
AC 2011-1073: ENGAGING CSULA ENGINEERING STUDENTS IN BIOMEDICAL ENGINEERING LEARNING ACTIVITIES WITH THE TABLET PC

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Introduction

Biomedical engineering (BME) has been a burgeoning field for decades now, but at California State University, Los Angeles (CSULA), the seeds are just now being planted for BME to take root on the campus and grow into a full-fledged curriculum and degree-offering program. Two new courses were introduced in 2009 into the Electrical and Computer Engineering Department program, one of which was entitled Introduction to Biomedical Instrumentation. A handful of students have also started to be involved in some BME research projects. As CSULA begins to develop this BME program, we have aimed to make the limited opportunities available to our students in BME thus far as enriching as possible.

Over the past year, we have exploited the unique user interface of the HP Tablet PC to restructure the teaching / student learning paradigm in the Biomedical Instrumentation course and to involve students in a biomedical engineering research project. Our objectives were to engage students in learning BME course material by incorporating a technological gadget which students find fun and interesting in and of itself, provide an avenue for interaction with the teacher and other students, and aid instruction by allowing for an engaging method for on-the-spot assessment and feedback. More specifically, we used the HP Tablet PC in achieving the following aims:

- 1) Create interactive in-class exercises which increase class participation
- 2) Improve learning assessment by monitoring student work in class
- 3) Enhance student learning by providing immediate feedback
- 4) Encourage collaborative thinking among students on class projects

The Tablet PC has features which we expected would encourage active learning [1]. The Tablet PC has been used in classrooms and laboratories to engage students in learning subjects ranging from physics, chemistry, mathematics, and engineering disciplines such as chemical engineering and mechanical engineering [2-6]. It has even been employed in the clinical setting to aid technicians efficiently manage data in maintenance of hospital equipment [7]. However, to our knowledge Tablet PC-based instruction has not been implemented in biomedical engineering courses. We employed the Tablet PC to create biomedical engineering courses which are instructor-driven but yet relies fundamentally on active learning elements [8].

Implementation of Tablet PC-Based Learning Activities in Biomedical Instrumentation

We implemented a new teaching strategy to achieve our aims using the Tablet PC, in conjunction with DyKnow classroom management software. The Hewlett Packard (HP) Tablet PC is designed to act as a digital form of a writing tablet. It accepts touchscreen input from a stylus so that the user can write on the screen as though using “digital ink”. The monitor swivels and can be laid flat to make writing on it feel more like writing on a paper tablet. The low profile of the Tablet makes it easy to outfit a whole classroom with these very portable PCs. A software suite made by DyKnow provides classroom management and interactive teaching tools that are well-suited for interactive learning activities on the Tablet PC.

The class was provided with 30 Tablet PCs and a DyKnow software site license. Each of the 21 students in the class was assigned one Tablet PC along with a user ID to use during the class

period throughout the quarter. The students were not allowed to take the tablets out of the classroom, but they could download software to view DyKnow lectures on their personal computers.

In this paper, we present our approach to creating a more engaging Biomedical Instrumentation class through the use of various Tablet PC and DyKnow software features, and the faculty instructor's view on the benefits of incorporating this computer technology into the class. The Tablet PC is compared with two of the most commonly used media for engineering classroom lectures today: 1) dry-erase / white board and 2) digital slideshow presentations (e.g., Microsoft PowerPoint presentations). Survey results reveal the students' perspective on the use of the Tablet PC and DyKnow in this class.

DyKnow Tools Employed on the TabletPC in the Biomedical Instrumentation Classroom

The use of Tablet PCs and DyKnow software in the Biomedical Instrumentation course provided a technology-savvy way to make lectures more interactive and dynamic. For example, live illustrations of circuits during class made lectures more dynamic; polls and student submission of answers during class provided the instructor with a means of assessing student understanding; the "share control" tool, which gives any specified students capability to make live markings visible to everyone in the session, engaged the students in a more participatory classroom setting. In-class exercises were developed which gave students more opportunities to think about device design on their own and to demonstrate as well as further their understanding. For example, students completed block diagrams and schematics of certain biomedical devices in real-time during class. Lectures were re-created in DyKnow and then made accessible online after class, so that students could review lecture notes and follow the thought process in real-time. DyKnow also readily enabled collaboration in class, as it allows groups to be created in which students can view and work on a common screen which appears on each of their own displays.

