MULTIPURPOSE MOBILE HP LABORATORY FOR SCIENCE AND ENGINEERING STUDENTS

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Abstract

Students' retention remains one of the main challenges in Science and Engineering education. Often, students experience a lack of connection to the material taught in class and, as a result, gradually lose motivation and interest in the course. Technology-enhanced learning has a potential to shift the classroom environment from professor-centered to student-centered, thus improving student learning outcomes. At Ryerson, we frequently experiment with various technologies to support active learning. The electronic pen and screen capture technologies utilized in the tablet personal computers open up new exciting opportunities in teaching Science, Mathematics, Engineering and Technology (SMET) disciplines. Thanks to the generous HP Educational Technology Initiative grant, we have been able to create HP Multipurpose Mobile Science Laboratory for our students in Sciences and Engineering Programs. Since the Fall 2008, tablet PCs have been used in our second year *Modern Physics* and third year *Electricity and Magnetism* courses. The tablets allowed us to create collaborative studio-style environment blending together lecture and tutorial where the students can annotate instructor's lectures, collaborate on problem solving, run applets and simulations, and submit their work. In-class use of tablets significantly increases student-instructor communication. We have recently expanded the use of tablets to offer selected laboratory assignments. We use tablet PCs to create Camtasia mini-lessons on selected particularly challenging topics of the undergraduate curriculum. We believe that the tablet inking and screen capturing capabilities have largely unexplored potential to engage the students in active learning in SMET courses. This work is being supported by HP Innovations in Education Initiative.

Keywords: Tablet computers, active learning, conceptual understanding, collaborative learning, learning outcomes

1 PROJECT MOTIVATION

Ryerson University in Toronto, Ontario, is known for its excellence in teaching, long-standing tradition as a provider of innovative career-focused education and for its mission to serve societal needs. Located in the heart of downtown Toronto, Ryerson is a distinctively urban university with fast-growing student and faculty populations reflecting the unprecedented ethnical and socio-economic diversity of Toronto. Large segment of Ryerson's students' population consists of new immigrants, first generation, mature, and returning students. Over 23,000 students are currently enrolled in a variety of undergraduate programs. Ryerson has an array of fully accredited Engineering Programs. However, our Science Programs are relatively new. The first cohort of B.Sc. in Medical Physics graduated in the spring of 2009. Introductory undergraduate physics courses are taken by the students from all Science (300+), Engineering (800+) and Architecture and Building Science (120+) programs. In addition, advanced physics courses are taken by the students enrolled in our unique Medical Physics B.Sc. Program, as well as by some other science students. Our goal is to improve physics learning by creating and fostering a student-centered learning environment where students, while working in small collaborative groups aided by modern technology, develop problem solving and critical thinking skills.

We strongly believe that a student-centered studio style learning environment that integrates lectures, tutorials and laboratories is more conducive to student learning than the traditional "transmission" type instructor-centered lectures [1-6]. Introduction of computer-enhanced pedagogies, such as real time data acquisition [7, 8], computer modeling and simulations [4, 9, 10], interactive problem-solving online tutoring systems [11, 12], and frequent student-student and student-instructor collaboration [13] requires the students' access to computers during the class time. Unfortunately, our regular classrooms and undergraduate laboratories are not equipped yet with a permanent set of computers that would support interactive teaching. A few instructors have used electronic response system (clickers) in their classes since as early as the fall of 2005 [5, 14-17]. More instructors joined the clicker users' community when a single standard clicker system was adopted by Ryerson in the fall of 2007. Using the Modified Peer Instruction pedagogy [18-21] together with the clickers helped us promote active learning in both large introductory level classes and smaller upper level physics classes. In addition, our instructors pioneered in Canada the use of clickers in the courses beyond the introductory level [14]. However, the opportunities for truly interactive open-ended and technology-enhanced teaching before receiving HP grant in May 2008 [22] were very limited, since relatively few students owned laptops and almost nobody owned a tablet. Unlike clickers, tablets do not limit instructors to using multiple-choice questions. Tablets can be used to expose the student's thinking process during problem-solving. Thus tablets present an ideal tool for supporting in-class student-student and student-instructor interactions. Several members of our Department have experimented extensively with various technologies to support active learning pedagogy in the classroom and beyond. The examples of technologies we tried to adopt in our large lectures include clickers, various sensor technologies supported by Vernier software (Logger Pro) for real data acquisition and analysis [9, 23, 24], computer simulations and applets [4]. Online homework/tutoring systems such as MasteringPhysics [11, 12] were used to extend the student's learning beyond classroom. The electronic pen/digital ink technology utilized in tablet personal computers opens up a wide range of new exciting classroom opportunities. For example, by using tablets in class, students are able to add their notes to pre-prepared electronic documents, save their notes at the end of class, and use them at home to review the material.

