AC 2012-3403: DOES THE USE OF CLICKERS INCREASE CONCEPTUAL UNDERSTANDING IN THE ENGINEERING ECONOMY CLASSROOM?

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Does the Use of Clickers Increase Conceptual Understanding in the Engineering Economy Classroom?

Abstract

Response devices or "clickers" are seeing increased use in many engineering classrooms. These devices allow students to anonymously respond to a question posed by the instructor and then compare their response to the rest of the class. They are an active learning tool that can be used to increase student engagement in the classroom and assist both students and instructors in assessing what students know and don't know. But do they increase conceptual understanding of course concepts (that is, do they improve learning)? This paper reports on an experiment in which several sections of an engineering economy course at the University of Pittsburgh are compared. Each section was taught by the same instructor, who used the same lecture notes, homework, quizzes, projects and so forth. The only difference was the use of clickers in the classroom in the experimental section. To assess learning, an engineering economics concept inventory was given to all students in all sections of the course both at the beginning (pre) and end of the semester (post). While a gain in the average concept inventory score is certainly expected in any section of the course, this paper reports on whether a larger gain is seen in the experimental section (using clickers). In addition, the evaluation of teaching survey is also used to determine if other differences are apparent between the sections. Findings in this study are consistent with the literature. That is, that the use of clickers in the engineering economy classroom can improve the learning environment and student perceptions of learning and do not negatively impact learning outcomes.

Introduction – "Why Clickers?"

"Audience response systems" (ARSs), "Classroom Response Systems", "Response Devices" or more simply, "Clickers" that allow students to actively engage in the teaching/learning process are seeing increased use in many engineering classrooms. With these small hand-held devices, students can electronically and anonymously submit an answer to a multiple choice question posed by the instructor and displayed to the class. The instructor is then able to gauge how students are doing with respect to particular course concepts or simply gather general information about the class. The students are able to compare their responses with the class and assess their own understanding.

There has been a quite a bit of research on the use of clickers in higher education and while some may argue that the use of this type of technology results in more "entertainment" than in increasing learning, many improvements to the classroom environment, learning, and assessment have been identified and reported. Kay and LeSage did a review of 67 peer-reviewed papers related to the benefits and challenges associated with ARSs.[1] They found that while much of the research has focused on issues such as whether clickers increase student attendance, attention levels, and engagement in the classroom many studies have also looked at learning benefits including whether student performance has increased. Other research focuses on assessment, both formative and comparative. Calwell[2] also completed an extensive review of the literature and concluded that ARSs do enhance students' participation, active learning, and enjoyment of classes and will have either a neutral or positive effect on learning outcomes depending on whether they are combined with other kinds of cooperative learning. In addition, she found that clickers can help to promote student accountability and make it easier for instructors and students to receive quick feedback on teaching and learning effectiveness. These reviews as well as an earlier one by Fies and Marshall[3] concluded that more rigorous, systematic research may be needed and studies need to be done in a broader range on contexts. And, in fact, other studies are continuing to be done in a broad range of educational areas[4-6]. Many of these studies have concluded that the clickers can positively impact the learning environment (increased student engagement, motivation, positive perceptions of the classroom, and so forth) and will have either no impact on or will increase learning outcomes.

Recent research has been done in engineering education as well. Chen, et. al.[7] focused on the use of clickers for rapid feedback to students (in foundation engineering courses) on their understanding of key concepts and skills. They found a significant and positive effect when students received feedback using clickers. Fang[8] found a statistically significant correlation between student clicker performance and exam performance in an Engineering Dynamics course and that students are satisfied with clickers in their learning environment. In comparing different multiple choice question assessment delivery methods (including clickers, WebCT, and pen and paper), Chan, et al.[9] found that students in an electrical engineering course ranked clickers as their first choice and that they are effective for fostering peer interaction, student-teaching interaction and self-learning.

There have also been papers presented at previous American Society for Engineering Education conferences. In a 2011 paper, based on a literature review and experience with their use, Nicholls, et. al.[10] also found clickers to be effective for increasing student engagement in the classroom, although they noted that they do tend to slow the pace of the class. Hung[11] reported on the use of clickers to administer quizzes in an introductory manufacturing course and noted that while there were implementation difficulties (as always with a new teaching technology), students reported positive attitudes towards the clickers and quiz results were encouraging when compared to data for classes not using the clickers. Papers at the 2010 conference[12, 13] also reported on the effectiveness of clickers for the classroom environment and no change in learning outcomes.

