Lessons Learned When Gathering Real-Time Formative Assessment in the University Classroom Using Tablet PCs

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Abstract - **Worldwide, higher education instructors are exploring ways of enhancing classroom learning experiences with their Tablet PC-equipped students. To collect real-time formative assessment, instructors pose an open-format question to the class and the students utilize the digital ink of Tablet PCs to respond with answers in the form of handwriting, diagrams, graphs, equations, proofs, etc. Instructors receive the responses instantaneously. Built on principles well-grounded in educational research, this not only actively engages the students in their learning, but also increases student metacognition and provides valuable real-time formative assessment to guide the instructor. Several types of software are readily available both commercially and for free to facilitate this classroom exchange. This paper transcends the specifics of various types of software and discusses the experiences of instructors as they mesh their use of this technology-enabled feedback with the delivery of their undergraduate courses. The lessons presented here are drawn from our own experiences as well as input from instructors at other institutions on four continents, received by their voluntary completion of a written survey (n=19).**

Index Terms–active learning, real-time formative assessment, student feedback, Tablet PCs.

INTRODUCTION

At institutions of higher education around the world, engineering instructors are exploring ways to enhance classroom learning experiences by using Tablet PCs. In fact, a recent analysis of the relevant literature [1] found research-based support for the use of Tablet PCs to promote all seven of Chickering and Gamson's principles of good practice in undergraduate education [2]. One of the most intriguing of these explorations is the use of this technology to collect real-time formative assessment from students. In this teaching model, an instructor poses an open-format question in class. Students equipped with Tablet PCs use digital ink to prepare responses (words, equations, diagrams, graphs, etc.) and transmit them to the instructor, who receives these responses instantaneously. Built on principles well-grounded in educational research [3], this not only actively engages the students in their learning, but also increases student metacognition and provides valuable real-time formative assessment to guide the instructor [2]. As student understandings and misconceptions are revealed, the instructor can use class time to effectively correct and refine those understandings.

There are a variety of tools available to facilitate this exchange between instructor and students; some are free and others are available commercially. In STEM classrooms, *DyKnow* [4], [5] and *Classroom Presenter/Ubiquitous Presenter* [6], [7] have been effectively used to promote active learning and metacognition through real-time formative assessment. For illustration, Figure 1 shows an instructor screen as student responses are received via another robust tool: *InkSurvey*, free software that was developed at Colorado School of Mines specifically for gathering real-time formative assessments from engineering students [8]. Since it is entirely web-based, it is platform independent; it has been tested successfully with input submitted by over 60 Tablet PCs in a classroom. The comments in this paper, however, are not specific to any one software package.

This teaching model is suitable for individual or collaborative work. One of its great strengths is the instructor's ability to pose open-format (as opposed to multiple-choice) questions to better probe student understanding [9].

It is not the intent of this paper to present convincing data that this teaching model is effective, nor to summarize the emerging body of research-based evidence supporting its use, nor to compare the merits and shortcomings of various software products available for its implementation. Rather, this paper's compilation of lessons learned will serve those who are weighing the advantages and disadvantages of implementing this active learning model in their own undergraduate engineering classes, as well as those who have already decided to utilize this technology in their classes but would like to benefit from the experiences of others who are exploring the potential presented by this teaching model.

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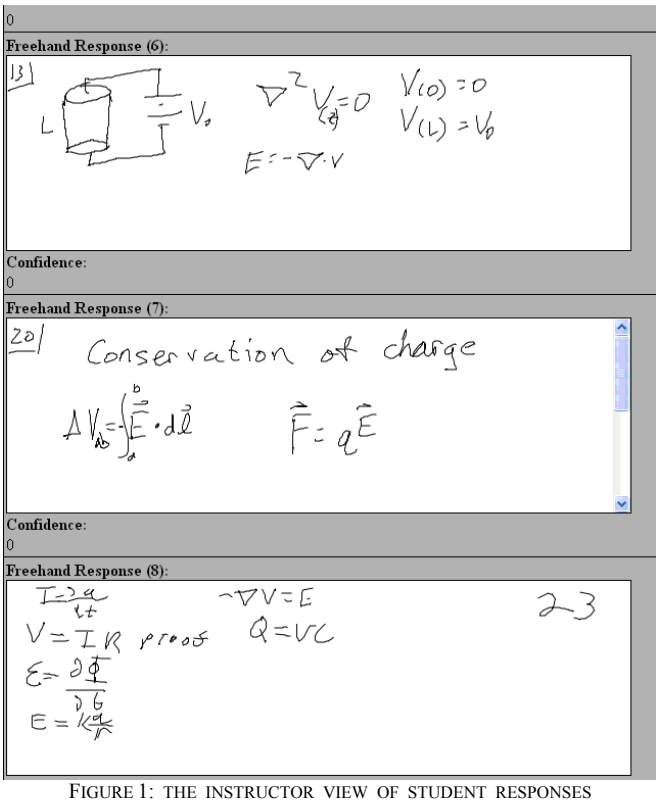

