THE USE AND IMPACT OF TABLET PCs IN UNDERGRADUATE EDUCATION

Patricia A. S. Ralston, Jeffrey L. Hieb
Department of Engineering Fundamentals
University of Louisville

Since about 2005 a number of early adopters have been experimenting with using Tablet PCs in the classroom. This study provides a review and discussion of Tablet PC literature that summarizes different ways faculty have used Tablet PCs in the classroom, different ways they have measured the impact, and the results they found. The study identifies four primary categories of Tablet PC use: enhanced lecture presentation, improved note taking, video recording and lecture capture, and creation of interactive classroom experiences. Students and faculty both report liking Tablet PCs but there is insufficient data to support general conclusions about specific impacts on teaching and learning. There is a clear need for larger studies as well as work on the development of tablet pedagogy.

Keywords: Tablet, STEM, DyKnow™, Digital Ink

Introduction

The use of Tablet PCs in education has been an active area of interest and investigation since the introduction of the Tablet PC edition of Windows XP in 2002. The recent surge of tablet type devices (from the iPad™ to the Samsung Galaxy Tab™), has dramatically increased awareness and enthusiasm for the potential use of tablets in education. Though there are important differences between recent slate devices like the iPad™ and Tablet PCs, research results relating to the use of Tablet PCs can inform on-going efforts to adopt and use Tablet PCs and other tablet or slate devices in education. For the sake of clarity we define a Tablet PC as a full notebook or laptop computer, running a standard commercial operating system (usually a version of Windows), that has a screen capable of rotating and folding onto the keyboard (slate mode) and which has hardware that allows a pen to be used as an input device. This article presents a review of the literature on the use of Tablet PCs. The focus is on the use of Tablet PCs in post-secondary STEM education, though some relevant K-12 papers are reviewed as well.

Many different pen computers have been available over the past 15+ years, though it is difficult to put an exact date on when the first Tablet PC appeared. Two seminal dates from the perspective of educators would be the introduction of a Tablet PC edition of Windows XP in 2002 and the beginning of the Hewlett-Packard tablet incentive program in 2004. Interest in the potential use of Tablet PCs as an educational tool began in earnest in the early 2000's. As pointed out by Joel Backon, "Tablet PCs merge the productivity improvement afforded by PC technology with the fundamental learning functions supported by the pen" [4]. By 2006 a number of universities had begun to experiment with Tablet PCs in the classroom, including Clemson[52], Depaw [5], the University of Washington [2], Virginia Tech [49] and the authors' ABET accredited engineering school. The HP Tablet PC Grant incentive program, which funded over 250 colleges and universities from 2004-2008 [21], and the development and release of Classroom Presenter [3] and DyKnow™ greatly invigorated interest in tablet PCs in the higher education community. HP's K-12 Technology for Teaching Grants similarly stimulated interest in the elementary and secondary school communities. If the recent rise in the number of different commercially available and affordable slate devices is any indication, then we can expect to see greater penetration of these kinds of devices in student populations and the educational arena.

This study provides a review and discussion of the Tablet PC literature that summarizes different ways faculty have used Tablet PCs in the classroom, different ways they have measured the impact, and the results they found. The authors both teach with Tablet PCs, and have done so since 2007. They use DyKnow™, and all of their students have Tablet PCs. Building on their experience with Tablet PCs, the authors conducted a review of Tablet PC literature in both the area of K-12 and undergraduate education. The scope of the literature search was not limited to engineering or STEM education, but the vast majority of Tablet PC programs have been in these areas. Therefore, many of the results will have a clear bias towards STEM disciplines, but that bias was not imposed by the authors. Of each paper the authors asked the questions:

- how have Tablet PCs been used in the classroom?
- how has their impact been measured?
- and what were the results, if any?

The different ways Tablet PCs have been used were compared to identify general categories of use. For each general category of use, the authors then determined how the impact of that approach was measured and what the finding was.

Summary of Articles

For instructors, the most obvious use of tablet PCs is simply as a replacement for the blackboard, whiteboard, or overhead projector. The ability to annotate imported images, to easily write complex formulas and equations, and to easily create colorful and detailed drawings, all while facing students, make tablet PCs particularly attractive for STEM educators. Similarly the most obvious and natural use of Tablet PCs for students is to use them as a digital replacement for the ubiquitous spiral bound notebook and writing utensil. However, much of the use of Tablet PCs included the use of Tablet PC software tools, specifically collaborative learning software (CLS), CLS [6].

Central elements of all CLSs are: shared white space that students and instructors can ink on and collection of student work by the instructor. DyKnow™ and Classroom Presenter are by far the two most widely used pieces of Tablet PC collaborative learning software. Both create a white space that is shared by the instructor and the students during class. Digital ink applied to the white space by the instructor is transmitted to the students' Tablet PC and their view of the white space. DyKnow™ also includes a special private ink for instructors that can be seen on the instructor's projector, but is not transmitted to students. In addition, students can make their own annotations which are local to their version of the white space stored on their Tablet PC. In both Classroom Presenter and DyKnow™, the white space is organized around panels, much like PowerPoint® slides, and instructors can collect students' work in real-time during class, share and annotate it with the class, or save it for grading later. Instructors may also prepare material before class and this prepared material can be seamlessly folded into the shared white space during class. Prepared material can include images, text, ink, graphics, and live web pages (DyKnow™ only). Using the polling feature, instructors can pose multiple choice or true false questions to students, the results of which can be used during class in real-time or saved for later. Using DyKnow™'s "Share Control" feature, one or more students can ink on slides that are shared with the entire class, allowing anonymous collaboration on open ended problems. Other CLS tools include Ubiquitous Presenter [53], InkSurvey [31] and Group Scribbles [41].

