HP GRANTS FOR TABLET TECHNOLOGIES IN SCIENCE TEACHING: FROM DREAM TO INNOVATION

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Abstract

This paper presents a case study describing the implementation of the Hewlett Packard Mobile Science Lab Project in undergraduate physics classes in a mid-size urban Canadian University. The authors describe the results of the first year of Project implementation. We touch upon the advantages and limitations of in-class tablet computer use, as well as provide examples of classroom practices we found effective with our physics 2nd and 3rd year undergraduate students. We also discuss the effects of tablet-enhanced pedagogy on student learning and course satisfaction.

Keywords - Tablet computers, undergraduate science teaching, active learning, conceptual understanding, collaborative learning, student engagement.

1 INTRODUCTION- FROM DREAM TO INNOVATION

Ryerson University considers itself to be Canada's leader in innovative, career-focused education. Located in downtown Toronto (Ontario, Canada), it is fast-growing a distinctly urban university with a mission to serve societal need, and a long-standing commitment to community engagement. Both our student and faculty populations reflect the unprecedented ethnical and socio-economical diversity of Toronto. Large segment of Ryerson's student population are new immigrants, first generation students, mature students, returning students leaving workforce to upgrade their skills. Over 23,000 are currently enrolled in a variety of undergraduate programs. At Ryerson, introductory undergraduate physics courses are taken by the students from all Science (300+), Engineering (800+), Architecture and Building Science (120+), and an Environmental Science (100+) programs. In addition, advanced physics courses are taken by the Medical Physics students, as well as by some students from different Science Program options. Being a university, with a strong tradition of excellence in teaching, our goal is to improve physics learning in all our courses by creating and fostering a student-centered learning environment where the students, while working in small collaborative groups aided by modern technology, develop problem solving and critical thinking skills. Science programs at Ryerson are relatively new. The first intake of students in sciences programs took place in the fall 2005, and the first cohort of B.Sc. in Medical Physics graduated in the spring of 2009.

We have always envisioned our ideal physics classes as a studio style learning environment that integrates lectures, tutorials and laboratories. Unfortunately, our classrooms and undergraduate laboratories are not equipped yet with a permanent set of computers that would support interactive teaching. Introduction of novel computer-based pedagogies, such as real time data acquisition, computer simulations, interactive problem-solving online tutoring systems, and student-student and student-instructor collaboration require the students to have access to computers during class. By the time the Hewlett Packard (HP) Educational Technology Project began in the fall of 2008, several instructors were already employing electronic response system (clickers). Using the Modified Peer Instruction pedagogy [1, 2] in conjunction with clickers helped us promote active learning in both large introductory level classes and the smaller upper-level advanced physics classes. In addition, our instructors pioneered in Canada the use of clickers in the courses beyond the introductory level. However, the opportunities for truly interactive open-ended and technology-enhanced teaching before receiving HP grant were very limited, since very few students had laptops and nobody owned a tablet. With the HP funding, we were able to create the HP Mobile Science Lab for Physics and Engineering Students at Ryerson [3]. Unlike clickers, tablets do not limit instructors to using multiple-choice questions. Moreover, unlike clickers that present the final result only, tablets can be used to expose the student thinking in the process of problem-solving. 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 classroom and beyond. The technologies we tried to adopt in our large lectures include, but are not limited to clickers, sensor technologies supported by Vernier software (Logger Pro) for real data acquisition and analysis [4, 5], using computer simulations and applets [6]. In addition, online homework/tutoring systems such as Mastering Physics [7, 8] were used to extend the student learning beyond classroom. The electronic pen/digital ink technology utilized in tablet personal computers opens up a wide range of new exciting opportunities in science teaching. It is changing the way the instructor presents information, as well as how the students follow the instructor's presentation and take their notes. Using tablets in class, students are able to add their notes to pre-prepared electronic documents, and save their notes at the end of class.