In 2008, a team of two faculty members and one technical support staff from the Department of Physics at Ryerson applied for and received HP Educational Technology Initiative grant, which allowed us to create HP Mobile Physics Lab for Science students [22]. As HP 2008 Grant recipients, we were provided with 20 HP tablet PCs for the students and one HP tablet for instructor's use, a color large-format printer, a digital camera, a large computer monitor, a cart for tablets' storage and transportation (mobility), and $20,000 for educational research on the effective use of tablet technology in the classroom. This generous support from HP allowed us to implement active learning in our undergraduate physics courses beyond the introductory level. Moreover, since HP grant also included a monetary support, it allowed not only to introduce changes in our classes, but also to do a research on various effective ways of tablet implementation in undergraduate physics curriculum. This unique opportunity is particularly valuable for Canadian science education researchers, as subject-based science education research has very limited funding in Canada [25-28]. The Mobile Lab has been an ideal solution to our local issues of the lack of permanent computer labs designated for physics teaching. Currently, tablet computes are used in our second year *Modern Physics* and third year *Electricity and Magnetism* courses and in two undergraduate laboratories. We focus on the use of two different free academic software packages: InkSurvey by the Colorado School of Mines [29] and Classroom Presenter by the University of Washington [30]. We also started using Camtasia software [31] that provides a screen capturing opportunity which is especially valuable when used with tablet computers to record short video clips demonstrating problem solving process.

2 IMPLEMENTATION OF MOBILE SCIENCE LAB

The electronic pen / digital ink technology utilized in tablet computers opens up a wide range of new exciting opportunities in science teaching and learning. However, a tablet computer is merely an educational tool that will not enhance learning just by virtue of being present in the classroom. One of our goals was to investigate how the tablets can be used more effectively and what is the impact of using tablets on both students and teachers. The HP Mobile Science Lab Project aimed at addressing three main goals: 1) To explore effective ways of using tablet technology in undergraduate physics curriculum through the design, implementation and evaluation of appropriate classroom and homework activities for an active-learning environment, 2) To evaluate the impact of HP Mobile Science Lab learning environment on student learning, and 3) To suggest a set of recommendations for effective tablet use for our colleagues.

2.1 Project Participants

During the pilot year of the project (2008-2009), the HP Mobile Science Lab was implemented in two upper-level newly designed physics courses. In the fall of 2008 the HP tablets were used in the second year *Modern Physics Course.* Out of 25 students who were enrolled in the course, 19 participated in an anonymous pen-and–paper survey and 10 students participated in 30-minute long interviews at the end of the course. During the winter of 2009, the HP Mobile Science Lab was used in the third year *Electricity and Magnetism Course.* Out of 40 students in this course, 29 students participated in anonymous pen-and-paper survey and 19 students participated in interviews at the end of the course. The majority of the students in both classes were enrolled in B.Sc. in Medical Physics Program. The participation in both pen-and-paper survey and interviews was strictly voluntary. The research was approved by the Ryerson Human Research Ethics Board, and written consent was obtained from all participating students. The surveys were conducted and analyzed by the person other than the course instructors, and the results complied and presented to the instructors only at the end of the term after all the term marks were released. Encouraged by a strong positive feedback, we continued to use the HP mobile lab in the *Modern Physics* and *Electricity and Magnetism* courses in 2009/1010 academic year. In addition, we expanded the use of the lab to the experimental component of two other courses. The lab was used for selected activities such as Spectroscopy Lab in *Optics and Photonics* course for Medical Physics Students and for the Projectile Motion Lab in introductory *Mechanics* course for first year engineering students.

2.2 Project Evaluation Methodology

During the pilot year of the HP Mobile Lab implementation we collected data on the impact of the project on both students and instructors. Since the courses involved were newly developed, there was no control group to compare class performance with and without tablet computers. Moreover, while the standardized diagnostic tests readily available to monitor learning gains in introductory level courses [8, 32], the diagnostic testing materials for the upper-level courses involved in the study is scarce. For example, as far as we know, no reliable and widely used test exists to measure student understanding of special relativity. To obtain some indications on the effect of tablets in our classes, we relied on classroom observations and examined the results of both summative and formative students' assessment. As a part of the project evaluation process, we conducted exit interviews with the students and anonymous paper surveys in both courses. The interviews were conducted by our research assistant after the course was concluded and the results were presented in an aggregated anonymous format. Based on the results of the pilot study, we refined our evaluation tools and continued using the evaluations (both anonymous survey and exit interviews) in the same courses as during the pilot year. The results of this year evaluations are yet to be analyzed.