Inking

Biomedical Instrumentation combines two disciplines, engineering and medicine, that are best taught through equations, images, and technical diagrams that cannot be created as easily with

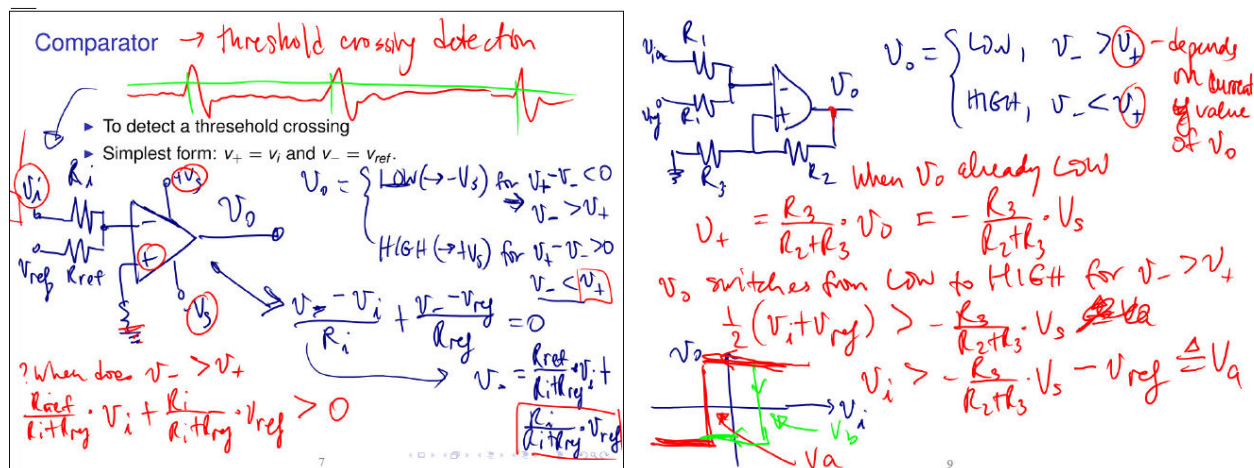


Figure 1) Example of the use of the digital ink feature: A comparator circuit with noise margins was illustrated as a method for detecting neural action potentials. A couple slides on the design of the circuit are displayed here.

traditional forms of digital media as with the Tablet PC's inking capability. A Tablet PC user can write and draw on the screen utilizing the attached stylus and digital ink feature with almost limitless flexibility. A variety of colors, highlighters, and line thicknesses can be selected to create text and figures digitally and in real-time. This allowed for equations to be easily written and technical diagrams sketched easily in real-time for students to process the information as the instructor was writing and drawing.

For example, a Schmitt trigger circuit to detect neural action potentials was explained with circuit diagrams, a sample neural signal diagram, derivation of equations step by step, and the hysteretic transfer curve (Fig. 1). The explanation was aided by use of colors, ability to draw in real-time, and ability for students to review the whole derivation later on their own.

Overlay

The digital ink can be used on clean digital sheets (or panels) as described above, or to annotate and overlay other markings on a digital image. Students in Biomedical Instrumentation typically cannot observe actual physiological signals that are monitored in the clinic or laboratory, see all the biomedical devices they will learn about, or look inside the human body to observe how the devices interact with human physiology. However, with digital media, the instructor can help students visualize all these things. The Tablet PC allowed the instructor to add markings on a digital image of the relevant human anatomy or biomedical device, for example, to help explain the operation or mechanism of some biomedical technology. One such example is shown in Fig. 2a. Images of different types of bioelectrical signals that are used in medicine for diagnosis or in biomedical engineering for the development of medical technology were prepared on a panel before the class period. During the class, the instructor could ask the students if they knew what the acronyms represented and the type of tissue that generated these types of signals. Then, the instructor could dynamically write the answers as students correctly identified them. The instructor also used the overlay feature to overview the operation of a deep brain stimulation device (Fig. 2b) and illustrate the different phases of the neural action potential (Fig. 2c).