What follows is a comprehensive discussion of the literature related to the use of Tablet PCs in the classroom beginning with a brief, but inclusive, review of Tablet PCs in K-12 classrooms, followed by more lengthy results for the use of Tablet PCs in undergraduate classrooms. The use of Tablet PCs in the undergraduate classroom falls into four categories: enhanced lecture presentation, improved note-taking, video recording of lecture material, and creation of an interactive classroom. Finally, discussion of the impact of the Tablet PC on these classrooms concludes with best practices, challenges, and future directions for educators.

The Use of Tablet PCs in K-12 Classrooms

The use of the Tablet PC can be aligned with several K-12 benchmarks of Standards for Technological Literacy for K-12 students [45]. States are interested in improving their STEM education and anxious to incorporate technology as part of the solution, so it is likely that tablets will soon be commonplace in K-12 classrooms. The analysis of the literature on K-12 Tablet PC programs identified two different and significant themes: K-12 teacher education and use by students in K-12 classrooms.

For K-12 teacher education programs, Tablet PCs were used to provide instruction and model technology integration [16, 46]. The impact of this use was measured by curriculum integration in K-12 classrooms. For example: a survey by Franklin [16] of recent education graduates reported that "curriculum integration of technology into methods courses significantly influences curriculum integration into the elementary classroom".

In K-12 classrooms the following uses of Tablet PCs were found in the literature:

- On a Tablet PC, students used worksheets and workbooks created in Microsoft OneNote® and PowerPoint® [37],
- Teachers created video libraries that use freehand mathematical notation and drawing using Tablet PCs, these were available for students to view [22],
- Students used Tablet PCs to ink their work on math and science exercises developed from existing lesson plans, and teachers viewed and annotated students work in real-time during class [28]
- As a computer based testing platform [44].

Assessment of the impact of Tablet PCs on K-12 classrooms included quantitative data related to student performance on assignments and qualitative data ranging from observations of classrooms to interviews with teachers and students. O'Brien and Dean [37] report quantitative data for middle school students showing student improvement in mathematics from a trial tablet deployment for 15 students, compared to students in a traditional class that did not use Tablet PCs. Results support the use of tablets as an effective instructional tool with demonstrated performance increases for students. Impact assessment of Hamilton and Harding's project [22], a pilot study involving 21 mathematics teachers making digital libraries, was purely qualitative. They reported that the use of Tablet PCs made digital libraries more usable in the classroom, enhanced teacher professional development, and leveraged creativity. Kolie et al. [28] conducted Tablet PC computing trials in eight upper-elementary and middle school science and mathematics classes in the Boston, Massachusetts area that included over 400 students. During each of the trials, teachers were guided to adapt their lessons to exploit the capabilities of the Tablet PC. Data collection included formal observation of classes, interviews with teachers, student focus group discussions, analysis of student work samples and student evaluations. This study concluded that the Tablet PC has much to offer elementary and middle school classrooms and that classroom learning characteristics are consistent with those of project-based learning, active learning, and inquiry-based learning. Siozos et al. [44] evaluated the impact of Tablet PCs on computer based testing but reported only qualitative results that the Tablet PC platform was more useable and useful than a standard PC (n=31, 37).

Use of Tablet PCs in Undergraduate Education

The analysis of the literature on the use of Tablet PCs in undergraduate classrooms identified the following categories:

(1) Tablet PCs are used by the instructor to create an enhanced lecture presentation,
(2) Tablet PCs are used by students for improved note-taking capabilities,
(3) Tablet PCs are used for video recording and lecture capture,
(4) Tablet PCs and a CLS are used to create an interactive classroom experience (student-teacher and student-student collaboration and interaction).

In these studies, assessment of the impact of Tablet PCs was most commonly done using student surveys. There have been some uses of class performance and of performance on individual tests, quizzes or assignments. Other studies have looked at the reduction of DFW rates, or the reduction in C/D rate and increase in B/C for entire populations of students. The following sections elaborate on each of these categories and summarize the assessments presented in the literature.

Enhanced lecture presentation

Using a Tablet PC, OneNote®, and a digital projector an instructor can easily replicate the ubiquitous whiteboard and dry erase markers. Obvious and easy enhancements include never having to erase, facing students, markers never running dry, and a stored copy of all class annotations presented during the semester. With minimal effort other digital artifacts can be easily woven into the lecture presentation using screen clipping, drawing tools, and text editing tools. This replicates and improves on the use of overhead projection transparencies. The use of a CLS further enhances lecture presentation by transmitting (some or all of) the instructors notes to the students' Tablet PCs, assuring formulas, derivations, etc. are transcribed accurately and giving students more time to absorb the instructor's comments.

Impact assessment of enhanced lecture included student survey responses and DFW rates. Survey results presented by Walker et al. [50] (n=90) showed students were more likely to pay attention and recognize salient points during Tablet PC enhanced lecture. In contrast, Birmingham and DiStasi [6] have interesting survey results that show 154 students seem to prefer lecture enhanced using a CLS and Tablet PCs to overheads and chalk boards but not to PowerPoint® and OneNote®. Hieb and Ralston [23] looked at both survey responses and students grades in a course where a CLS was used to provide some, but not all, notes to students. Student survey results confirm those of Brimingham and DiStasi that students prefer the use of CLS for lecture presentation. While the number of A's and B's did not change when compared to a semester when the CLS was not used, they did find a decrease in the DFW rate, and a small increase in the number of C's.