2.3 Classroom Environment

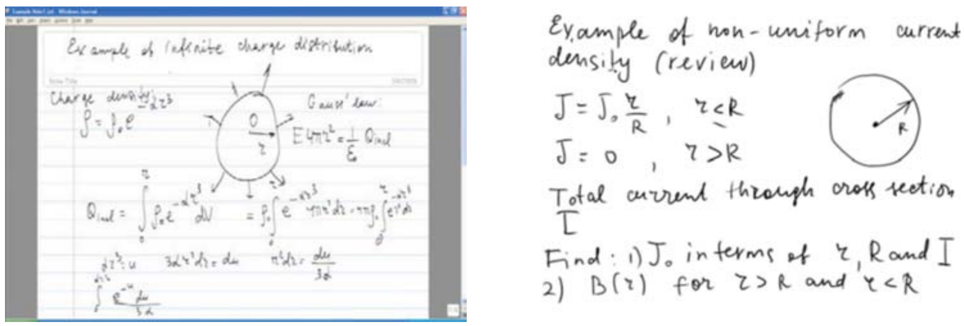
Both *Modern Physics* and *Electricity and Magnetism* classes took place in technology-rich newly-designed classroom equipped with a classroom podium that included a computer, an option to use an individual instructor's laptop/tablet, two screens and projectors, multiple writing areas (whiteboards and chalkboards), a Smart Board, a set of clickers, and wireless internet access. Movable furniture was of particular importance to us, since it allowed us easily rearrange the physical environment and alternate between group and individual work.

2.4 Project Implementation Stages

Initially, we used the tablets just as laptops, taking advantage of their portability without using the ink technology. This was especially helpful during problem-solving sessions or science labs when every team of students is given a tablet to record work on their assignment. Our next step was utilizing tablet's inking capabilities by the instructor. Annotating the presentations prepared in advance in the course of the lecture made the lectures much more interactive and spontaneous. It slows down the lecture to the natural pace, and changes the way the students follow the presentation and take their notes. Eventually we started utilizing tablet's inking capabilities both by the instructor and the students during class In this case, the students were able to add their notes to prepared in advance electronic documents, work collaboratively on problem solving, save their notes and e-mail them at the end of the class. Another related project involved utilizing Camtasia [31] – a screen capturing software, to produce video clips showing the problem solving process or explanation of a concept. Utilizing the screen capture capabilities allows creating mini lessons that expose the process of problem-solving, illustrate the use of specific software or procedures, or explain a concept.

2.5 Classroom Activities: Student-Instructor Interactions

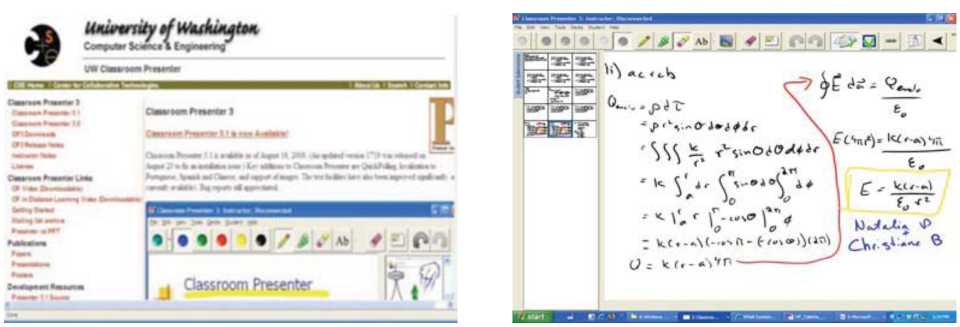
Both course instructors were already using clickers to promote active learning in their other classes [14, 33]. However, clickers were insufficient to develop higher-level problem solving skills in our courses beyond the introductory level. A number of interactive pedagogies the instructors planned to use in their classes relied on the in-class use of personal computers by the students [1, 24, 34]. During the Fall of 2008, the instructor annotated her PowerPoint skeleton notes during the lecture to show the students the process of problem solving instead of using traditional, completely prepared in advance, Power Point slides. Although the instructor consistently used inking capability to deliver the lecture material, the students used tablets mostly as laptops. Most of the students annotated the hard-copy skeleton lecture notes printed out in advance. At this stage, only a few students felt comfortable making the annotations on the tablets themselves. The majority used the tablets to work with spreadsheets, run computer simulations, download YouTube videos, and conducted internet search for their course work. In the winter of 2009, in the 3rd year *Electricity and Magnetism* course, the instructor encouraged the students to start using tablet's inking capabilities more extensively utilizing specific tablet features. For example, Fig. 1 shows a problem solving process using Windows Journal (Fig. 1a) and a Whiteboard feature of the Classroom Presenter (Fig. 1b). The instructor's notes were saved and posted to the Course Management System at the end of the class.