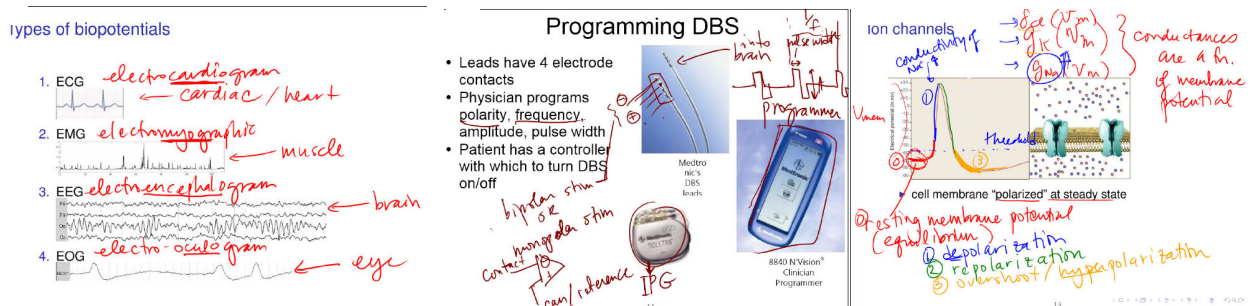


Figure 2) The ability to overlay digital ink on prepared slides with biomedical engineering related images aids the explanation of (a) various types of bioelectrical signals, (b) the basic operation of a deep brain stimulation system, and (c) the process of generating a neural action potential.

Share Control

Normally, the students' monitors display what ever appears on the instructor's panels. However, the instructor can grant to any selected student or set of students control over what appears on

everyone else's monitors. The shared control can be turned on or off at any time. The instructor found the Share Control feature in DyKnow a particularly useful tool to effectively engage students in the class and allow them to demonstrate their knowledge and understanding of the course material. Once concepts were explained to students, the instructor would share control of the display with a student to work through an example.

For instance, after a lecture on neuromotor prostheses, the instructor asked a student volunteer to sketch a block diagram of a closed-loop brain-machine interface (BMI) for a paralyzed patient (Fig. 3a). The student could stay relaxed in his seat, rather than coming up to the front of the classroom, while drawing his block diagram and simultaneously explaining it to the class. He captured the major concepts, as seen in the top portion of Fig. 3a. The instructor then drew what she explained was her idea of a more conventional block diagram representing the BMI that he had just described. All students could see this being drawn in real-time, and the volunteer also had both his own drawing and the instructor's in a digital form that he could save and review outside of class.

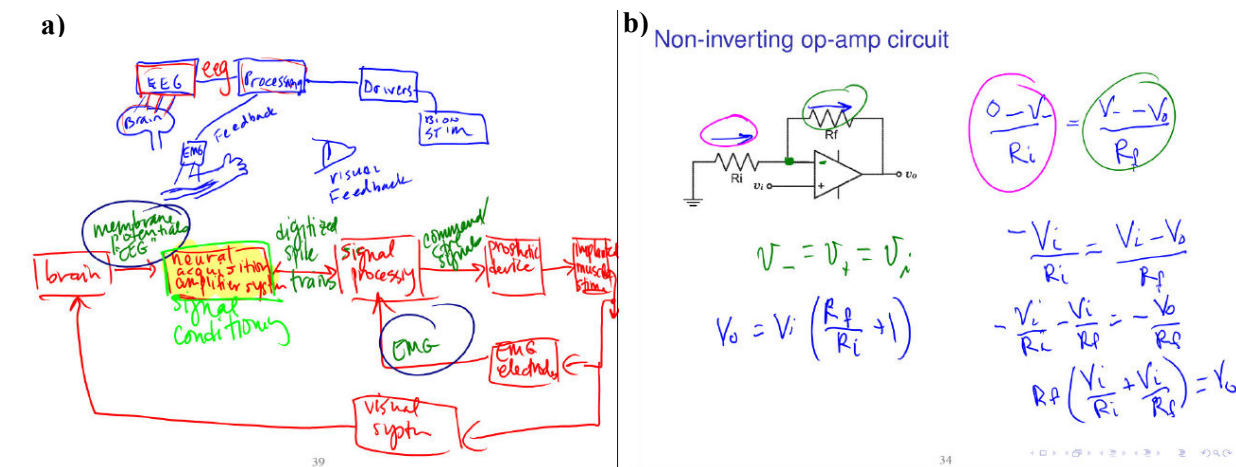


Figure 3) Two examples of using the share control feature: (a) Block diagram of a neuromotor prosthesis with closed-loop control as drawn by a student volunteer (top) and by instructor to provide some feedback to the students. (b) Student's derivation of the transfer function of an op-amp circuit.