Improved Note-taking

Many tablet papers, with sample sizes ranging from 26 to 540, and averaging 249 emphasize note-taking; specifically the ability of software and digital ink to improve note-taking and organization [11, 13, 15, 35, 36, 47, 54]. Kobayashi's research [27], a meta-analysis of 33 studies related to note-taking in general and not specifically note-taking on tablets, concluded that note-taking and reviewing have a substantially positive effect on student learning, and that the benefits can be increased by intervention in note-taking or in reviewing procedures. Specifically, larger intervention effects were found when a framework or instructor notes were provided to students as a guideline for their note-taking. The use of a CLS is the easiest way to provide a note framework to students, though the approach can also be implemented by providing students with a digital framework (perhaps as a set of PowerPoint® slides) before class. One paper, by Li and Frizell. [34], has data that shows 86 students placed more value on class attendance and note-taking if partial notes were available for download rather than the entire lecture with annotations. When students could get complete notes without attending class, they often did not attend. Williams et al. [55] discuss how providing notes for students to annotate with their tablets opens up time for more engagement and collaboration. Hieb and colleagues [24] discuss the impact of coupling this approach with an active learning exercise that required the use of the Tablet PC in their class. They found that many students (72.9%, n=72) took notes using their Tablet PCs in other classes, where a Tablet PC was not required. Some other results indicate that Tablet PCs and improved note-taking can greatly help poor performing students [19], and also enhance performance of marginalized students [8].

Video recording of lecture material

Video recording of lecture, mini-lecture, or supplemental lecture material existed prior to the entrance of the Tablet PC. However, prior to Tablet PCs, this required specialized equipment that was costly and perhaps difficult to operate for the average user. Tablet PCs make recording freehand drawings, sketches and annotations of prepared slides with synchronized audio very simple. Videos recorded using a Tablet PC can then be used for supplemental instruction, review, remediation, or to implement an inverted classroom. The term *inverted classroom* [33] refers to a teaching strategy that enables instructors to address students' different learning styles within the time constraints of the class. In an inverted classroom, the events that traditionally take place during class time take place outside the classroom and vice versa. So, before coming to class a student might watch a video of a lecture or do assigned reading, and then during class students work problems and have discussions. Impact assessments of these approaches have found some evidence of increased understanding, reduced student anxiety, improved test performance, and that students report liking an inverted classroom.

Porter and Baharun [39] report on a way to engage others in the sharing of Tablet PC created video mathematics learning resources. The use of the Tablet PC and associated technologies allowed production of resources by faculty and students rather than trained video technicians. More important, evaluation for three different courses in years 2009 and 2010 [n=89, 191, n=66,49 n=20,14], revealed that the use of video clips created by tablets has been associated with increased understanding and reduced student anxiety. Wangberg et al. [51] report how a web-based interactive digital ink tutorial program and an open-source online homework system have helped struggling calculus students understand prerequisite material. They conclude that digital ink engages students in solution of mathematics-based problems better than text-based solutions. Comparative results [n=43 for web-based system] and [n=45 for static web page system] showed that after adjusting for a student's pre-test score and total hours using the tutorial, the expected post test score for a student using the static system was lower than the active web system.

Frolik, et al. [17] have used Tablet PCs and screen capture software to develop modular instructional videos for use in a course with an inverted classroom structure. They are developing curricula based on "systems thinking" which centers on the ability to conceive and design complex systems that are interdisciplinary in scope. Even though the number of students is small (n=17, 27), surveys indicated that the modular content demonstrated systems thinking and they liked the inverted classroom format.

Creating an interactive classroom experience

Many of the papers reviewed for this study included an interactive classroom experience component, usually implemented using a CLS such as DyKnow™. This is the area where the Tablet PC has the greatest potential. To realize this potential, both students and instructors must have a Tablet PC, though two or three students to one Tablet PC is possible, most often each student has a Tablet PC, and this is typically referred to as a one-to-one Tablet PC class. Interaction can be teacher-student, student-teacher, and student-student. The Tablet PC, in combination with a CLS such as DyKnow™, creates a platform for implementing active learning strategies that is not possible using more traditional classroom technology. The ease and speed with which instructors can combine student created content (digital ink) and provide real-time feedback on that content make possible interactive classroom experiences that are much more challenging to implement using a whiteboard, pencil and paper. Methods employed for student/teacher and student/ student collaboration to achieve improved interaction and engagement include: using polling and in-class testing and feedback [7, 40], interactive learning networks [20] improving teamwork via digital collaboration [18], and developing an advanced learning laboratory and a digital ink based computerized testing system [34].

Impact assessment of these techniques ranged from survey questions about enjoyment and perceived benefit to performance on quizzes and tests to DFW rates and retention. In general, impact measures were not statistically significant due to the small number of participants. However, results were primarily positive and support the claims of Tablet PC enthusiasts that the use of Tablet PCs to create interactive classrooms can improve teaching and learning. Specific results and summaries of significant studies are presented below.

