilities increase markedly when a special pen that produces digital ink—hence, the term *pen-based technologies (PBTs)*—is added as a component of the user interface. The tablet PC—a conventional portable computer with a screen that acts as a device for both presentation and data entry, thanks to this special pen—is among the leading devices that use this technology. These devices accept all types of strokes made by the user’s hand, raised to the screen, for writing, drawing, creating schematics and diagrams, making sketches, expressing ideas visually—all in a manner similar to the way one would do it using pen and paper but with the additional advantages of the digital format.

By virtue of their features, tablet PCs help educational environments to become far more interactive and, at the same time, allow for modification of both the teacher’s and the student’s role in the classroom. In particular, this technology’s potential increases considerably when the teacher’s computer and the students’ computers are networked. If, in addition, the so-called presentation and collaboration tools are used, such as *Classroom Presenter*<sup>1</sup> and *DyKnow*,<sup>2</sup> a number of educational capabilities become available, among which the following may be highlighted:

- a. Teachers can upload a digital presentation to share with the students. They can also make spontaneous annotations to the original presentation that are visible on the students’ computers, as well.
- b. Students, in turn, can make their own annotations to the copy received on their computer.
- c. Students can transmit their contributions to teachers, who can then preview them privately on their computer or, using a data projector, show them to the entire class, thereby stimulating discussion. Likewise, teachers can make annotations to the material shown and, if considered appropriate, can transmit the annotated material to all students.
- d. Teachers can poll their students with true/false or multiple choice questions that can be answered by choosing the appropriate option. This utility resembles the various *classroom/student/audience response systems* (Deal, 2007), better known as *clickers*. Just as with these systems, the teacher can collect the responses and display the corresponding statistics graphically.
- e. Students can work in groups and share specific documents which, upon completion, can then be made public.
- f. All the information teachers and students generate in the classroom, including the digital ink annotations, can be stored in digital format and, of course, published in any repository for that subject matter.

Given the complexity of these technologies and how rapidly they have evolved, it seems crucial that procedures be established whereby teachers can receive guidelines or recommendations for incorporating PBTs into a particular educational context. The procedures proposed are based on an initial modeling of the various knowledge elements characterizing 1) the instructional approach for the course or training experience and 2) the technology to be incorporated—the PBTs, in our case.

Of the various approaches to organizing knowledge, concept maps (Novak, 1998) were chosen because they can be used to represent different types of information and because their

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<sup>1</sup> *Classroom Presenter* (<http://www.cs.washington.edu/education/dl/presenter/>)

<sup>2</sup> *DyKnow* (<http://dyknow.com/products/vision>)

format is structured but very flexible, as well. Although the formulation these structures provide is not, strictly speaking, a semantic formulation, they can be converted to other formal notations that can then be processed systematically. For example, they could be an initial step in constructing an ontology. Moreover, because of their flexibility, concept maps may be used to represent specific educational designs adapted to environments incorporating ICTs (Buendía, 2011). Lastly, another advantage concept maps have over other options is that many teachers are already familiar with this structure: they are accustomed to utilizing them and evaluating them in different educational contexts. In summary, this article analyzes the advisability of using concept maps to model the instructional and technological domains, as an initial step in generating guidelines or recommendations for designing and implementing a more interactive, tablet-PC-supported learning environment.

The remainder of the article is organized as follows:

- section 2 reviews related articles, with special emphasis on those focusing on guidance for teachers in designing tablet-PC-based courses;
- section 3 describes how concept maps are used to help teachers incorporate these technologies into their educational environment;
- section 4 presents a specific example of guidelines generated for an Industrial Computer Science course;
- section 5 presents the evaluation of the proposal; and
- section 6 states the conclusions.