In 2008, a team of two faculty members and one technical support staff applied for and received HP Educational Technology Initiative grant, which allowed us to create HP Mobile Physics Lab for Science students at Ryerson University [3]. 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/transportation (mobility), and $20,000 for educational research on effective use of tablet technology in the classroom. Thanks to this generous support, we were able to implement active learning in our undergraduate physics courses beyond the introductory level. Moreover, HP support allowed us to study effective ways of tablet implementation in undergraduate physics. This unique opportunity is particularly valuable for Canadian science education researchers, as subject-based science education research has very limited funding in Canada [9-12].

Portability was of a particular importance for us, and the Mobile Lab has been a tremendous solution to the issues of the lack of permanent computer labs designated for physics teaching. Currently, tablet computers are used in our second year *Modern Physics* and third year *Electricity and Magnetism* courses. Our students annotate lectures, collaborate on problem solving, run applets and simulations, and submit their in-class work using tablets. We focused on the use of two different free academic software packages: InkSurvey by the Colorado School of Mines: [13] and Classroom Presenter by the University of Washington [14]. We also started using Camtasia software [15] that provides a screen capturing opportunity which is especially valuable in the case of tablet computers. Camtasia allows us to record short video clips ilustrating problem solving, explanining science concepts or showing step by step derivations, and then uploading them online as a resource for our students. In the future, we plan to ask students as part of their course assignment to create mini-lessons and record them using Camtasia as video clips.

2 TABLET-ASSISTED STUDIO-STYLE LEARNING ENVIRONMENT FOR ADVANCED PHYSICS COURSES

We strongly believe that 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 an educational tool that will not enhance learning by virtue of being present in the classroom. Therefore, being science educators, we wanted to investigate how this tool can be used more effectively and what are the effects of using tablets on students and teachers. The HP Mobile Science Lab Project aimed at addressing a number of goals: 1) To create an active-learning collaborative environment in the physics courses mentioned above; 2) To explore effective ways of using tablet technology in undergraduate physics curriculum through the design, implementation and evaluation of appropriate classroom and homework activities; 3) To evaluate the impact of HP Mobile Science learning environment on student learning and their attitudes toward science, and 4) To formulate a set of recommendations for the effective tablets' use for our colleagues.

There are many ways to incorporate tablets in order to enhance science learning.

1. Using tablets as laptops by students and the instructor: Initially, tablets can be used just as laptops, when the major advantage is their portability. This is especially relevant during field trips, problem-solving sessions or science labs when every team of students is given a tablet to record work on their assignment.

2. Utilizing tablets' inking capabilities by the instructor: The next step is utilizing tablet's inking capabilities by the instructor. For example, annotating prepared in advance presentations makes the lectures much more interactive. It changes the way the instructor presents information, it slows down the lecture, as well as alters how the students follow instructor's presentation and take their notes.

3. Utilizing tablets' inking capabilities by the instructor and the students during class: In that case, the students are able to add their notes to prepared in advance electronic documents, work collaboratively on problem solving, e-mail their notes to the instructor during the class and save them at the end.

4. Utilizing screen recording software to produce video clips showing problem solving process, or concept explanation: Utilizing the screen capture capabilities allows creating mini lessons that show the process of problem-solving, illustrate the use of specific software, or clarify a concept. Tablet's inking feature allows the presenter to explain the concept in the most natural way.

2.1 Study 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 a second year *Modern Physics Course* in a Medical Physics program. 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 voluntarily. The research was approved by the Ryerson Human Research Ethics Board, and written consent was obtained from all participating students. The students were given assurance that the participation in the survey would not affect their grades. 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.

2.2 Methodology

Since the courses involved were newly developed, there was no control group to compare class performance with and without tablet computers. Moreover, unlike the standard diagnostic tests readily available to monitor learning gains in introductory level courses [16, 17], such materials exist but are scarce for the specific upper-level courses involved in the study. For example, as far as we know, no reliable and wide-spread tests exist to measure students' understanding of special relativity. To obtain some indications on the effect of tablets in our classes, we relied on classroom observations during collaborative activities and examined the results of students' assessments (both formative and summative). As a part of our project evaluation process, in both courses we conducted exit interviews with the students and anonymous paper surveys. The interviews were conducted by our research assistant after the course was concluded and the results were presented in an aggregated anonymous format.