FIGURE 1: THE INSTRUCTOR VIEW OF STUDENT RESPONSES

SURVEY RESULTS

During the winter of 2009, we distributed a survey to university educators around the world who are using or have used Tablet PCs to collect real-time formative assessment from their students. In all, we received 19 responses from four continents, including instructors of chemical engineering/chemistry, computer science/engineering, food chemistry, electrical engineering, engineering design, engineering physics/physics, engineering statistics, mathematics, and marketing. Not all respondents answered every question on the survey. The majority of those responding used *InkSurvey* or *DyKnow*, but others used *Classroom Presenter* and *Ubiquitous Presenter*. The average length of experience with this teaching model was just over 4 semesters. Most respondents used this teaching model at least once a week, some at every class meeting.

The survey consisted of several parts. The first section asked instructors to evaluate their experiences using a Likert scale (4=strongly agree, 1=strongly disagree). The results appear in Table 1.

This data displays clear favorable trends in the thinking of the respondents, regardless of course content and software used. Perhaps this is not surprising, since this use of technology to enhance learning is an extension into practice of educational theory and research. It is, however, reassuring that the survey respondents unanimously confirmed the positive impacts in their classrooms. We acknowledge that completion of this survey was voluntary, and it is possible that those who had experiences and conclusions inconsistent with this group may have chosen not to respond. Nevertheless, it is clear that there is emerging a group of educators who have had very positive experiences when using this model to enhance learning in their classrooms.

It is noteworthy that the statement that generated the strongest agreement among the respondents was the second, indicating that instructors feel this teaching model engages their students in a manner previously unmatched. This is particularly significant since active learning is sometimes difficult to implement in engineering classrooms with larger enrollments [10]. Here, we are looking at technology that engages learners, shown to work effectively with class sizes exceeding 60 students [9].

The statement that generated the most disagreement was the fifth, addressing the use of class time. In the accompanying responses to open-ended questions (see below), some survey respondents indicated that they could not cover as much material when this model was used. Still, an even greater number felt that they were actually using class time more efficiently when they used this model, since they could focus on identifying and modifying student misconceptions rather than belaboring concepts already mastered by the students.

The second section of the survey probed the respondents for additional insights by using open-format questions. In speaking with others who have adopted this teaching model, we consistently hear them claim, "This (model) has changed my teaching!" Therefore, one of the survey questions specifically asked how instructors felt their teaching had been altered as a result of this teaching model. The responses to this question indeed reflect that fundamental changes in teaching have occurred among the respondents, based on four main (albeit somewhat overlapping) trends.

1. Changes in the Use of Class Time

Many of the educators spoke of how this teaching model transformed how they spend the precious minutes of class time, as shown by these responses:

"My class time has completely changed. There is constant conversation, collaboration, and engagement during the lecture time….I actually had a student say 'aha!' last week."

"I direct my teaching more toward what the students don't understand. I also spend more time on problem-solving techniques that are more generic than the course content."