## **Related Articles**

In recent years, experience with tablet PC use has been gained at all educational levels—from elementary school to high school and beyond. In the realm of higher education, some of the world's most prestigious universities have been committed to PBTs for a number of years. We could name United States institutions, such as Massachusetts Institute of Technology (MIT), Virginia Tech, Georgia Tech, Carnegie-Mellon, DePauw, Purdue, Michigan, and the University of California at San Diego (UCSD), and, in Australia, Monash. Articles published by authors from these universities highlight the impact these technologies have had on academic performance, student motivation, and student involvement in the learning process (Tront, 2007; Koile and Singer, 2008; Logan et al, 2009). A recent research project (Mckenzie and Franke, 2009) reviewed 144 articles on the educational use of tablet PCs, and, of the articles on university-level education, it was noted that 45% were related to Computer Science disciplines. While some of these articles were about multidisciplinary settings (Anderson et al, 2004; Simon et al, 2004), others focused on specific subject areas, such as Introduction to Computer Science (Koile and Singer, 2006), Data Structures (Calder et al, 2007), Computer Theory (Mauch, 2008), and Computer Architecture (Almeida and Azevedo, 2009).

Although there are numerous articles in the literature describing experiences with the use of tablet PCs at different educational levels, it is far more difficult to find articles on how to establish strategies that would guide teachers in incorporating these technologies. The most important of these articles are reviewed below.

Hammond and Mock (2008) offer some practical advice for incorporating non-networked tablet PCs into the classroom. Their effort focuses on how to make presentations and on adapting instructional materials to this technology. Evans (2008), taking a new approach, calls for developing a route map as the sole pathway to achieving successful deployment of tablet PC technology. This route map should articulate the project's objectives, first of all; then, it should identify the critical factors and steps to be taken in implementing the project; lastly, the work plan should help all participants to understand the decisions that were made, before the project is launched. These initiatives make it possible to address general questions about implementing tablet PC projects, but they do not provide teachers with definitive guidelines.

Other articles focus more on supporting teachers in designing tablet-PC-based courses. Tront (2007) describes the Virginia Tech College of Engineering program, in place since Fall 2006, for promoting best pedagogical practices, which could translate to improved learning. Among many other things, this program offers ideas and software tools for transforming teaching style as well as the corresponding instructional materials. The Wolfman article (2005) explores tablet PC technology's potential for addressing the needs of university-level instructors. First, it describes the major concerns—student participation, time management, the comprehension and adoption of new pedagogical perspectives, and large group management—that, in the author's opinion, teachers must use this transformation to address. It then describes how the tablet PC's technological features—such as annotations, collaboration via networked mobile devices, personal expression, and file storage capability—can help to address these issues.

Even though all these articles do indeed offer ideas for adapting a teaching model to tablet PC technology, we have found no methodological approach to providing guidance for these processes. In the next section, we will introduce our proposal for supporting teachers who wish to incorporate tablet PC technology to create a more dynamic educational environment.

## **Using Concept Maps to Support Teachers**

The proposal presented here begins with modeling the knowledge for a particular course and environment in terms of both its educational and its technological aspects. Representing this knowledge on concept maps makes it easier for the teacher to understand the capabilities of tablet PCs and, at the same time, discover what features could best be adapted to the proposed educational requirements.

The first step in the proposed process is to develop a concept map representing the instructional model for the learning environment where the intervention is to be made. Thus, a first approximation would be for the teachers involved to create from scratch a concept map summarizing their particular educational approach and specifying the various aspects of the course or module to be represented. This concept map could include aspects related to learning objectives, discipline, student body profile, didactic resources, teaching methods, and learning activities, among others.

However, and to facilitate the subsequent processing of the information contained in the maps, we opted to construct an instructional map that is generic enough for teachers to adapt to their particular situation. As an example for discussion in this article, a specific model of lecture-based classroom instruction is given, for this is still the prevailing approach used in engineering degree programs here in Spain. Figure 1 shows the generic concept map created to represent this instructional model. This map introduces a specific structure showing, in its upper part, the elements representing what have been considered the key concepts in this type of course: content, activities, interaction, and evaluation. The next levels down on the map detail the approach followed in configuring each of those concepts. Obviously, this instructional map could be much more complex so as to include many other teaching strategies. We decided to keep it simple, however, to facilitate the collection and analysis of data.