In another class spent looking at signal conditioning circuits for neural signal acquisition, basic op-amp circuits were reviewed. After teaching students how to derive the transfer functions for an op-amp circuit, a student was asked to use the same technique to derive the transfer function for the depicted non-inverting op-amp circuit (Fig. 3 b). The student had some difficulty starting the derivation, so the instructor started him off with the fundamental step of setting $v_- = v_+ = v_i$. The student then completed the derivation very well on his own and even did a nice job of using some color to clarify the steps he took.

Manage Groups

The students completed a research project at the end of the quarter on one of the biomedical devices they learned about in class; they were asked to propose some improvement to the present technology and show the hypothetical design of the improved device. Students worked in groups of 3, and the instructor gave them some time in class to work together in their groups using the group management capability in DyKnow. This feature was not exploited as much as it might

have been appropriate to do, but one example of its utility is shown in Fig. 4. The instructor assigned students in a project group to a group in DyKnow. Then all students in the same group could see a common display on which any of the students in that group could mark or to which they could add images/objects. In the example shown, one student uploaded a figure he had created to a blank panel. The other group partners could easily view this figure on their own screens concurrently and add some of their comments and edits to the figure and could feed off each other's input.

Polling

The instructor can send multiple choice questions to appear on all students' screens, and students anonymously submit their responses. Results can then be compiled and displayed immediately following collection of anonymous student responses in a bar graph or pie chart (Fig. 5). Multiple choice polls were a way to quickly assess students' prior knowledge of a topic or acquisition of knowledge after a lecture on a given topic. The instructor used the polling feature primarily as a way of getting students participating in class, especially at the beginning of class when students were just settling into class and changing modes from a commute or previous class into "biomedical instrumentation mode".

Submit panels

Students are also able to overlay their own work on top of digital images/diagrams prepared ahead of time by the instructor and then submit their work to the instructor to save to a file. This capability provided a useful assessment tool. The instructor created some in-class exercises that tested their comprehension of material recently covered without worrying about the cost of resources and time in printing copies of the exercises and the worry of losing information and clarity when printing color images in black and white. Two examples of in-class exercises completed and submitted by students are shown in Fig. 6. The first tested their retention of a circuit model of the electrophysiological characteristics of neuron's membrane (Fig 6a). The second shows a schematic diagram of a cochlear implant on which the student had to label the different components of the prosthetic device. Grading by the instructor is shown in green marks; this marked panel was returned to the student in the following class period.

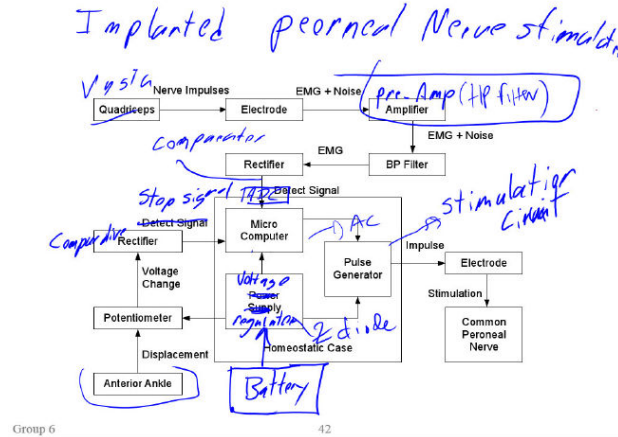


Figure 4) Members of the same final project group could view and mark on the same panel simultaneously from their own Tablet PCs.

Signal conditioning

signal conditioning

- Signal conditioning involves
 - A) using transducers to prepare the brain for electrical recording
 - B) image processing tools to refine data extracted from the body
 - C) microprocessors, large amounts of RAM, wireless transmission, and displays
 - D) amplifiers, analog filters, multiplexors, and A/D converters
 - E) microprocessors, A/D converters, multiplexors, and serial communication
 - F) opamps, power supplies, fiber optic cables, and transformers

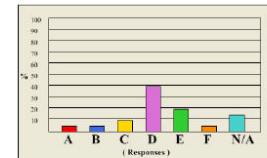
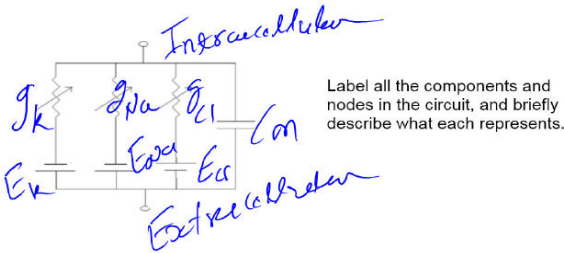


Figure 5) A multiple choice poll was launched at the beginning of lecture to review a topic briefly covered at the end of the previous lecture. This provided a way to ease students into the class period and a quick assessment indicating to the instructor that more time needed to be spent on explaining signal conditioning.