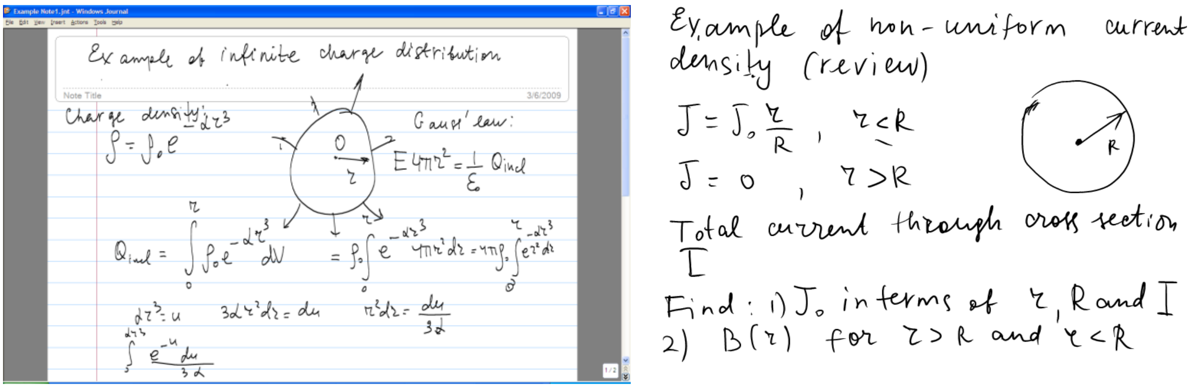
2.3 Student Activities and Classroom Environment

Both 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 tablet, two screens and projectors, multiple writing areas (whiteboards and chalkboards), a Smart Board, a set of clickers, and a wireless internet access. Movable furniture was of particular importance to us, since it allowed us easily rearrange the physical environment and alternate between the group and individual work.

Both course instructors were already using clickers to promote active learning [18, 19]. However, clickers were insufficient to promote learners' higher level problem solving skills. A number of interactive pedagogies the instructors planned to use in their classes depended on the student use of personal computers [20-22]. This only became possible with the beginning of the Project. During this first stage of the Project we used the tablets both as mobile computers (laptops) and specifically as tablets.

During the fall of 2008, while we still had limited experience with the educational applications of tablets, the instructor annotated her Power Point skeleton notes during the lecture to show the students the process of problem solving as opposed to completely prepared in advance PowerPoint slides used in the past. Although the instructor consistently used inking capability to deliver the lecture material, the students used tablets mostly as laptops. Most of the students annotated printed in advance lecture notes. Only a few students felt comfortable making the annotations on the tablets, even though the tablets were available. They used tablets to work with spreadsheets, run computer simulations, download YouTube videos or other relevant materials. The students also learned how to conduct meaningful 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. The instructor modeled tablet-enhanced note taking and helped the students get started. For example, she demonstrated problem solving process for students using the Windows Journal (Fig. 1a) and a Whiteboard feature of the Classroom Presenter (Fig. 1b). At the end of class where tablets were used, saved instructor's notes were made available to the students through the Course Management System.

In addition a few of the classroom activities were specifically designed to utilize tablet technology and promote student collaboration in problem solving. Classroom Presenter [14] and InkSurvey [13] were used consistently to promote student collaboration. Tablet PCs were used again in the fall of 2009 and the winter of 2010. In one of the courses where the tablets were used, 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 1: Screen Shot Images of (a) a Windows Journal Document and (b) a Whiteboard saved in the Classroom Presenter. The images represent Gauss's and Ampère's laws' applications respectively.

In addition, the students started using InkSurvey software [13] to submit answers to homework questions for a formative assessment and to respond to informal course surveys. Since InkSurvey has a dual input screen allowing both handwriting (inking if the tablet is available or scribbling with a mouse in case of an ordinary laptop) and type-in screen, the students are able to do the assigned work even outside of the classroom when most of them do not have access to tablet computers.