(a) (b)

Figure 1: Screen Shot Images of (a) a Windows Journal Document and (b) a Whiteboard saved in the Classroom Presenter. The images represent applications of Gauss's and Ampère's laws' respectively.

Classroom Presenter [30] (Fig.2) and InkSurvey [29] were used consistently to promote student collaboration. Tablet PCs were used again in the fall of 2009 and winter of 2010. In the *Modern Physics* course the students had open-book exams during which they were encouraged to use tablets to retrieve needed information, run computer simulations or use mathematical software packages.



(a) (b)

Figure 2: Two screen shot images of: (a) The main page of the Classroom Presenter software. (b) A physics problem solved by the students and presented to the class. The boxes on the left show different solutions to the problem submitted by different groups, and each one of these solutions can be presented to the class in real time as shown on the right.

The example of problem solved by an instructor with notes added by the student is shown in Fig.3.

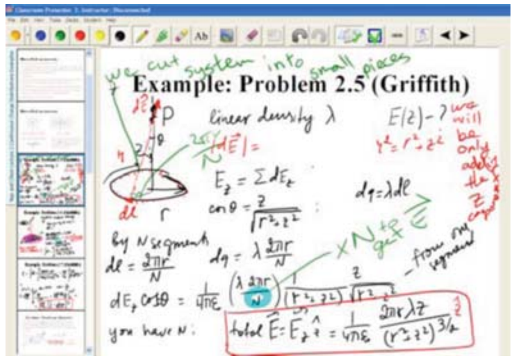
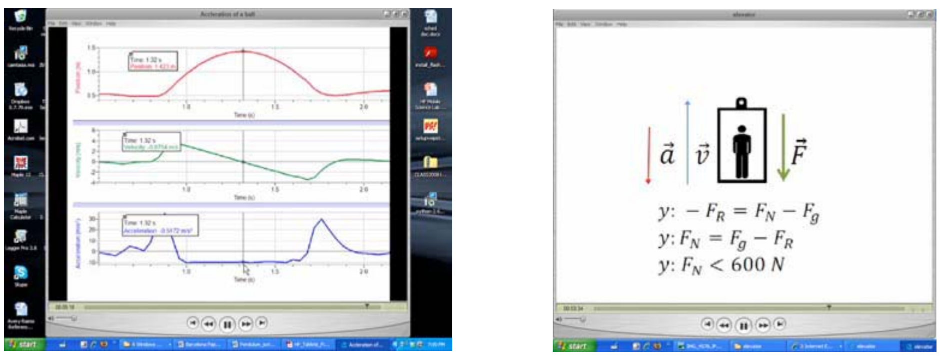


Figure 3: A screen shot image of a student computer screen: a problem solved by the instructor in front of the class, and annotated by the student on his tablet.

It is important to emphasize that the advantages of using tablet computers extend beyond their use by the instructors or even by individual students. The tablet's capability for student-instructor interaction and student-student collaboration is a feature that can strongly facilitate classroom active-learning collaborative environment [35-39]. The Classroom Presenter software [30] developed by the University of Washington Computer Science faculty was used to deliver some of the lectures. This allowed the students to join and follow the instructor's presentation as it unfolded in real time, and to add their own notes to the original document. When the instructor decided to ask the students to solve a particular problem, draw a graph or a diagram, they did it easily using the tablet ink technology. The instructor also collected and analyzed open-ended in-class responses from the students. The group work on collaborative problem solving was greatly enhanced by the use of inking technology. The students were able to submit their work in an open-ended format and receive instant feedback. The lecture notes were prepared in advance, and included pictures, diagrams, graphs, etc. In both courses during the tablet-based activities, each pair of students was provided with a tablet during the class time. In the *Modern Physics* course, the problem solving activities were carried out in two different modes of instruction. In the first one, the students were asked to solve different problems while working in small groups (3-4 students per group). Several problems were assigned simultaneously, but different groups were responsible for different problems, and each group was required to produce a solution of their assigned problem, submit it to the instructor using the appropriate feature of the Classroom Presenter software, and, finally, present their solution to the entire class (Fig. 3). In the second mode, the entire class was assigned the same problem. This problem was chosen to be more difficult and of a nature that allowed multiple approaches. As a result, different groups used different strategies to solve the same problem. Consequently, presenting multiple solutions to the same problem facilitated an important in-class discussion on the merits of different approaches. At the end of the class, the students had their own versions of annotated lecture saved on memory sticks or had the presentations sent to their own e-mail accounts. The big advantage is that everything that instructor writes in front of the class and everything the students submit can be saved for future use, as opposed to the use of a regular white board.