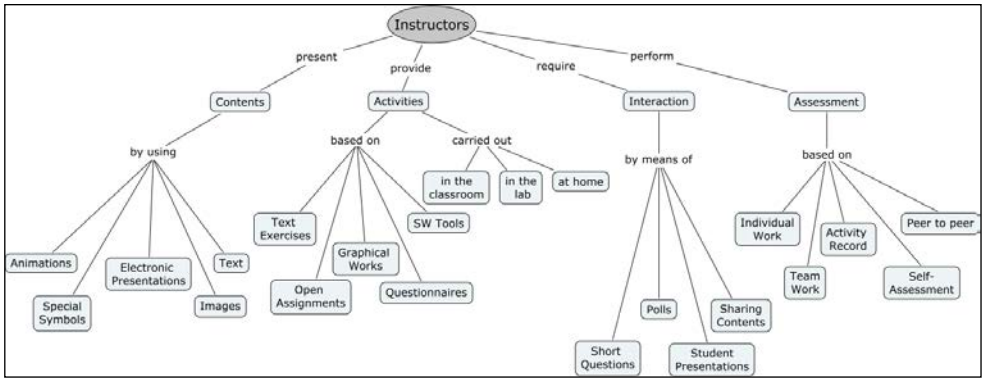


Figure 1. Generic Concept map for a Lecture-Based Approach

The blocks defined can easily be linked with the issues typically associated with this type of context, such as student motivation, choosing and sequencing content, configuring activities to be performed either in the classroom or as part of the student’s independent work, and establishing evaluation criteria and procedures, among others.

Similarly, a concept map was developed for the technological domain for modeling the area of PBTs. This other map, with the tablet PC as root node and starting point, attempts to give an overall concept of these technologies: their features and the types of devices that provide them, the operating systems that support them, the services they offer, and the associated software tools, among other aspects. Because of the size and complexity of the map created, we opted to show two submaps here that are related to two of the most important concepts included on the complete map. To be specific, Figures 2 and 3, respectively, show digital ink concepts and tablet PC services.