Papers, with sample sizes ranging from 15-55 and averaging 45, report that faculty and students like the active learning and collaboration that can be accomplished during class and the immediate assessment that is often possible via polling or collection of student work [9, 10, 11, 13, 14, 29, 30, 48]. Many of these papers relied on surveys or a combination of surveys and classroom performance. Formative and immediate feedback was reported in several studies to be a significant interaction that positively affects learning [12, 30, 40]. In contrast, a comparison by Bravo and Batson [7] showed no statistically significant difference in the understanding of the subject, thermodynamics, by students in a Tablet PC class compared to a control group (although 28 students that used Tablet PCs reported greater satisfaction with the course). Similarly, Hrepic and Reed [25] analyze the learning gains in an inquiry-based physical science course for elementary education majors and found no cumulative beneficial effect of the technology on gains in student learning.

A study by Romney, [40], where students participated in interactive problem solving of algebra and trigonometry problems, showed increased attendance, retention, and performance as compared to non-tablet enriched courses. Students obtained instructor PowerPoint slides through Classroom Presenter and took additional notes by inking directly on the slides (enhanced note-taking). Students worked problems during class and the instructor could choose to display these for peer-critique. The instructor's Tablet PC simultaneously used Camtasia Studio 5.0 to produce videos that captured slides and student and instructor comments. These recordings could be accessed after class. Results on student performance are given for the course for two years as compared to non-tablet enriched courses from the previous 3 years. The number of students was small, 50 students in tablet classrooms and 56 in non-tablet courses. More students in the tablet enriched courses made C- or above and fewer withdrew. Of greater interest is the fact that the students in tablet enriched courses had higher retention after the end of one year (74% vs. 49%) and two years (63% vs. 33%). The retention impact is confirmed by Garcia and Cruz [18] who report achieving 100% retention of 20 students with the addition of tablets in several computer science courses at a minority institution.

Garrick and Koon [19] present a compelling study for the potential of Tablet PCs and DyKnow™ to decrease the number of D, F, and W grades in a class that typically had 23% D, F, and W grades. They were motivated to perform this study because an earlier study at their institution [38] demonstrated that Tablet PC based lectures helped students with lower GPAs to a greater extent than students with higher

GPAs. For this study, the class lecture was given in a traditional format in a computer lab one day of the week and in a Tablet PC/DyKnow™ lab the other day. Study evaluation was comprised of a review by an independent instructional designer who attended classes, an end of class student survey, a student focus group, and student performance. Students liked the inked notes they could create by annotating the professor's PowerPoint slides, the ability to work virtually in groups, and they reported using their tablet notes more than they used paper/pencil notes from the traditional PowerPoint slide lecture. They liked submitting their work and viewing other students' work. Most encouraging was that for this class of 27 students, there were no D, F, or W grades, whereas historical data of classes with similar tests would have predicted six D, F, or W grades.

Mario Simoni [43] describes an initial study of using Tablet PCs and DyKnow™ in Integrated Circuit Design courses. He presents explicit examples from three different IC design courses to explain the types of cognitive activities that can be facilitated using this technology. All examples show how prepared slides can be used to improve student engagement during class. He created problems in various formats depending on the particular course. Some simply required the student to complete them while watching the instructor (annotated note-taking), but others required students to do part of, or all of, the problem on their own and then share with the class or submit for grading. Student solutions were discussed or sometimes polling was done to both motivate discussion and test understanding. Assessment data was collected from students that were taught before and after the introduction of Tablet PCs and DyKnow™. Sample sizes were too small for conclusions to be drawn with statistical significance (n=47 pre-tablet group, n=22 tablet group). Normal distributions of the final exam scores were computed from the means and standard deviations of the two groups. Final exam score mean and standard deviation changed from .785 and .119 for the pre-tablet group to .826 and .073 for the tablet group. Graphs of the normal distributions showed that due to the change in variance the C/D performing students moved into the B/C performance level while the A level students remained the same.

Samson [42] discusses laptops for use in keeping 182 students engaged in large lecture classes. Specifically, he presents LectureTools, an interactive suite of tools designed specifically for larger classes. The issues he discusses are relevant for tablets as well as laptops. He provides a convincing argument that laptop use can provide pedagogical benefits that outweigh the potential distractions. LectureTools provides mechanisms to support active learning via engagement; including the ability to take notes synchronized with the instructor's slide, pose questions and get answers in real-time during lecture, reflect on and report understanding during lecture, and the ability to respond to questions asked by the instructor and see results in real-time.

Alvarez et al. [1] present results from a comparative analysis of small size laptops and Tablet PCs used during lectures for a graduate level engineering course (n=20) as a supporting technology for face-to-face collaborative learning activities aimed at solving open-ended questions. Their findings indicated that Tablet PCs strengthened collective discourse capabilities and facilitated a richer and more natural body language. They concluded that Tablet PCs are more appropriate than laptops for supporting collaborative work in the classroom. They noted that this conclusion could not be generalized to scenarios involving different demographics or tasks.

Seneca College of Applied Arts and Technology developed a bridging program to provide a pathway for students without adequate mathematics or science to satisfy entry requirements [8]. These students enroll in a two semester program to strengthen these skills. To determine the effect of the Tablet PC and DyKnow™, one program using Tablet PCs and

DyKnow™ software was offered and one traditional program with lecture, pencil/paper note-taking and computer lab activities was offered. For the Tablet PC program 75 students enrolled in the first semester and 40 in the second semester; for the non-tablet program 66 students enrolled for the first semester and 17 the second semester. Of those students using Tablet PCs in the first semester, 71% had grades C or better, and only 64% had C or better grades in the non-tablet program. Second semester, 78% of the tablet group made C or better grades but only 59% of the non-tablet group made C or better grades. They interpret these early results to show promise of increased student success and retention with the interactive Tablet PC environment.