2.6 Conceptual Mini-Lessons: Students Creating Physics Teaching Materials

We used tablet PCs to create mini-lessons on selected topics that are known to be particularly challenging for the undergraduate students. Camtasia Studio software that allows capturing screen activity is particularly valuable with the tablet technology, since it can capture writing on the screen to produce a video clip [31] . The audio part can be recorded simultaneously, or, alternatively, can be added later. Therefore, the entire problem-solving process can be recorded in a form of a short (typically, several minutes in length) video. This video can be posted on the course management system website where the students can access and play it as many times as they need to, or download the video to their own computers. During 2009-2010 academic year our team created a number of mini lessons targeting particularly difficult concepts in introductory physics. The mini lessons (shorter than 10 minutes) included a problem statement, diagrams, interactive quiz to probe student initial knowledge, detailed explanation and solutions, including derivations, as well as a final summative quiz. Fig. 4a is a frame from mini-lesson explaining why the acceleration of the ball tossed vertically up and moving under the force of gravity only ("free fall" condition) is not zero at the uppermost point of its trajectory. The frame displayed represents simultaneous graphs of the position, velocity and acceleration obtained from real data collected with motion detectors [23]. Camtasia environment allows mixing and matching the data and information from different sources. This first mini-lesson describing a free fall motion of a ball, was posted on a Class Management System and was assigned to the students in the *Physics for Architects* Course (120 students). Student feedback on this activity was mostly positive. For example, the students liked that the concepts were explained step by step and presented with clear examples; they also liked the interactivity of the mini-lesson and its visual aspect. In addition, they appreciated the opportunity to rewind the lesson as many times as needed. Encouraged by the student feedback, will expanded this project to target several more known students' misconceptions in introductory physics. Figure 4b below represents a screen shot - a single frame from the "Apparent Weight during the Elevator Ride" video clip. It is worth mentioning that one of our Research Assistants was a former student in one of the courses for which these lessons are being created. In the future we are planning to ask students to create their own Camtasia mini lessons, as part of the course project.



(a) (b)

Figure 4: Screen capture of the frame (a) in the "Acceleration of the Ball" and (b) in the "Apparent Weight during the Elevator Ride" mini-lessons created in Camtasia Studio.

2.7 Second Year of Implementation and Future Plans

During the 2009-2010 academic year, we continued using tablets in our second year *Modern Physics* and third year *Electricity and Magnetism* courses. Encouraged by the positive feedback from our students, we have recently expanded the use of tablets to offer selected laboratory assignments in our both introductory and upper year courses: the Optical Spectroscopy lab in our *Photonics* Course for second-year Medical Physics students as well as for Video-Based Motion Analysis lab in a large *Mechanics* course for the first year students in Engineering Programs. We also plan to expand our project on creating more Camtasia mini-lessons targeting common misconceptions in introductory physics as well as series of mini-lessons for our advanced *Electricity and Magnetism* Course.

3 IMPACT ON STUDENTS AND INSTRUCTORS: LESSONS LEARNED AND SUGGESTIONS

Based on the collected data, we believe that even at the pilot stage of the Project, the employed pedagogy had a profound effect on the students. The HP Mobile Lab has allowed us to introduce interactive teaching at a level that we have not been able to provide before. The results of the students' interviews in the *Modern Physics* course showed that 8/10 students found the use of tablets to be effective; 9/10 students find simulations helpful, easy way to visualize complex material; 7/10 believe that computer simulations helped them to bridge course material to real life. Students think that tablets are most useful in chemistry, physics and overall note taking. The results of anonymous paper survey in the *Electricity and Magnetism* course are presented in Table 1.