Examples of instructor's screen with the list of questions and with students' responses in both freehand and typed format are presented in Fig. 2 and Fig. 3.

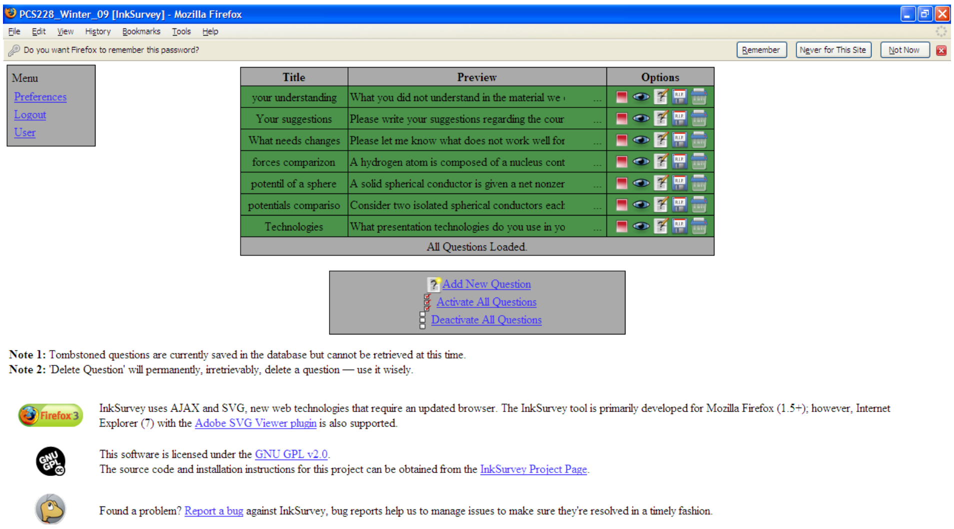


Figure 2: Instructor's page view in InkSurvey.