Conclusions

The synthesis of the literature presented above supports continuing to challenge faculty in K-12 and undergraduate institutions to embrace the potential of tablets to have a positive impact on teaching and learning. Use of tablets to improve teaching and learning include: enhancing presentation and delivery, assisting students with organization and note-taking, and implementing active learning. As Stickel [47] points out, it may be that tablet based instruction has its greatest impact on students in the bottom half of the class by helping students work more efficiently, be more organized, and be more engaged and attentive. Toward this end, we provide a summary of the best practices, challenges and directions for future research based on the experiences discussed in the literature and the authors own experiences using Tablet PCs in the classroom.

Best Practices

The use of tablets in the classroom is still in its infancy, so there are not many easily identifiable best practices. One best practice that is supported by both the authors' experience and the literature is that proficiency with the technology must precede using advanced features, particularly those associated with a CLS. One way to gain proficiency is to begin using tablets in the classroom by replicating established and familiar classroom practice using tablets. After replicating current practices, faculty can begin to explore leveraging the power of tablets and CLSs. The creation of framework notes (or skeleton notes) is a logical progression for using tablets in a way that the research indicates has positive impacts on teaching and learning.

For institutions considering adopting Tablet PCs for instructors or students or both, selecting a single Tablet PC model is another best practice. Though all Tablet PCs offer basically the same features, there are enough idiosyncrasies between models, even from the same vendor, that the efficiencies that come from solving problems once far outweigh the benefits of heterogeneous tablet population.

Finally, in initial course offerings using tablets students must be explicitly required to use the ~~tablets~~Tablets, or it is likely that they won't. To make sure the benefits are realized, students need to have faculty model tablet use, explain the benefits of organization and note-taking and offer suggestions and concrete examples of how to take notes. In these authors' experience, when faculty are enthusiastic and dedicated in helping students learn how to use their tablet and become disciplined to use them, students will embrace their Tablets as a learning tool.

Challenges to Tablet PC Adoptions

Based on the authors' experiences using Tablet PCs and on comments made by the authors in the reviewed articles, three major challenges to Tablet PC adoption are: faculty training, student distraction and technical issues.

The need for faculty training mirrors that identified in K-12 teacher training: familiarity with the technology and experience with its use in actual classroom settings leads to better adoption and use of technology. In higher education, workshops and training seminars are needed if Tablet PCs and other tablet devices are to be effectively used in class. The authors have been experimenting with tablet faculty learning communities as a way to provide faculty with a combination of technical training and an opportunity to share their implementation ideas and questions and discuss other faculty's success and failures using Tablet PCs in the classroom.

Another major challenge to the effective use of Tablet PCs in class is the distraction they may cause students. Several of the papers included in this review acknowledge that students are often distracted by non-class related software applications and therefore fail to stay focused on the material. Kraushaar, Chittenden, and Novak [32] actually gathered data on use of distracting software such as gaming or email and discuss briefly the difference between laptop and tablet distractions. A disturbing finding from this analysis of 108 students was that on average, students using a tablet during class opened 93 active windows during a 75 minute lecture. Hrepic and Shaw [26] report on a study to determine the impact of an open policy for wireless computers in their introductory physics class. They conclude that when a computer-facilitated active learning experience is provided, consistent wireless-computer users are likely to benefit more than non-users. However, inconsistent or sporadic users are likely to be harmed by the availability of an open wireless network.

In general, technical problems are decreasing as Tablet PC hardware and software improve. However, hard drive failures, broken screens, dropped computers, and flaky wireless connections are still issues that students and instructors must face. When a CLS is used, these issues can be compounded because planned, and possibly graded, class activities depend on all students using their tablets. The frustration that students may experience dealing with technical problems can also distract from the impact of Tablet PCs.

Future directions

There are two important next steps for educational research on the use of Tablet PCs in the classroom. Surveys have been an important measure of the perceived impact of Tablet PCs, and have been effective in establishing that students perceive some benefits of Tablet PCs. However, to move forward, more and larger studies are needed that collect quantitative measures of the impact of Tablet PCs on teaching and learning. For STEM disciplines, the impact of Tablet PC use on DFW rates is a potentially valuable quantitative measure. A second and orthogonal direction for Tablet PC research is to investigate the development of effective, discipline specific, frameworks for implementing active learning using tablet devices. This might include the basic structure of a class assignment with a specific example. Faculty could then replicate the active learning exercise in their class by simply substituting content. As more and more students come to college having used a tablet device in their K-12 classrooms, faculty must be prepared to make effective use of them in their own classes.

References

1. Alvarez, C., Brown, C., & Nussbaum, M. (2011). Comparative Study of Netbooks and Tablet PCs for Fostering Face-to-Face Collaborative Learning. *Computers in Human Behavior*, *27*(2), 834-844. doi:10.1016/j.chb.2010.11.008

2. Anderson, R., Anderson, R., Davis, K. M., Linnell, N., Prince, C., & Razmov, V. (2007). Supporting Active Learning and Example Based Instruction with Classroom Technology. *SIGCSE Bull*, *39*.