This paper reports on a study specifically aimed at the use of clickers in an Engineering Economy course in the Industrial Engineering Department at the University of Pittsburgh. The purpose of the study was to determine if the use of the clickers contributed to improvements in conceptual learning and go beyond reporting anecdotal evidence or evidence of only improvements in the classroom environment (which have been shown in much of the research discussed above); that is, did the clickers improve learning in the Engineering Economy classroom?

Methodology – Comparing Engineering Economy classes taught with and without clickers

Three sections of an introductory engineering economy course taught in the Swanson School of Engineering at the University of Pittsburgh were compared. All sections were taught by the same instructor, introduced the same course material, and students were given the same homework assignments, quizzes, and exams. Clickers were introduced in the experimental section but not in the two comparison sections. The experimental section (fall, 2011) consisted of 67 industrial engineering students and while comparison section A (fall, 2010) also consisted of only industrial engineering students (61 students enrolled), comparison section B (fall, 2011) consisted of 69 students that were primarily civil engineers but also included students from mechanical, computer, and electrical engineering. In addition, while both the experimental and comparison section A were taught in two one hour and fifteen minute lectures per week, comparison section B was taught in one two and a half hour lecture per week. The experimental section and comparison section B were taught in the same semester and used the same textbook.

In order to assess learning, all students enrolled in the course completed pre- and post-concept inventories. In all cases students were given the concept inventory during the first class session (pre) and then again during the last week of the course (post). We have previously used this and other concepts inventories and have been able to compute effect sizes for different courses and modes of instruction.[14, 15] The concept inventory consists of 10 questions which are a mix of multiple choice and short answer questions. These questions cover various topics in the course including: the time value of money, cost estimation, comparing alternative investments, benefit-cost ratios, consideration of all relevant criteria, and dealing with uncertainty. Questions are worth five points each for a total possible score of 50 points. The grading was done by the same research assistant for both the pre and the post concept inventories. The score on the pre concept inventory is not included in the student course grade; however the post concept inventory is given as a "quiz" and students are given an automatic 10/10 for that quiz if their score improves from the pre. This method was used to minimize student absenteeism on the last day of class and increase student effort on the inventory.

In the experimental section of the course, the instructor required all students to purchase the "ResponseCard RF LCD" from Turning Technologies. The software is integrated with Microsoft PowerPoint and therefore the instructor was easily able to integrate new multiple choice questions into previously developed PowerPoint lecture notes. In the early part of the course, the instructor used the clickers to review quiz questions immediately after the quizzes were given, and then beginning with the 5th chapter of the course material, questions were integrated into the PowerPoint lecture notes. Figure 1 shows some examples of the kinds of questions that were used.