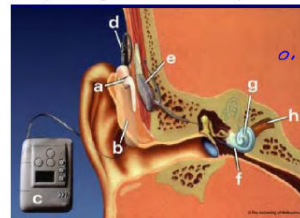
a) What does this "leaky integrator" circuit model?



b)

1. Identify the components in this system diagram of the cochlear implant. Choices are:

- b • decoder
- h • hearing nerve ✓
- a • microphone ✓
- F • cochlea ✓
- C • speech processor ✓
- E • transducer
- d • transmitter ✓
- g • electrodes ✓



3/4

Figure 6) Students completed in-class exercises prepared ahead of time by instructor on (a) the leaky integrator model of a neural membrane’s electrical properties and (b) the parts of a cochlear implant. Students submitted their work online and the instructor returned the panels after marking them.

Educational Value Added

With inking and overlay, the lectures were made more dynamic. Inking has similarities to writing on a dry erase board but with the key advantage of being able to save lecture material for students to review offline. It also solved practical problems such as marker odor and markers that frequently run out of ink. PowerPoint allows custom animations, but programming the presentation to reveal different text, figures, and objects at different times is a time-consuming task that can be easily carried out in real-time in a DyKnow presentation. Furthermore, running through slides and custom animations often does not leave students enough time to process the information. Table 1 outlines the advantages the instructor subjectively found Tablet PC-based DyKnow presentations had over traditional usage of the dry-erase board and PowerPoint slide presentations.

The instructor found the Tablet PC to help make the class more interactive and engage students better. The main disadvantage to using the Tablet PC was the overhead in time to distribute and boot up PCs and log into DyKnow sessions. Occasionally a slow or dropped internet connection disrupted the class and students had to wait to see what the instructor had written or even had to reboot machines in the middle of class. The Tablet PC had the potential to pose a distraction to students, since they could browse the internet or use other computer applications if the instructor did not block these applications. However, the instructor found that the students were engaged in Tablet PC-based active learning components enough that they stayed focus on learning in class.

Feature	Primary Educational Value Added
Inking	Enables dynamic lectures
Overlay	Facilitates labeling and annotating of diagrams
Share Control	Engages students; an interactive mode of student participation
Submit Panels	Provides a resource-efficient method of in-class assessment
Polling	Eases students into class participation in an interactive way and allows instructor to gauge overall class competency on a particular topic or question
Manage Groups	Encourages group collaboration
Digital storage	Allows students to review lectures offline

Table 1) Tablet PC/DyKnow features that the instructor found to add value to student education.

The Tablet PC was already adopted in another biomedical engineering course entitled Neural Computation. The overlay feature was particularly useful in BME courses. For example, the Tablet PC enabled the students to visualize how different components fit together or interfaced with the body without the difficulty of sketching complex biomedical devices or accurate depictions of physiological signals and the like. Application of the other Tablet PC features could also be usefully extended to other Engineering courses. In particular, Share Control was very effective for inviting student participation and giving them opportunities for hands on practice with engineering problems, such as solving and deriving equations, while receiving feedback from the instructor, and would be a very suitable tool for many Engineering courses at CSULA ranging from Circuit Analysis to Digital Engineering.

Survey Results

On the last day of the quarter, students were asked to complete a survey. The survey had 4 sections: Section 1 asked for demographic information and what features were used in the class. In Section 2 and 3, students were asked, on a scale of 1 to 5, to indicate how strongly they agreed or disagreed with a number of statements, which are shown in the first column of Table 2. Section 4 provided space for students to provide additional comments, such as which activities worked well and which did not.