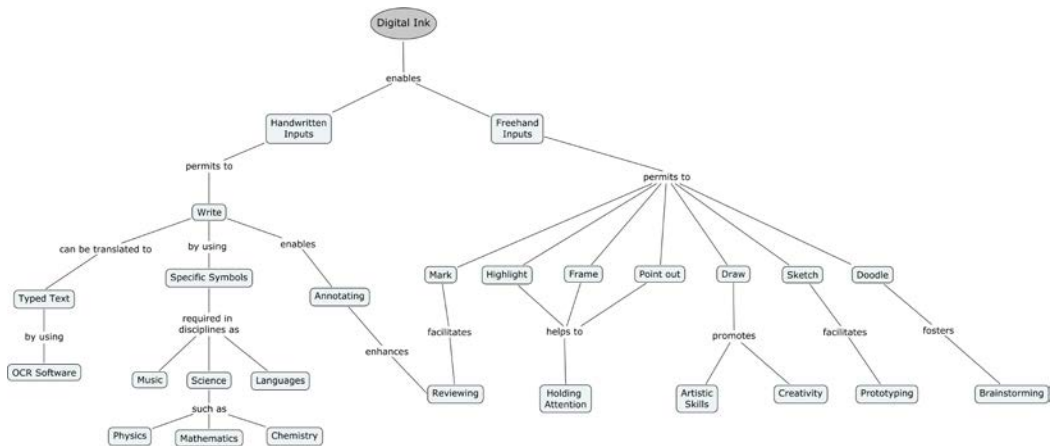


Figure 2. Conceptual Submap for Digital Ink and Its Educational Capabilities

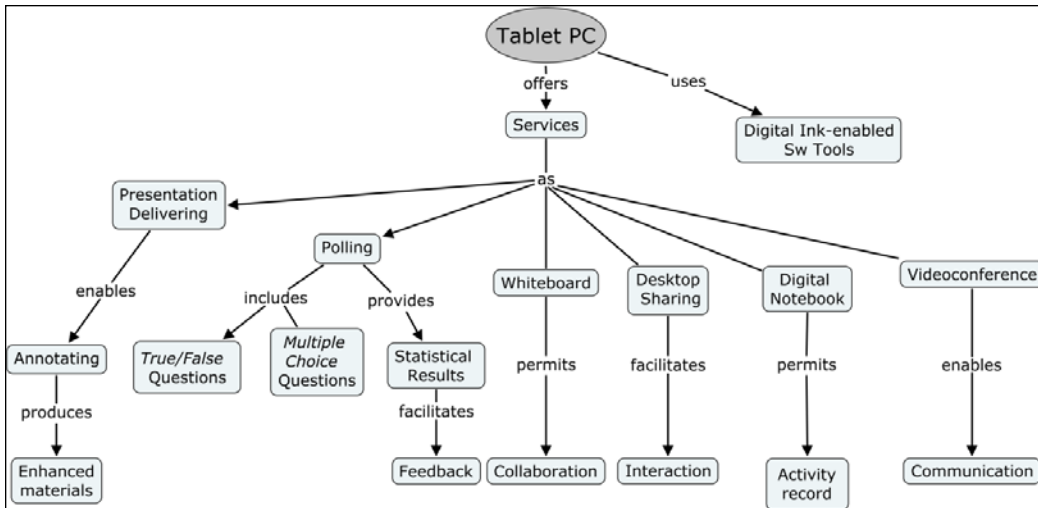


Figure 3. Conceptual Submap for Tablet PC Services

It is important to point out that the digital ink submap correlates the capability of producing all types of strokes directly on the screen surface with the educational activities that may be enhanced by this capability, such as annotating, reviewing, brainstorming, prototyping, and designing, among others. Likewise, the submap shown in Figure 3 correlates tablet PC services with the aspects of instruction that may be enhanced by them, such as taking notes, working collaboratively, interacting, communicating, and giving feedback, among others.

Once the instructional and technological (tablet PC) domains have been defined using the appropriate concept maps, the next step is to correlate them to each other. In other words, our proposal aims to infer information from the elements that make up the two concept maps (concepts and correlations) so as to give teachers some guidelines for using these technologies that have been adapted to their particular instructional approach. This aspect is discussed in the next section.

## Generating Recommendations

To facilitate adaptation of the generic concept map (Figure 1) to each teacher's specific scenario, the different concepts on that generic map were converted to questions, and a complete questionnaire was developed by listing these questions in the same hierarchical order as the concepts on the map from which they were taken. Based on analysis of the corresponding responses, instructional requirements may be listed for each teacher and, at the same time, a submap may be generated where those concepts representing the teacher's particular instructional approach appear highlighted. Figure 4 shows an example of a concept map created from the questionnaire responses of a professor who teaches an Industrial Computer Science course. On this map, the concepts correlating with the professor's instructional approach are those shown with a darker background.

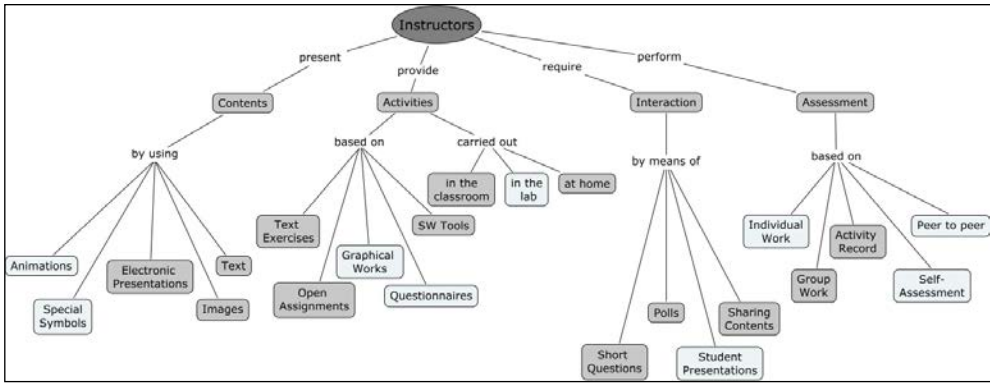


Figure 4. Selection of Concepts on the Instructional Concept map

As we can see, in this particular context, the professor uses text documents, images, and digital presentations to impart his content. He introduces learning activities in class that are open assignments, exercises based on readings, or exercises based on the use of software tools; he promotes interaction with his students through short questions to the class, taking polls, and sharing content between work groups; and lastly, he completes student evaluations through recording their activity and assessing their group work.