2. Pre- and Post-Teaching Changes

With such significant revisions in how class time is spent, it is not surprising that this teaching model also changes the way instructors prepare themselves for class. One respondent explained it this way:

TABLE 1. SURVEY RESULTS

Survey Statement	SA	A	D	SD	Average response
Using Tablet PCs to gather real-time feedback has changed my teaching.	79%	21%			3.78
When I use Tablet PCs to gather real-time feedback in my class, I feel my students are more engaged in their learning.	86%	14%			3.86
When I use Tablet PCs in this manner, I feel I am more aware of the misconceptions of my students at a time when I can more effectively help them revise their understanding.	72%	28%			3.71
When I use the Tablet PCs in this manner, I feel my students are more aware of their misconceptions about the course material.	64%	36%			3.64
When I use the Tablet PCs in this manner, I feel I am able to make better use of class time.	64%	22%	14%		3.5
When I use the Tablet PCs in this manner, I feel my students are better grasping main concepts of the course.	57%	43%			3.57
Compared with other innovations I have made in my teaching, I feel that using Tablet PCs in this manner has improved the learning that is occurring in my class.	57%	43%			3.57

Percentages have been rounded to nearest whole percentage.
Key: SA= strongly agree, A=agree, D=disagree, SD=strongly disagree.

"Preparing the formative assessment questions also means I prepare my lectures more carefully now, paying more attention to student understanding."

Furthermore, many of the survey respondents felt that the use of Tablet PCs to collect real-time formative assessment as they teach a topic has led to more fundamental shifts in their evaluation of learning that occurs. For example:

"I now look for deep rather than surface learning."

3. Changes in Student/Teacher Interactions

A large majority of the respondents welcomed the increased interaction with their students and the active learning that occurred in their classrooms.

"Teaching does not mean passive delivery of course content anymore. With this…teaching has become more dynamic, more interactive. My students are now more engaged in the learning process."

Other comments noted better attendance and "tremendously" better classroom dynamics.

4. Changes That Better Align Practices with Theories

It is worth noting that many respondents, without explicitly couching their ideas in terms of learning theory or educational psychology, indicated that when they use Tablet PCs to garner real-time formative assessment, their teaching is better aligned with what we know about how people learn. This is certainly buttressed by the previous three trends, but a distinct acknowledgment of constructivist learning theories and the importance of metacognition are revealed in comments such as:

"I am able to easily draw out and work with the preexisting understanding students bring with them. This is extremely important since students' initial conceptions provide the foundation on which more formal understanding of the subject matter is built."

"The frequent, formative assessments help make students' thinking visible to themselves, their peers, and me. Therefore, everyone can provide feedback that can guide modification/refinement in others' thinking."

With such positive comments from instructors, one next wonders how the students feel about this teaching model. Adjectives most often used to describe students in targeted classrooms include engaged, interested, awake, and attentive. About half the respondents generalized their students' reactions as being very positive, citing enjoyment with using the Tablet PCs (the "cool factor") and a belief among students that this technology helps in their learning, particularly of difficult concepts. Some indicated that their students were obviously appreciative of this teaching model and one reported that students are now usually waiting outside the classroom before class begins and are reluctant to leave when it is over. The other half of the respondents felt that although the overall reaction of students was positive, some students are less enthusiastic and find the technology frustrating or distracting. Several instructors in the latter group felt that student attitudes improved as the instructors improved their own fluency in using this technology in their classroom. One instructor noted that although students enjoy the interaction, they seem to worry about submitting incorrect answers, even though they know that incorrect answers will not hurt their grade.

In the survey, M. Aguilar-Cornejo, M. Castro-García, and G. Román-Alonso, instructors at Universidad Autónoma Metropolitana-Iztapalapa, Mexico, noted that their students usually go through three stages in their attitudes toward this use of technology to enhance their learning. At first, they are excited. Next, they enter a phase of adaptation in which they are somewhat discouraged as they overcome some of the technological hurdles of efficiently using Tablet PCs. Finally, they master the technology and then again have both more enthusiasm for this teaching model and more progress in learning.

Another survey question assessed which students the instructors felt benefitted most from this teaching model. There was widespread agreement that this teaching model could enhance learning for nearly all students, across wide ranges of learner types and abilities. A few, however, singled out specific elements of their student populations that they feel are particularly well served. A. French of Albion College (MI) reflected this when he pointed to the quiet, shy student who is uncertain, and unwilling to publically respond to a question, but will respond on the Tablet PC. When the instructor then shows this response to the class (anonymously), this encourages and engages that student. The outgoing/dominant, confident students can no longer dominate the class with their answers. In a similar vein, an electrical engineering instructor noted that in a traditional classroom setting, educationally disadvantaged students are reluctant to raise questions or respond to the instructor's questions, since they are not confident. With this teaching model, they are more open to asking questions without the fear of being put on the spot. Again, with more interaction with the instructor, the students are more engaged in learning and can gain better understanding of the course material. Finally, another instructor believes that it may be the best students who benefit the most from this teaching model, since she can go into more depth in some topics than she otherwise could, and hence these students remain interested where they might otherwise get bored.