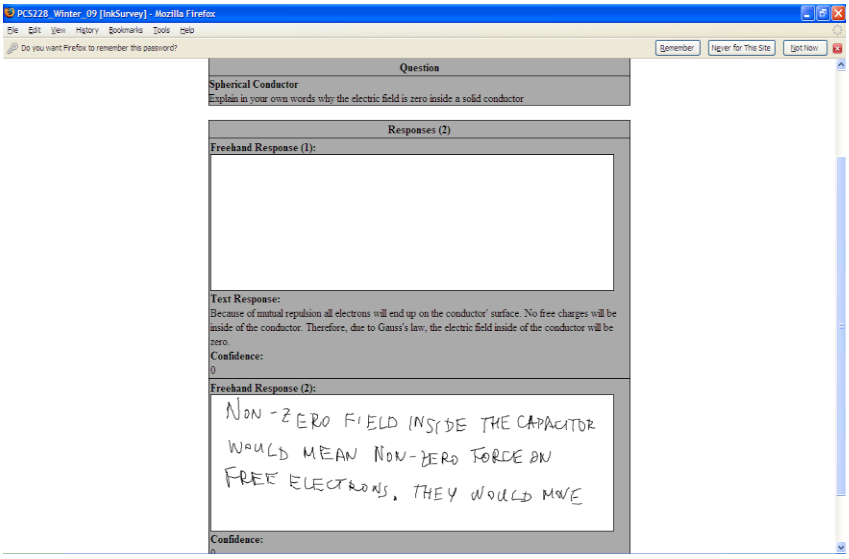


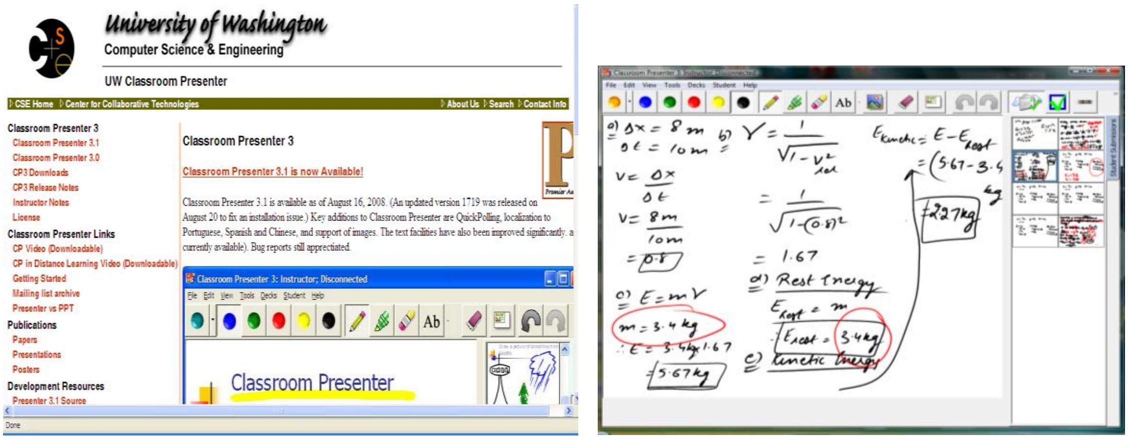
Figure 3: Example of freehand and typed responses: instructors view in InkSurvey.

It is important to emphasize that the advantages of using tablets computers extend beyond their use by 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. The Classroom Presenter software [14] 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 students' responses. Student group work on collaborative problem solving was greatly enhanced by the use of inking technology. The students submitted their work in open-ended format and received instant feedback on their progress. The lecture notes were prepared in advance, and included pictures, diagrams, graphs, internet links, etc.

In both courses during the tablet-based activities, each pair of students was provided with a tablet during the class time (Fig. 2). 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 various 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 each class the students had an option to save their versions of the annotated lecture notes on their personal memory sticks or to e-mail their annotated document to themselves. In addition, the instructor posted her annotated lecture notes on the Course Management System.

Figure 2: Classroom environment for technology-enhanced teaching: movable furniture, noise absorbent ceiling and walls, multiple white and black boards, two computer projectors, a podium and a Smart Board.



(a) (b)

Figure 3: Two screen shot images of: (a) a main page of the Classroom Presenter software. (b) A physics problem solved by the students and presented to the class. The boxes on the right show 8 different solutions to the problem and each one of these solutions can be presented to the class in real time.

The example of problem solved by an instructor with notes added by the student is shown at Fig. 4.

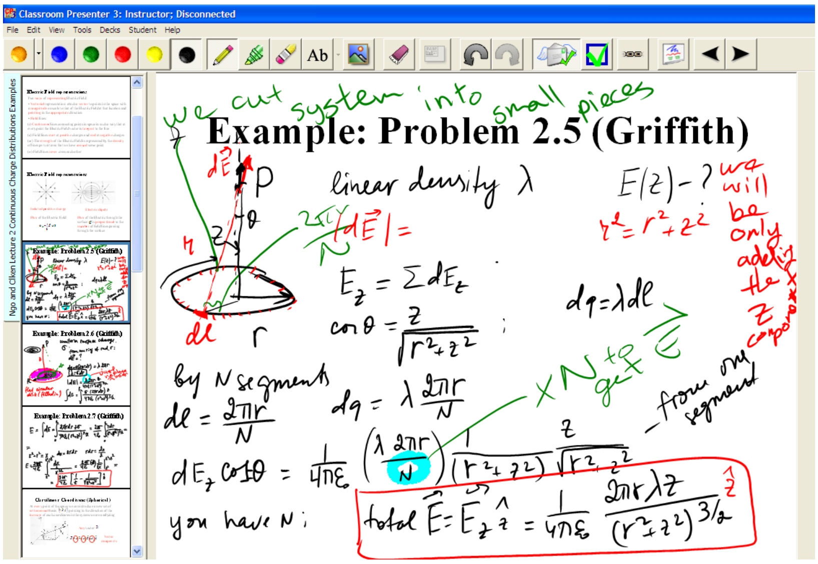


Figure 4: A screen shot image of a student computer screen: a problem solved by the instructor in front of the class, and annotated by the student on his tablet.