	A) Biomedical Instrumentation	B) Neural Computation
Helped me better communicate and collaborate with my classmates	3.92	4.11
Resulted in more rapid feedback from my instructor	4.50	4.00
Helped me gather background information on course material better	4.25	4.33
Helped me learn better overall	4.00	4.33
Helped me better organize my thinking about course materials	4.08	4.22
Helped me gain better hands-on design skills	4.17	3.78
Made class more interactive	4.33	4.22
Helped the instructor to present the course material	4.25	4.22
Made the class more engaged	3.92	4.33
Made the instruction more effective	4.08	4.33
Made the note-taking more effective	3.75	4.22
Was a distraction for the class	3.25	4.78

Table 2) Column (A) Average scores from 12 of 19 surveys for Biomedical Instrumentation. The other 7 surveys were dropped because of contradictions in results most likely due to misinterpretation of the rating scale. (B) Average scores from all 9 surveys taken in Neural Computation. In all columns, **1 = Strongly Disagree; 2 = Disagree; 3 = Neutral; 4 = Agree; 5 = Strongly Agree.**

Surveys were completed by 19 of 21 students. The survey results provided very useful feedback regarding the students' perspective on the incorporation of the Tablet PC in the Biomedical Instrumentation class. In retrospect, the investigators realized a design flaw in their survey: "1" represented "strongly agree" whereas "5" represented "strongly disagree", which proved to be counterintuitive. The instructor neglected to remind the students to make themselves aware of which end of the scale represented "strongly agree" and which "strongly disagree". In reviewing the survey results, contradictions between comments and ratings indicated quite obviously that some students had reversed the scale. For example, some students gave positive comments but then gave all ratings of "5" or "4" except on "Was a distraction for the class"; a couple students commented that activities that worked well were discussion and interaction but then gave a score of "5" or "4" for "Made class more interactive" and "Helped me better communicate and collaborate with my classmates" but did not have any comments for activities that did not work well; a couple others commented that note-taking worked well but gave a "5" or "4" to "Made the note-taking more effective" and did not have any comments for activities that did not work well. Therefore, first all scores were completely reversed, so that "1" corresponded to "Strongly disagree" and 5 "Strongly Agree". Then each survey was carefully inspected and if contradictions were found, that survey was removed from the data. The averages of data in the remaining 12 surveys are shown in Fig. 7. The average scores of 12 out of 19 received surveys are reported in Table 2, Column A. The 7 dropped surveys were ones for which the investigators are confident that students had reversed the scale, as evidenced by contradictions in their responses.

To lend credence to these results, average scores are also shown for a class entitled Neural Computation (Table 2, Column B). Neural Computation was taught by the same instructor, and Tablet PC use was implemented similarly as in Biomedical Instrumentation. All the same features were used in both classes with the exception of using the online chat feature once in Neural Computation. The only other considerable differences between use of the Tablet PC in Neural Computation and Biomedical Instrumentation were: 1) Neural Computation was the second time the instructor had implemented Tablet PC use in her classroom, and was slightly more adept at using the features, perhaps explaining the slightly more positive scores in Neural Computation in general. 2) Biomedical Instrumentation was more of a design class, and thus, the Share Control feature was used much more than in Neural Computation to have students do design problem; this is consistent with the higher score on "Helped me gain better hands-on design skills" in Biomedical Instrumentation. 3) The instructor did not return any graded/marked submitted panels in Neural Computation, which may explain the lower score on "Resulted in more rapid feedback from my instructor" in Neural Computation.

The bar graph in Fig. 7 shows the average of scores from data set A; i.e., across 12 scores for each question. (Again, note that to display the results so that it is more intuitive for the reader to interpret, all the data was re-interpreted to make "5" be the most positive end of the scale, i.e. "Strongly Agree", and "1" the most negative, i.e. "Strongly Disagree"). According to these averages, students appeared to generally agree that using the Tablet PCs enhanced their educational experience. In particular, average ratings of 4.50, 4.33, 4.25, and 4.00 out of 5 indicate that students found use of the Tablet PCs to generally aid with gaining feedback from the instructor, make the class more interactive, help the instructor to present the course material, and learn better overall, respectively. However, there was a slight tendency for the students to