Once teachers have specified the instructional aspects of their course, related concepts on the map for the technological domain—tablet PCs, in our case—are discovered through the process of correlating the domains and, from there, appropriate recommendations for use may be generated. This process focuses on the services submap (Figure 3) and its terminal concepts, especially, for those are the ones that list the tablet PC's educational capabilities. Continuing with the Industrial Computer Science example, we find that there is correlation with the following concepts (darker background): enhanced presentations, interaction, collaboration, feedback, and activity record, which leads us to recommend a certain array of services (dark background and shaded), as shown in Figure 5.



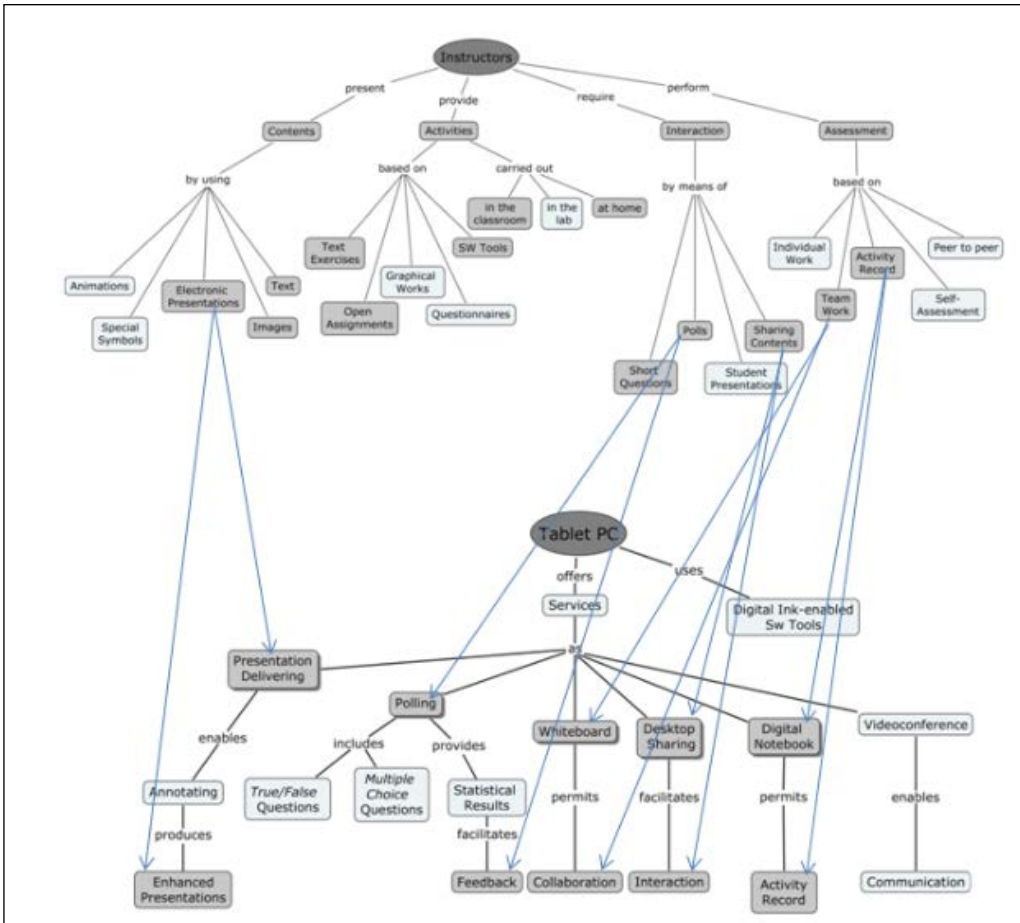


Figure 5. Correlation between Concepts on the Instructional and Technological Maps

Lastly, the services submap is correlated to the submap of software tools that support digital ink (not shown here due to its complexity) to find specific examples of applications that would be recommended.