3. Anderson, R., Anderson, R., Davis, P., Linnell, N., Prince, C., Razmov, V., & Videon, F. (2007). Classroom Presenter: Enhancing Interactive Education with Digital Ink. *Computer*, *40*(9), 56-61. IEEE Computer Society. doi:10.1109/ MC.2007.307

4. Backon, J. (2006). Student Minds and Pen Technologies: A Wonderful Pedagogical Marriage. In D. Berque, J. Prey, & R. H. Reed (Eds.), *The Impact of Tablet PCs and Pen-Based Technology on Education* (pp. 1-13). West Lafayette, Indiana: Purdue University Press.

5. Berque, D. (2006). An Evaluation of A Broad Deployment of DyKnow Software to Support Note Taking and Interaction Using Pen-Based Computers. *Journal of Computing Sciences In Colleges*, *21*(6), 204-216.

6. Birmingham, W., & Distasi, V. (2008). Active Learning Accross the Computer Science Curriculum. *Proceedings of the 2008 ASEE National Conference*. Pittsburg, PA: ASEE.

7. Bravo, R., & Batson, B. (2010). Assessment of Student Learning when using Tablet PCs and the Software DyKnow(TM). *Proceedings of the 2010 ASEE National Conference*. Louisville, Kentucky: ASEE.

8. Carruthers, C. (2010). Engagement and Retention of Marginalized College Students Using Hewlett-Packard Tablet PCs and DyKnow Software. In R. Reed & D. Berque (Eds.), *The Impact of Tablet PCs and Pen-Based Technology on Education* (pp. 11-20). West Lafayette, Indiana: Purdue University Press.

9. Chambers, Z., Chidanandan, A., DeVasher, R., Merkle, L., Minster, M., Mitra-Kirtley, S., Mutchler, D., et al. (2006). What is beyond the laptop initiative? Perhaps: Tablet PCs and DyKnow Vision software. *Proceedings of the Frontiers in Education 36th Annual Conference* (pp. 8-13). IEEE. doi:10.1109/FIE.2006.322525

10. Chidanandan, A., DeVasher, R., Ferro, P., Fisher, D., Mitra-Kirtley, S., Merkle, L., Mutchler, D., et al. (2007). Evaluating the Symbiosis of DyKnow Software and Pen-Based Computing in the Rose-Hulman Classroom. In R. Reed, D. Berque, & J. Prey (Eds.), *The Impact of Tablet PCs and Pen-Based Technology on Education* (pp. 21-32). West Lafayette, Indiana: Purdue University Press.

11. Colwell, K. E. (2004). Digital Ink and Notetaking. *TechTrends: Linking Research & Practice to Improve Learning*, *48*(3), 35-39.

12. Enriquez, A., & College, C. (2007). Developing an Interactive Learning Network Using Tablet PCs in Sophomore-Level Engineering Courses. *Proceedings of the 2007 ASEE National Conference*. Honolulu, Hawaii: ASEE.

13. Filer, K., Tront, J., Scales, G., & Olsen, D. (2008). The Tablet PC as a Catalyst for Pedagogical Innovation and Improvement in Higher Education. *Proceedings of the Asia-Pacific Educational Research Association Conference*. Singapore.

14. Fisher, D., Cornwell, P., & Williams, J. (2007). Teaching Dynamics Using Interactive Tablet PC Instruction Software. *37th Annual Frontiers in Education Conference* (p. S3J-3-S3J-4). IEEE. doi:10.1109/FIE.2007.4417887

15. Fister, R. K., & McCarthy, M. L. (2008). Mathematics instruction and the tablet PC. *International Journal of Mathematical Education in Science and Technology*, *39*(3), 285-292. doi:10. 1080/00207390701690303

16. Franklin, C. (2007). Factors that Influence Elementary Teachers's Use of Computers. *Journal of Technology and Teacher Education*, *15*(2), 267-293.

17. Frolik, J., Weller, T., Flimkkema, P., & Haden, C. (2010). Implementing an Inverted Classroom Using Tablet PCs for Content Development. In R. Reed & D. Berque (Eds.), *The Impact of Tablet PCs and Pen-Based Technology on Education* (pp. 21-29). West Lafayette, Indiana: Purdue University Press.

18. Garcia, J., Jose, S., & Cruz, W. (2010). A Technology-Assisted Simulation of Distributed-Team IT Solution Development. *Proceedings of the 2010 ASEE National Conference*. Louisville, Kentucky: ASEE.

19. Garrick, R., & Koon, M. (2010). Using Tablet PCs and Pen-based Technology to Address Poor Student Performance in an Engineering Technology Class. In R. Reed & D. Berque (Eds.), *The Impact of Tablet PCs and Pen-Based Technology on Education* (pp. 31-38). West Lafayette, Indiana: Purdue University Press.

20. Gutierrez Cuba, J., Lopez-Malo, A., & Palou, E. (2011). Using Tablet PCs and Associated Technologies to Reveal Undergraduate and Graduate Student Thinking. *Proceedings of the 2011 ASEE National Conference and Exposition*. Vancouver, B.C.: ASEE.