ADDITIONAL LESSONS LEARNED

Although it is not the intent of this paper to present research-based evidence of the effectiveness of this teaching model, we offer the results in Table 1 as a convincing argument that using Tablet PCs to collect real-time formative assessments via digital ink has matured to the point that its pedagogical potential is becoming a reality. However, as with any new tool we place in our teaching toolbox, there are some obstacles instructors must overcome before they can fluently integrate this use of technology into the delivery of their courses. Based on our own experiences as well as comments provide by the survey respondents, we are aware of some common pitfalls as instructors first explore the use of this teaching model in their classrooms. These fall into three broad categories:

1. Asking the wrong type of question

In order to effectively reveal student misconceptions using this teaching model, it is essential that the formative assessment questions posed be well-constructed and thought-provoking. If they are targeting learning too low on the scale of Bloom's taxonomy, for example, they will not adequately probe student understanding of complex engineering concepts and the responses will not provide very rich insight into what is going on in the students' minds. Likewise, if the questions are too difficult, the instructor may be faced with very few responses and will again learn little.

Another common pitfall is asking questions that require too long to solve. For example, if it takes twenty minutes before any students submit real-time data when the instructor poses a complex problem, they may have spent a long time going down the wrong path in terms of solving the problem. Other students may sit there for the entire twenty minutes, unable to figure out how to proceed. Most instructors find this teaching model is more useful when they ask for short answers that reveal student misconceptions at various critical points along the journey to the successful solution of the problem. In this way, students can be guided in making the final leaps of interconnecting necessary principles and concepts. Having thus figured things out for themselves (with guidance), they are more likely to learn how to solve the problem than if they are just told.

2. Asking the wrong number of questions

It is sometimes a fine art to know how many questions to pose to the students when using this teaching model. If too many questions are asked, there is a danger that this becomes nothing more than a tedious exercise. If too few questions are asked, the bridge from one question to another may be too great for the students to maintain interest or to follow the intervening discussion. Fortunately, with practice and an awareness of this pitfall, the instructor can use the real-time feedback itself to gauge how often to pose a question to the class, based on the class population and the difficulty of the concepts involved.

3. Not accounting for individual differences among students

The larger the class enrollment, the greater the chances for significant diversity among the students in terms of work speed, academic abilities, facility at grasping new concepts, etc. Likewise, the more probing the question posed, the greater the chances that it will require a broader range of response times for the students. These inherent aspects of this teaching model have clear implications in terms of student behavior: students who quickly finish submitting their responses have in their hands a tool that provides the incredible temptation of easy access to computer games and to the internet. Although these temptations can be highly controlled and filtered through the technology itself, some do not choose to restrict their students in this way. Instead,

they provide differentiated learning experiences that acknowledge the diversity among their students. One way to do this is to allow students to be able to choose from a sequential menu of questions to answer. For example, when using *InkSurvey*, one question that we always have available for the students to select is: do you have any questions? In this way, if a student is floundering at the beginning of problem, they can anonymously submit a question to the instructor. The instructor can then verbally offer some guidance to align the student's thinking with the principles and concepts that will lead to the successful solution of the problem. Similarly, we use a menu of questions to keep the faster workers engaged. As the instructor sees that some students have successfully submitted solutions to the question posed, he/she can make available additional questions to guide students in further explorations or applications of the concept. Students who are working more slowly may never tackle the enrichment questions. Offering these differentiated learning opportunities allows the instructor to better meet the needs of the individual students and greatly decreases off-task activities on the part of the students.

CONCLUSIONS

The use of Tablet PCs to collect real-time formative assessment from students is becoming more common in engineering classrooms around the world. Survey results indicate a high level of instructor and student satisfaction with this method of enhancing learning, particularly after a period of gaining proficiency with this technology. In hopes of shortening the length of this learning period for instructors wanting to adopt this teaching model, we have compiled some specific suggestions and described common pitfalls to avoid.

ACKNOWLEDGMENT

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