The entire array of correlations for the example described in this article has been summarized in a table of recommendations (Table 1) with three columns: 1) the specific capabilities available through technology use, with specific examples of software tools; 2) the educational capabilities that these tools present; and 3) the results that may be expected in the teaching-learning process.

**Table 1. Recommendations for Using Tablet PCs in the Educational Process**

Use of Tablet PCs	Educational Capabilities	Results in Teaching-Learning Process
<p><b>Presentation delivery</b> services, included in tools such as <i>Classroom Presenter</i> and <i>Dyknow</i>, make use of digital ink functionalities and could be used to:</p>	<p>Increase flexibility of teacher while teaching class to be able to make annotations on the presentations.</p> <p>Make it easy for students to take notes directly in the presentations.</p> <p>Enable students to transmit class activities to the teacher for subsequent review and discussion.</p> <p>Enable both annotated presentations and student assignments to be saved in digital format.</p>	<p>Enriched and dynamic didactic materials.</p> <p>Higher degree of student participation in the process.</p> <p>Collaborative learning (students can learn from their classmates' responses).</p> <p>Improved communication with classmates and with the teacher.</p> <p>Timely feedback for students and for the teacher himself.</p>
<p><b>Desktop sharing</b> service, such as that provided by <i>Yugma</i> and <i>Adobe Connect</i>, could be used to:</p>	<p>Get students' attention by introducing classroom activities that make use of computer simulations.</p> <p>Make it possible for students to assume the role of teacher in making presentations to the group.</p>	<p>Realistic approximation of the subject matter through the use of simulation tools, such as <i>P Spice</i>, for example.</p> <p>Student involvement and role switching.</p>
<p><b>Polling</b> services, also included in tools such as <i>Classroom Presenter</i> and <i>Dyknow</i>, could be utilized to:</p>	<p>Improve achievement of student learning goals.</p> <p>Give teachers increased awareness of how well the key concepts presented in lectures have been understood.</p> <p>Detect misunderstandings and propose reinforcement.</p>	<p>Student self-esteem and confidence.</p> <p>Timely feedback for students and for the teacher himself.</p>
<p><b>Whiteboard</b> service, incorporated into tools such as <i>Vyew.com</i> and <i>Echalk</i>, could be utilized to:</p>	<p>Facilitate group work projects by offering a shared virtual space.</p>	<p>Collaborative learning.</p>
<p><b>Digital notebook</b> services, such as the one offered by <i>MS Office OneNote</i>, could be used to:</p>	<p>Collect all related activities throughout the course (like a portfolio).</p> <p>Review student assignments and give them comments and suggestions for learning.</p>	<p>Student involvement.</p> <p>Tracking students' activities (ongoing evaluation).</p>

### Validation of the Proposal

To validate the proposal described, a number of workshops were conducted during academic years 2010-2011 and 2011-2012, in which teachers were given a presentation on PBT capabilities and, at the same time, experimented with tablet PCs and other digital ink devices in a classroom configured for this purpose. More than 70 engineering professors participated in these workshops.

At the start of the workshop, participants were given a pre-questionnaire for the purpose of obtaining each one's particular instructional model. As previously described, the questionnaire was made up of a set of questions generated from the generic concept map in Figure 1. Based on the instructional capabilities of PBTs included on the technological concept map and experiences with applying them in various disciplines, a list of good practices in using these technologies was drawn up.

Figure 6 summarizes the responses obtained on the pre-questionnaire from those who attended the workshops held during those two school years. The percentages shown are for certain questions only—those pertaining to aspects of the generic instructional model where PBTs have shown superior capabilities. There is a remarkably high number of professors who use digital presentations in lecture-based classes (92%); who support their content presentation with graphic elements such as diagrams, figures, and schematics (80%); and who incorporate an element of student classroom evaluation (68%). Teachers also commonly assign activities that make use of graphic elements (73%) or open response exercises (70%). These may all be considered routine strategies in a large proportion of engineering degree programs here in Spain.