2.4 Tablet Driven Mini-Lessons: Students Teaching Students

Camtasia Studio software [15] that allows capturing screen activity, is particularly valuable with the tablet technology, since it can capture the writing and the problem solving process. In the fall of 2009 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. The 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. We were very encouraged by the student feedback, and we will expand this project to target several more known students' misconceptions in introductory physics. 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.

2.5 Impact on Students and Instructors

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 experienced 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 (5/10 of them attributed tablet's effectiveness to the extensive use of simulations); 6/10 students noted the problems with the pointer since during the first few weeks of the implementation the students were not provided with the mouse and were asked to use a pen instead**;** 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-type scale ranging from 1 – strongly disagree to 3 or 5 – strongly agree, as indicated above.

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

Open-ended students' interview questions in *Electricity and Magnetism* prompted a variety of responses that were classified into different categories.

When asked about the benefits and drawbacks of using tablets, the students produced the following answers (Table 2):

Table 2: The results of the student interviews in the *Electricity and Magnetism* Course. The students were asked to describe advantages and disadvantages of using tablets in physics courses.

Advantages of using tablets	**Disadvantages of using tablets and student suggestions**
Fast/saves time (2/15) Can be used for demos and simulations (2/15) Can do research (internet) on the spot (5/15) Can ask questions and submit answers on the spot (2/15) Interactive (2/15) Learn to use technology (1/15) Has educational potential (1/15) Easy to manage info/notes (4/15).	**Distractions:** Surfing internet for other than educational purposes, e-mail, Facebook, etc. **Suggestions:** Many students suggested limiting the access to the internet or to the educational websites only. Several students also mentioned that the tablets were not exploited in our classes to their full potential and suggested having more tablet-enhanced activities. For example, they pointed out that Classroom Presenter enhanced the effectiveness of the problem solving activities.

Here are some excerpts from the students' interviews.

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

It is worthwhile mentioning that the retention in both classes was excellent (no-one dropped either course, and none of the students failed either course). However, we do not have enough evidence to attribute it specifically to the use of tablets. More likely explanation might be student-centered classroom environment and healthy student-professor relationships. As these data demonstrate, the majority of the students believe that the use of tablets enhanced their learning. They also recommended using tablets more in this course as well as in other science and mathematics courses.

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 even fewer own tablets. The access to cutting-edge technology was exciting for them. Secondly, having access to online resources and computer simulations in class made a difference. It allowed the students to experience hands-on science in a very abstract context (special relativity, modern physics, electricity and magnetism), rather than learn everything from a lecture. Thirdly, the students learned to annotate lectures effectively and get more out of them. This, in our view, encouraged lecture attendance. Both the student-instructor and student-student communication has increased. The focus of our classes shifted from us (the instructors) to the students who were quite excited to use new technology in class. The students were very active and 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 are at ease with technology and often would give us hints how to use particular features we were less familiar with. They became very active and felt like co-creators of the *Electricity and Magnetism* course. They also appreciated that their opinion and expertise mattered. Toward the end of the semester we had quite a few discussions of how the tablets can be used more efficiently and effectively in our classes. Students' suggestions from both informal class discussions and formal research interviews include but not limited to: 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 so that the students cannot check sites not related to course work. Interestingly, one of the 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".

As it was mentioned before, two instructors and one technical support staff member were involved in the Project. In addition, 37 members of the Ryerson teaching community were introduced to the technology at a hands-on interactive workshop on tablet computers' use in science teaching during the 2009 Ryerson Faculty Conference in May 2009 [23]. We believe that the impact on us, instructors, is profound. The use of tablets enhances our teaching by promoting more interactive and dynamic teachers' behavior. It promotes spontaneity and allows the presenter to move away from static, almost completely pre-arranged notes and improvise quite a lot instead. 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. 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: "The project has a profound effect on my own teaching. I feel that tablet technology addresses the need for more interactive lectures, as compared to a standard PowerPoint. I still deliver my PowerPoint lectures format (through Classroom Presenter), but the presentations have become much more interactive as a result of using tablets. 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 particularly challenging concepts which are quite numerous in Electromagnetism. 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."