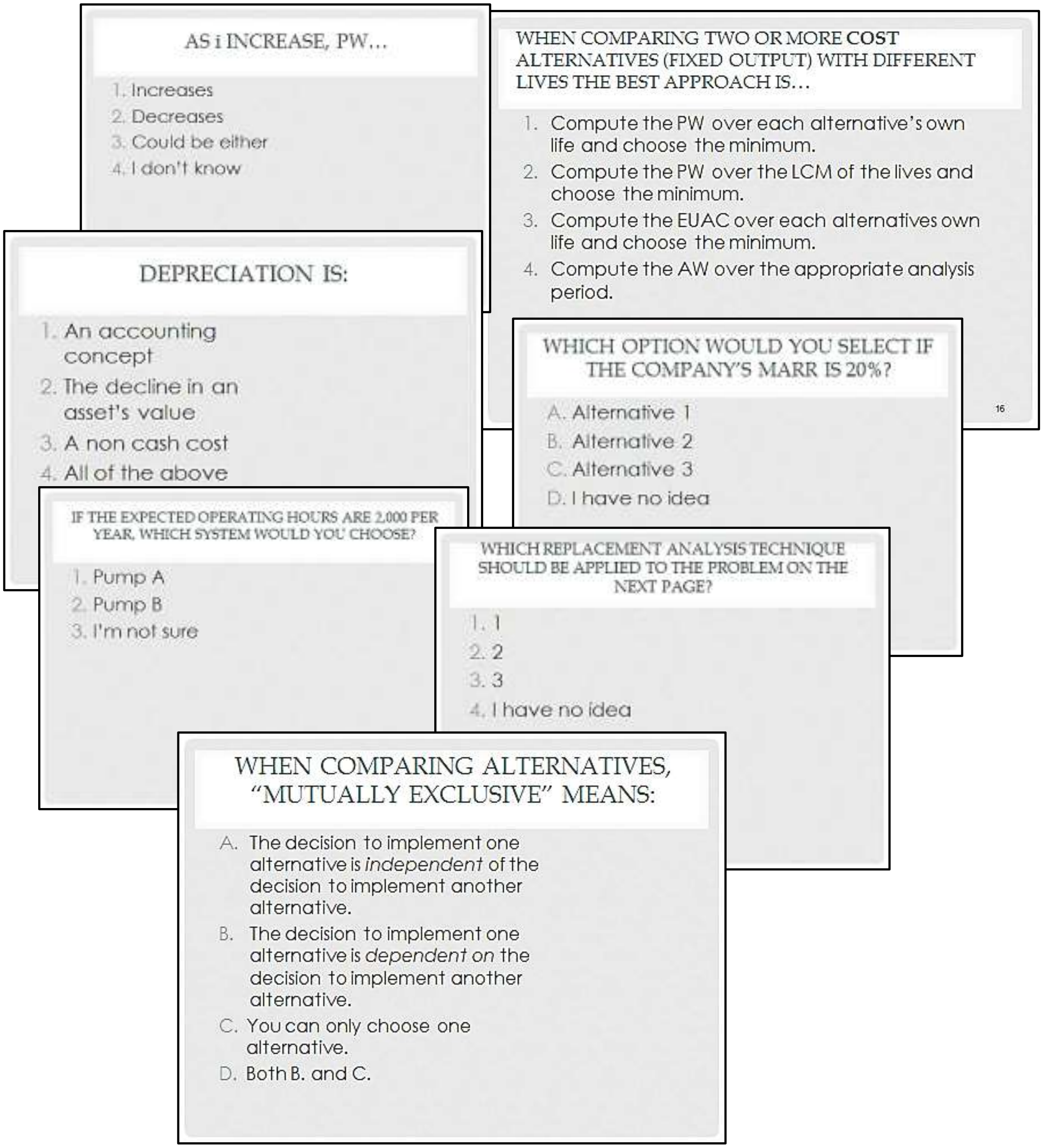

Figure 1 – Examples of clicker questions used in the Engineering Economy course

Results and Discussion – Were the clickers effective?

Table 1 provides the average and standard deviation of concept inventory scores, sample sizes, as well as the Cohen's d[16] effect size for each section of the course.

Table 1 – Results of Concept Inventories

		Experimental Section	Comparison Section A	Comparison Section B
Pre	Mean	24.39	19.32	23.13
	Std. Dev.	5.73	6.82	6.81
	Sample Size	66	60	67
Post	Mean	39.33	37.61	34.13
	Std. Dev.	4.53	7.14	6.23
	Sample Size	66	56	63
Effect Size		2.91	2.64	1.70

There is a clear statistical difference (*p*-value = 0) between the start and end of term mean concept inventory scores for all three sections of the course. This is not an unexpected result since the concept inventory is aimed at material covered in the course. Of more interest is whether the effect in the experimental section (with clickers) is larger than for the comparison sections. As can be seen, while the effect sizes are large for all three sections, both the Experimental and Comparison Section A have similarly larger effect sizes than Comparison Section B. This is an indication that there is some other factor influencing the learning in the course. This is quite possibly attributed to either the difference in the structure of the course – one day per week for Section B versus two days per week for Section A and the Experimental Section – or in the student populations – mix of engineering disciplines for Section B versus primarily IE students for Section A and the Experimental Section. Moreover, while the mean post concept inventory score is higher for the Experimental Section we cannot eliminate other differences in student populations as contributing to this difference (particularly given the significantly lower pre concept inventory score for Section A verses the Experimental Section.)

In addition to analysis of the concept inventory scores for the three sections we have other data available to consider. First, in comparing the in-class exercise scores, we can make a statement regarding whether attendance and engagement in class was affected by the use of the clickers. This is because students typically receive full credit for complete and correct in-class problems but do not receive any credit if they are not present in class and may only receive partial credit if problems are incomplete. Table 2 shows the average score (as a percent of total possible points for in-class problems) for the three sections. There is a significant difference between the results in the Experimental Section and Comparison Section A (p-value=0) as well as between the

Experimental Section and Comparison Section B (p-value = .05). It would therefore appear that the clickers did have a significant impact on attendance and engagement.