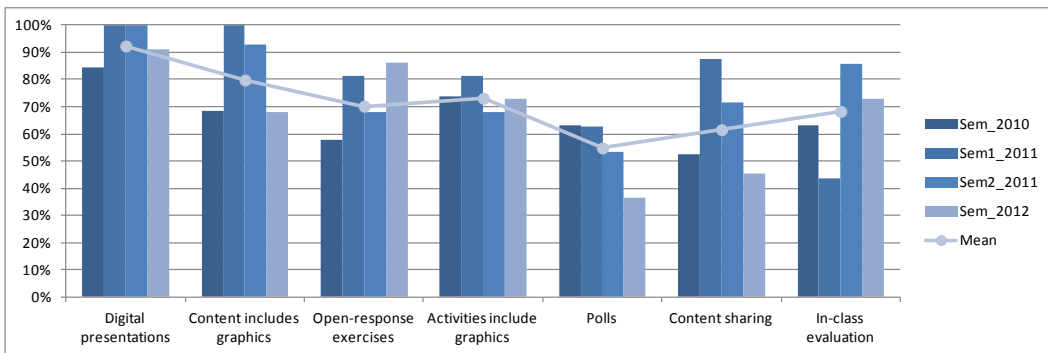


Figure 6. Summary of Pre-Questionnaire Results

The above-mentioned list of good practices was also useful in generating a post-questionnaire on PBT capabilities that was given to the professors at the end of the workshop. In this way, and after experimenting with the technologies, the workshop participants assessed the instructional capabilities of these devices in terms of suitability for their particular context.

Figure 7 summarizes the professors' responses on the post-questionnaire. What is noteworthy, first of all, is the high percentage obtained (above 79%) for practically all the dimensions analyzed; according to professors participating in the workshops, this confirms PBT's potential for improving those aspects. The percentages are particularly high for the ease of taking polls (94%), presenting ideas graphically (91%), performing tasks requiring graphic elements (88%), and evaluating students on class participation (83%). Future case studies along this line will attempt to reinforce the results obtained by conducting more workshops with more professors participating and by applying PBTs in other knowledge areas.

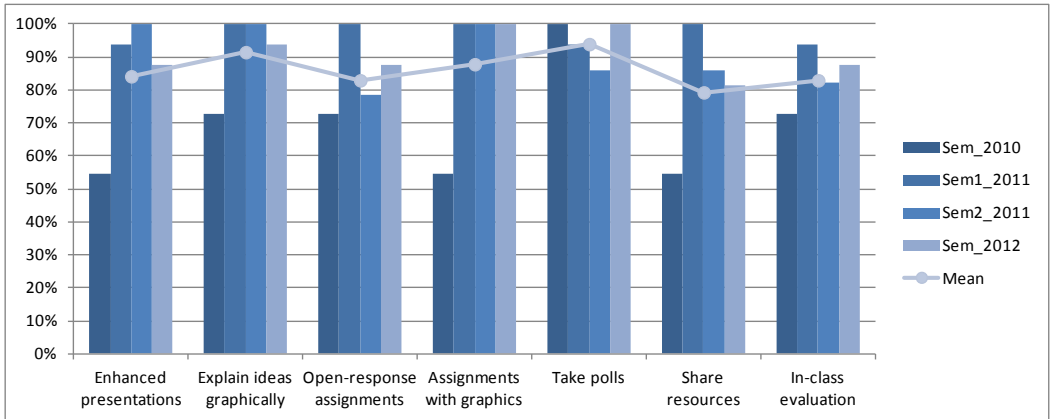


Figure 7. Summary of Post-Questionnaire Results

## Conclusions

This article has presented a proposal for helping teachers who wish to incorporate PBTs to create a more dynamic learning environment. The proposal suggests using concept maps to model both the instructional aspects of a specific environment and the educational capabilities of the digital ink technologies. From correlations between these two concept maps, a number of recommendations may be generated to help the teacher incorporate these technologies into that environment. To validate the model, a number of workshops were held that confirmed the potential these technologies have in the realm of engineering studies and through which the proposal may be steadily improved.

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