2.6 Second Year of Implementation and Future Plans

We continue using tablets in our second year *Modern Physics* and third year *Electricity and Magnetism* courses in which the tablets were piloted during the 2008-2009 school year. In addition, the tablets will be used in a new Spectroscopy lab for a second year course in Optics and Photonics.

We are also expanding the use of tablets beyond the Medical Physics Program and science students. In the winter 2010 the tablets will be used for Video-Based Motion analysis laboratory in the first

Mechanics course for engineering students. The students will be able to utilize the inking capabilities by writing their answers into pre-prepared laboratory assignments templates.

2.7 Lessons Learned and Suggestions

One important lesson we learned while implementing our project is the realization of the fact that the 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 [24, 25]. In order to utilize particular technology to the fullest, the instructors should practice before using it in a real classroom, because it is difficult 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 our exploration and utilization of the tablet capabilities in a more efficient manner was our participation in the HP Worldwide Summit (in La Jolla, California, February, 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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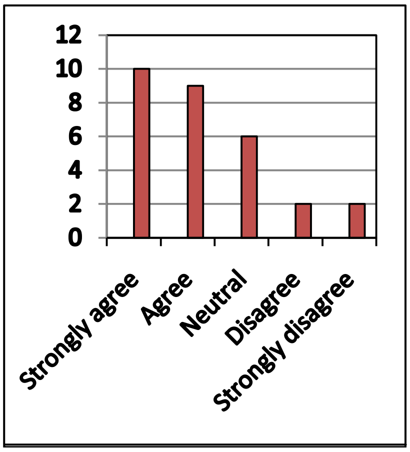
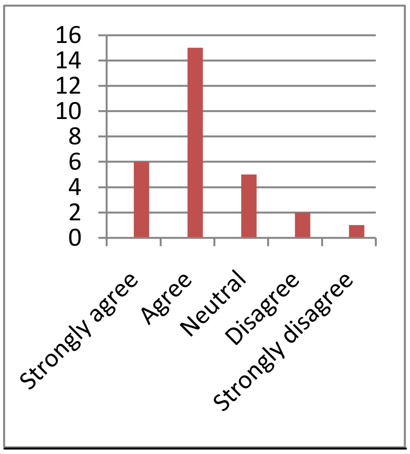
Appendix: Results of the Survey on the Use of Tablets in Upper-Level Physics Courses

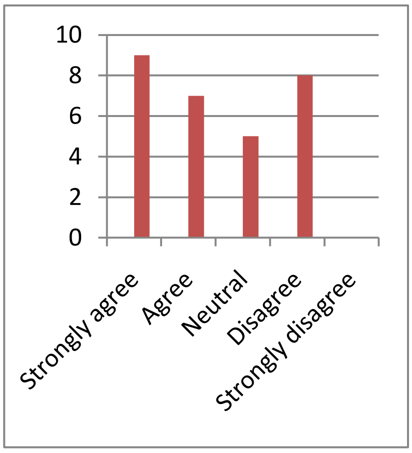
1. The use of tablet PC in class supported/enhanced my learning.



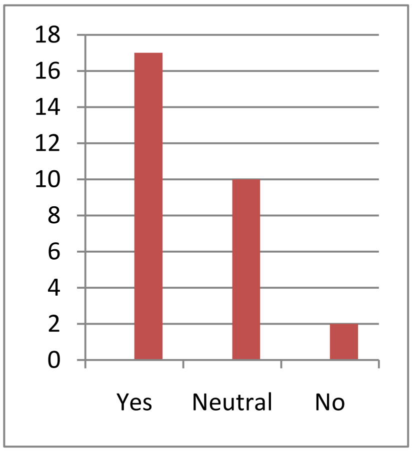
2. The use of tablet PC by the lecturer helped me actively engage with learning in the class.



3. The lecturer's use of tablet PCs in conjunction with clickers provided me with feedback on my progress.



4. Would you want to use tablets/laptops more in this course?



5. Would you recommend using tablet PCs or/and laptops in your other courses?