Table 2 – In-class exercise scores (%)

	Experimental Section	Comparison Section A	Comparison Section B
Mean	96.34	85.40	92.49
Std. Dev.	8.23	15.67	14.12
n	67	58	69

Another set of data to consider would be the results of the University's teaching evaluations. No significant differences were found on questions related to the instructor; however students also answered two "self-ratings" questions which provided interesting results and a bit of evidence that clickers can improve the classroom environment. The first of these questions asks students to rate the statement "Compared to other courses at the same level, the amount of work I did was" on a scale of 1 to 5 with 1 being "much less" and 5 being "much more". The second question asks for ratings on that same scale to "In this course I have learned". The results of these two questions (displayed in Table 3 for each section) give us further insight into student engagement in the class. Only the difference between the students' perception in what they learned in the Experimental Section verses Comparison Section B is statistically significant (p-value =.01), however the values are all higher for the Experimental Section.

Table 3 – Results from student self-ratings

		Experimental Section	Comparison Section A	Comparison Section B
Amount of Work	Mean	3.27	3.11	3.14
	Std. Dev.	.81	.51	.71
	n	63	38	59
I have learned	Mean	3.75	3.63	3.4
	Std. Dev.	.71	.67	.75
	n	59	38	58

Finally, after the completion of the course and the submission of final grades, students were asked via email to provide some general feedback on the use of the clickers in the engineering economy class. This was done not only for purposes of this study but also because other faculty are now incorporating clickers into their IE courses as well. Some of the feedback received provides further insight into using clickers.

Several students commented that they "*found the clickers to be very helpful*" and "*enjoyed the use*" of them. One student noted, "*I think it's a good way to keep everyone involved so every student feels like their input matters and it allow you to see if the majority of the class got a* *particular question wrong which can help with the class too*." Another noted, "*They are a nice, less stressful way to answer questions during class without being put on the spot, which I feel like a lot of students like.*" At least one student also commented that he felt that "*some students did not take the clicker idea seriously*" and that there should be "*some type of grade attached to the clicker usage*". One particularly strong student noted that:

> *"While the clickers were a good way for you to gauge how the class was doing in terms of people correctly answering sample problems. We almost always received an explanation of the problem, whether or not a large proportion of the class could answer the question. From my experience using clickers in class, it seems that they're a good tool for instructors to gather information about student performance, and to track statistical data for correct answers. From our end as students however, I'm going to do any example problems you give during lecture, and only care whether or not I understand the material enough to get the question right. Therefore, the clicker is just an added step in that process that doesn't influence my paying attention and participation in class."*

Thus it would seem that while the clickers can have an impact on those students who may not always be engaged and participating, stronger students are likely going to participate in any active learning regardless of the method used to facilitate it.

These results are consistent with previously cited studies. Patterson, et. al. concluded that "Although the clickers did not improve learning outcomes as measured by objective testing, perceptions shared by students indicated an increased degree of classroom engagement."[17] Also, while Chen, et. al. used quantitative analysis to provide "evidence for the value of rapid feedback and the currently popular clickers"[18] in foundation engineering courses, they did note that they could not make generalizations about the effectiveness in other learning environments and suggested that further study was worthwhile.

Finally, although it may be clear to any seasoned instructor, it is worth noting that implementing clickers in the classroom is time consuming. The instructor needs to spend time learning the technology and preparing appropriate questions, then planning how to go about incorporating them into the class plan or lecture. The engineering economy course described here required from a ½ to 1 hour per lecture to incorporate the "clicker questions" into previously developed PowerPoint slides.

Obviously, results are going to vary greatly depending on how well the implementation is planned and carried out. In addition, there is the issue of cost. With students typically already spending a great deal on a textbook, requiring them to also purchase a clicker (the model we use runs about $35 if purchased on line from the vendor) is difficult to ask. Our implementation of this technology has been school wide and therefore all classes that are using clickers are using the same model. Thus our students have the opportunity to not only spread this cost over one 15-week course but over their entire undergraduate career…making that extra cost less of a burden.

Conclusions

The findings in this study of the Engineering Economy classroom are consistent with those found by other researcher in various educational areas. The use of clickers can improve the learning environment (attendance, participation, and engagement) as well as improve students' perception about their learning. In addition, while clickers do not necessarily increase conceptual learning, they also do not appear to have negative effects on learning. Implementation is time consuming and often challenging but appears to be worth the effort.

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