21. HP Technology for Teaching Grant Initiative. (2008). Retrieved December 20, 2011, from http://www.hp.com /hpinfo/socialinnovation/us/programs/tech_teaching/index.html

22. Hamilton, E., & Harding, N. (2010). Tablet Computing, Creativity, and Teachers as Applied Microgeneric Analysts: A Paradigm Shift in Math Teacher Professional Development. In R. Reed & D. Berque (Eds.), *The Impact of Tablet PCs and Pen-Based Technology on Education* (pp. 47-55). West Lafayette, Indiana: Purdue University Press.

23. Hieb, J. L., & Ralston, P. A. S. (2010). Tablet PCs in Engineering Mathematics Courses at the J.B. Speed School of Engineering. *International Journal of Mathematical Education in Science and Technology*, *41*(4), 487-500. doi:10. 1080/00207390903477467

24. Hieb, J. L., Ralston, P. A. S., & Bays, C. L. (2011). A Tablet is Required: Promoting Effective Student Use of Tablets in the Classroom. *Computers in Education Journal*, *21*(2), 54-68.

25. Hrepic, Z., & Reed, R. (2009). Impact of Tablet PCs and DyKnow Software on Learning Gains in Inquiry-Learning Oriented Course. In D. Berque, L. Konkle, & R. Reed (Eds.), *The Impact of Tablet PCs and Pen-Based Technology on Education* (pp. 65-72). West Lafayette, Indiana: Purdue University Press.

26. Hrepic, Z., & Shaw, K. (2010). Open Policy for Wireless Computers in Classrooms: What Makes it a Good or Bad Idea? In R. Reed & D. Berque (Eds.), *The Impact of Tablet PCs and Pen-Based Technology on Education* (pp. 83-91). West Lafayette, Indiana: Purdue University Press.

27. Kobayashi, K. (2006). Combined Effects of Note-Taking/-Reviewing on Learning and the Enhancement through Interventions: A Meta-Analytic Review. *Educational Psychology*, *26*(3), 459-477. doi:10.1080/01443410500342070

28. Koile, K., Reider, D., & Rubin, A. (2010). INK-12: A Pen-based Wireless Classroom Interaction System for K-12. In R. Reed & D. Berque (Eds.), *The Impact of Tablet PCs and Pen-Based Technology on Education* (pp. 93-101). West Lafayette, Indiana: Purdue University Press.

29. Koile, K., & Singer, D. (2006a). Development of a Tablet-PC-based System to Increase Instructor-Student Classroom Interactions and Student Learning. In D. Berque, J. Prey, & R. Reed (Eds.), *The Impact of Tablet PCs and Pen-Based Technology on Education* (pp. 115-122). West Lafayette, Indiana: Purdue University Press.

30. Koile, K., & Singer, D. (2006b). Improving Learning in CS1 via Tablet-PC-Based In-class Assessment. *Proceedings of the Second International Workshop on Computing Education Research* (pp. 119-126). Canterbury: ACM. doi:http://doi.acm.org/10.1145/1151588.1151607

31. Kowalski, F., Kowalski, S., & Hoover, E. (2007). Using INKSURVEY: A Free Web-Based Tool for Open-Ended Questioning to Promote Active Learning and Real-Time Formative Assessment of Tablet-PC Equipped Engineering Students. *Proceedings of the 2007 ASEE National Conference*. Honolulu, Hawaii: ASEE.

32. Kraushaar, J. M., Chittenden, T., & Novak, D. (2008). A Descriptive Study of Perceived and Actual PC Use by Undergraduate Students in a Traditional Lecture-Based Graphical Modeling Class. In R. Reed, D. Berque, & J. Prey (Eds.), *The Impact of Tablet PCs and Pen-Based Technology on Education* (pp. 81-88). West Lafayette, Indiana: Purdue University Press.

33. Lage, M. J., Platt, G. J., & Treglia, M. (2001). Inverting the Classroom: A Gateway to Creating an Inclusive Learning Environment. *Journal of Economic Education*, *31*(1), 30-43. Retrieved from http://econpapers.repec.org/RePEc:jee:journl:v:31:y:2000:i:1:p:30-43

34. Li, L., & Frizell, S. (2010). Infusing Tablet PCs and Interactive Learning Technology into Computer Science Education to Enhance Student Learning. *Proceeding of the 2010 ASEE Annual Conference*. Louisville, Kentucky: ASEE.

35. Lohani, V., Castles, R., Johri, A., Spangler, D., & Kibler, D. (2008). Analysis of Tablet PC Based Learning Experiences in Freshman to Junior Level Engineering Courses. *Proceedings of the 2008 ASEE National Conference*. Pittsburg, Pennsylvania: ASEE.

36. Olivier, W. (2005). Teaching Mathematics : Tablet PC Technology Adds a New Dimension. *The Mathematics Education into the 21st Century Project* (pp. 176-181). Johor Bahru, Malaysia.

37. O'Brien, M., & Dean, B. (2009). Preliminary Quantitative Data Showing Student Improvement in Mathematics from a Trial Tablet PC Deployment. In D. Berque, L. Konkle, & R. Reed (Eds.), *The Impact of Tablet PCs and Pen-Based Technology on Education* (pp. 109-116). West Lafayette, Indiana: Purdue University Press.

38. Parthum, M. (2009). Teaching with a Tablet PC, a New Technology for the Classroom and Academic Usage. *Proceedings of the 2009 ASEE Annual Conference*. Austin, Texas: ASEE.

39. Porter, A., & Baharun, N. (2010). Developing a Learning Support System for Students in Mathematics Rich Diciplines. In R. Reed & D. Berque (Eds.), *The Impact of Tablet PCs and Pen-Based Technology on Education* (pp. 111-119). West Lafayette, Indiana: Purdue University Press.