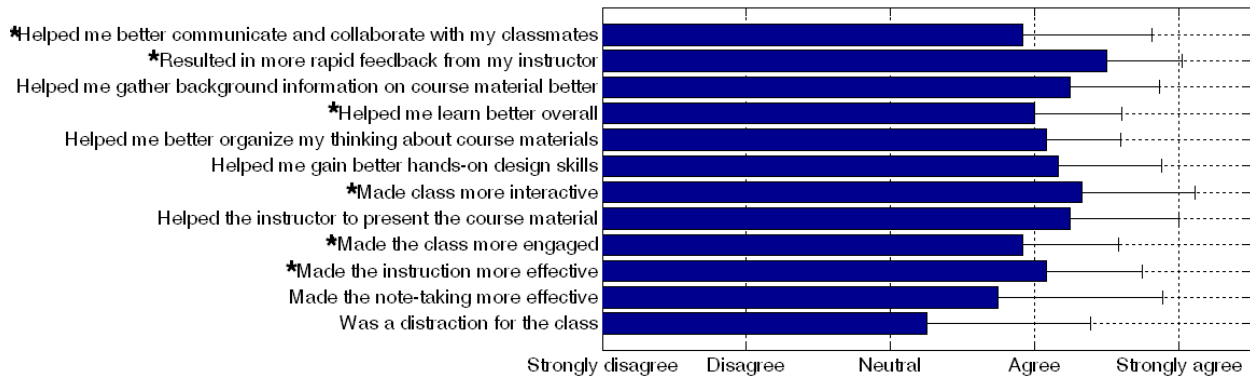


Figure 7) Average ratings (bar) + 1 standard error (stem) from student surveys. Students were asked to rate how much they agreed that the use of Tablet PCs in the Biomedical Instrumentation course benefited the class. The phrases along the vertical axis completed the statement “The use of Tablet PCs” The statements of particular relevance to the aims of this paper are highlighted by asterisk.

find the Tablet PCs distracting, and we would also like to find ways to help students collaborate more with classmates. Note-taking was the feature about which students showed the most ambivalence.

Student Comments

Eleven surveys had comments, most of which indicated that the students found using the Tablet PCs an enriching experience. Students commented that use of the Tablet PC was “a great experience”, “awesome”, and “very impressive, and that “Tablet PCs are compact, easy to use and rich with features”

Other positive comments indicating that students found incorporation of the Tablet PCs enhanced their learning and made the class more interactive included:

- Using the tablet PC ... made the class more exciting and interactive.
- Very effective! My professor tried to use all the features! very impressive, very effective in teaching for professor and learning for students.
- DyKnow gave us the chance to have interactive sessions with our instructor and enabled us to submit online quizzes, assignments and poll questions.
- Instant (pre-prepared) quizzes were interesting. It was nice to be able to go back and review notes.
- Overall, I really liked the Tablet PC. I thought it was a good learning tool for engineering courses.

Problems reported in the surveys mostly were related to slow or dropped internet connection. This is a university infrastructure problem that could be readily resolved by installing wired Ethernet connections to each tablet pc station in the tablet PC classroom. The only other negative comments included the long overhead time in getting the Tablet PCs in and out of the locked cabinet and one comment related to a hardware problem specific to one particular PC.

In class, what worked well using Tablet PC (projects, discussion, note-taking, etc.)?		In class, what did not work well using Tablet PC?	
Activities listed	# responses	Activities listed	# responses
Note-taking	10	Note-taking	3
Discussion	8	Discussion	1
Survey/prepared quizzes	2	Take-home activity	1
Lecture	2		
In-class exercise	1		
Collaborative work	1		

Table 3) Distribution of students who found various Tablet PC activities worthwhile.

Conclusions

We utilized several of the features of the Tablet PC along with supporting classroom management software called DyKnow including: the “digital-ink” input via the stylus; the swiveling display which could be written and drawn on just like a writing tablet; its portability; the capability to allow students’ work be displayed to the whole class in real-time and for the instructor to simultaneously mark on the screen; and the ability to submit and return digital panels. Incorporating use of these tools in the Biomedical Instrumentation class allowed us to achieve our aims, particularly of improving in-class assessment and feedback and creating an interactive classroom. Based on both student survey results and the instructor’s own perspective, DyKnow and the Tablet PCs could be better employed to encourage collaboration amongst classmates. The most prominent drawbacks of using the Tablet PC were the distraction it could present in the classroom and disruptions due to slow or dropped internet connections. Overall, incorporating the Tablet PC into classroom activities has enhanced student learning by increasing in-class interaction and engagement of students in their own learning.

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