Table 1: The results of the anonymous paper survey in the *Electricity and Magnetism* Course. The responses correspond to a Likert scale ranging from 1 – strongly disagree to 3 or 5 – strongly agree.

The use of tablet PC in class supported/enhanced my learning	3.79/5
The use of Tablet PC by the lecturer helped me actively engage with learning in the class	3.79/5
The lecturer's use of Tablet PCs in conjunction with clickers provided me with feedback on my progress	3.59/5
Would you want to use tablets/laptops more in this course?	2.53/3
Would you recommend using tablets/laptops in your other courses?	2.34/3

According to the data, the majority of the students believes that the use of tablets enhanced their learning and recommend using tablets more in this as well as other science courses.

Here are some fragments from the students' interviews:

Student 1: "We used the tablets much like the way we used clickers, except with more complex questions. Instead of using multiple choice type questions for the clickers, we were problem-solving with the tablets. This helped build on my problem-solving skills and learn how to use a new piece of technology as well".

Student 2 testified: "… tablets allow for quicker and more efficient note taking, increasing the time that a student actually listens to the professor".

Overall, we believe the use of HP Mobile Science Lab helped the instructors transform upper-level physics courses into much more interactive environment. First of all, many of our present students do not own laptops and no-one owned tablets. The students learned to annotate lectures effectively. This, in our view, encouraged lecture attendance. Both the student-instructor and student-student communication increased. The focus of our classes shifted from us, the instructors, to the students. The students were very vocal in discussing the use of tablets. They felt that their opinion matters and were eager to provide thoughtful and sincere feedback. This is reflected in a high interview participation rate (15/40) and paper survey response rate (29/40) in *Electricity and Magnetism* course during the winter 2009 semester. The students also appreciated that their opinion and expertise mattered. Toward the end of the semesters we had quite a few discussions of how the tablets can be used more efficiently in our classes. Students' suggestions from both the informal class discussions and formal research interviews include: do more problem-solving work using tablet-assisted group work, receive continuous feedback; do more computer simulations and analyze YouTube videos; use explicitly tablet inking capabilities and software that enhances two-way real time communication between the students and the instructors; limit internet access to prevent the students from visiting sites not related to the course work. Interestingly, one of the main themes that emerged from the students' interviews was the suggestion "to use materials and software that will maximize interaction between the instructor and the students, so the students would not be passive recipients".

In addition to the project participants, 37 members of the Ryerson teaching community were introduced to the technology at a hands-on interactive workshop on the use of tablet computers in science teaching during the 2009 Ryerson Faculty Conference in May 2009 [23]. In addition, close to 50 physics faculty from various Universities across Canada attended our workshop offered during the Canadian Association of Physicists Congress 2009 in Moncton, NB in June of 2009 [40, 41].

The impact on us, the instructors, was also profound. The use of tablets enhanced our teaching by promoting spontaneity and allowing the presenter to move away from static, almost completely pre-arranged notes. One of the project participants testifies: "The project also had a significant effect on my teaching, as it made me reconsider how I spend my class time, what my role is and how I structure my classes. It also made me learn new technology and explore new possibilities for my courses." Another instructor wrote: "The project has a profound effect on my own teaching. I feel that tablet technology addresses the need for more interactive lectures. I still deliver my PowerPoint lectures format (through Classroom Presenter), but the presentations have become much more interactive. Now I am able to do all the derivations in real time, adding them to my prepared skeleton notes. The students are able to follow my lectures and annotate them using Classroom Presenter. The ability to receive students' work in an open-ended format has increased my awareness of the difficulties my students face in grasping concepts presented. As a result, my classes have become more lively and engaging. Short lecture segments followed by the small group problem solving and the all-class discussions are much more meaningful to the students than a traditional lecture."

The important lesson we learned was the realization of the fact that mere availability of new technology will not necessarily make teaching better unless the instructor has a clear idea how this technology is aligned with her/his pedagogical goals [42, 43]. In order to utilize particular technology to the fullest, the instructors should practice enough before using it in a real classroom, because it is next to impossible to concentrate on pedagogy while still learning how to use the equipment in a real classroom. It is very important to establish the contact with the community of a particular technology. For us a pivotal point in staring to utilize tablet capabilities in a more efficient manner was our participation in the HP Worldwide Summit (2009) where we met other recipients of the HP Educational Grant initiative who demonstrated how they use the tablets in their projects and discussed how they evaluated the outcomes.

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