40. Romney, C. A. (2009). Tablet PC Instruction Improves Undergraduate Mathematics Learning. In D. Berque, L. Konkle, & R. Reed (Eds.), *The Impact of Tablet PCs and Pen-Based Technology on Education*. West Lafayette, Indiana: Purdue University Press.

41. Roschelle, J., Tatar, D., Chaudbury, S., Dimitriadis, Y., Patton, C., & DiGiano, C. (2007). Ink, Improvisation, and Interactive Engagement: Learning with Tablets. *Computer*, *40*(9), 38-44. IEEE. doi:10.1109/MC.2007.321

42. Samson, P. (2010). Deliberate Engagement of Laptops in Large Lecture Classes to Improve Attentiveness and Engagement. *Computers in Education Journal*, *20*(2), 22-37. Retrieved from http://www.asee.org/papers-and-publications/publications/division-publications/computers-in-education-journal/papers/16229_1.pdf

43. Simoni, M. (2011). Using Tablet PCs and Interactive Software in IC Design Courses to Improve Learning. *IEEE Transactions on Education*, *54*(2), 216-221. doi:10.1109/TE.2011.2105873

44. Siozos, P., Palaigeorgiou, G., Triantafyllakos, G., & Despotakis, T. (2009). Computer Based Testing Using "digital ink": Participatory Design of a Tablet PC Based Assessment Application for Secondary Education. *Computers & Education*, *52*(4), 811-819. doi:10.1016/j.compedu.2008.12.006

45. Standards for Technology Literacy: Content for the Study of Technology, 3rd. Edition. (2007). Retrieved July 26, 2011, from http://www.iteea.org/TAA/PDFs/xstnd.pdf

46. Steinweg, S., Williams, S., & Stapleton, J. (2010). Faculty Use of Tablet PCs in Teacher Education and K-12 Settings. *TechTrends*, *54*(3), 54-60.

47. Stickel, M. (2008). Effective use of Tablet PCs for Engineering Mathematics Education. *Proceedings of the 2008 Annual Frontiers in Education Conference*. IEEE. doi:10.1109/FIE.2008.4720564

48. Sutterer, K., & Sexton, S. (2008). Interactive Learning Using a Tablet PC in Civil Engineering Soil Mechanics. *Proceedings of the 2008 ASEE National Conference*. Pittsburg, Pennsylvania: ASEE.

49. Tront, J. G. (2007). Facilitating Pedagogical Practices through a Large-Scale Tablet PC Deployment. *Computer*, *40*(9), 62-68. doi:10.1109/MC.2007.310

50. Walker, D., Stremler, M., Johnston, J., Bruff, D., & Brophy, S. (2008). Case study on the Perception of Learning when Tablet PCs are Used as a Presentation Medium in Engineering Classrooms. *International Journal of Engineering Education*, *24*(3), 606-615.

51. Wangberg, A., Anderson, N., Malone, C., Adamu, B., Bertram, K., & Uber, K. (2010). Building a Better Math Tutor System with Tablet PC Technology. In R. Reed & D. Berque (Eds.), *The Impact of Tablet PCs and Pen-Based Technology on Education* (pp. 129-140). West Lafayette, Indiana: Purdue University Press.

52. Weaver, B. (2006). The Case of the Missing Ink. In D. Berque, J. C. Prey, & R. Reed (Eds.), *The Impact of Tablet PCs and Pen-Based Technology on Education* (pp. 13-21). West Lafayette, Indiana: Purdue University Press.

53. Wilkerson, M., Griswold, W. G., & Simon, B. (2005). Ubiquitious Presenter: Increasing Student Access and Control in a Digital Learning Environment. *Proceedings of the 36th SIGCSE Technical Symposium on Computer Science Education* (p. 116--120). St. Louis, Missouri: ACM.

54. Williams, J., Chidanandan, A., Coppinger, P., Fisher, D., Hirotani, M., Rogge, R., Sexton, S., et al. (2008). Measuring the Impact of Tablet PCs and DyKnow Vision Software on Students' Note-Taking Stratagies: A Cross-Discipliary Case Study. In R. Reed, D. Berque, & J. Prey (Eds.), *The Impact of Tablet PCs and Pen-Based Technology on Education* (pp. 145-152). West Lafayette, Indiana: Purdue University Press.

55. Williams, Julia, Hairi, M., Mitra-Kirtley, S., & Sexton, S. (2010). The Pen is Mightier than the Keyboard : Implementing Digital Ink in the Engineering, Humanities, Mathematics, and Science Classrooms. *Proceedings of the 2010 ASEE Annual Conference*. Louisville, Kentucky: ASEE.

Biographical Information

Patricia A. S. Ralston is Professor and Chair of the Department of Engineering Fundamentals. She received her B.S., MEng., and Ph.D. degrees in chemical engineering from the University of Louisville. Her educational research interests include the use of technology in engineering education, incorporation of critical thinking in engineering education, and ways to improve retention. Her other interests include process modeling, simulation, and process control.

Jeffrey L. Hieb is Assistant Professor with the Department of Engineering Fundamentals. He received his Bachelor's Degree from Furman University and the M.S. and Ph.D in Computer Science Engineering from the University of Louisville. His research interests include the use of technology in engineering education, computer security, and cyber-security for SCADA and industrial control systems.