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Classroom Questioning with Immediate Electronic Response: Do Clickers Improve Learning?

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ABSTRACT

A number of studies have focused on how students and instructors feel about digital learning technologies. This research is focused on the substantive difference in learning outcomes between traditional classrooms and classrooms using clickers. A randomized block experimental design involving four sections of undergraduate Operations Management classes was used to determine if clicker systems increase student learning of both quantitative and conceptual material in Operations Management. Learning was measured using the difference between the scores on an entrance examination and the final examination. The findings of this research provide evidence that the use of immediate feedback using a technology like clickers can have a positive impact on student learning as measured by test scores.

Subject Areas: Clickers, Digital Classroom Technologies, Immediate Response Systems, Learning Outcomes, Operations Management, and Questioning.

INTRODUCTION

The purpose of this study was to examine the effect on learning outcomes of using clickers in undergraduate Operations Management classes. Rather than examine attitudes of students and faculty about the new technologies, we examined learning outcomes. In short, we sought evidence to assess the difference in learning outcomes, as measured by examinations, covering both conceptual and quantitative material, when using clickers versus not using clickers.

Clickers allow the instructor to poll the class at selected points in time to sample the comprehension of the students and to then adjust the coverage of the topic. The instructor uses the clicker system to gauge comprehension as he or she moves through the material. The clicker system also provides the instructor with immediate summary information by student and by question. Prior research has been published on classroom-teaching technologies and questioning styles. This research quantitatively measured the difference in examination scores between

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clicker-based classes and non–clicker-based classes in a School of Business. The prior research that we cite here is from pedagogy research at the college level and the secondary education levels. The prior research to be discussed in the next section covers digital classroom technologies as well as the nature of questioning in the classroom in general.

PRIOR RESEARCH

Classroom Participation and Feedback

McKeachie (1990) and Smith (1977) found that classroom participation and discussion leads to higher-order learning. Clickers provide a potentially effective way to engage students in participation and discussion. Research conducted by Fassinger (1995) suggests that faculty may play less of a direct role in classroom interaction than one might assume. Student-to-student interaction might play a larger role in participation and learning. In the present study, we found that students using the clicker system became more engaged in the topic as well as in discussions with their peers about questions being posed. Fassinger (1995, p. 25) has observed, "Multiple regression analysis of teachers' responses suggests that class interaction norms, students' preparation, and student-to-student interactions significantly shape class involvement." Clicker systems clearly can be used to increase interaction among students during the class time (Reay, Bao, Li, Warnakulasooriya, & Baugh, 2005). An interesting question, one that motivates the present study, is whether or not these new digital technologies show some evidence of increasing the learning outcomes of the students.

Digital Technologies

Available digital teaching technologies include WebCT, Blackboard, publisher Web sites for online grading, clickers, tablet PCs, podcasting, instant messaging, text messaging by cell phone, Webcams, and more. Each of these technologies provides unique attributes for the learning environment. Certainly ease of use, cost, learning curve, and learning outcomes will differ. Research has shown that engaging the minds of the students during the class time draws the individual student into an active participant role in the learning process (Dufresne, 1996; EDUCASE, 2004; Mazur, 1997; Wenk et al., 1997). Differences across these technologies in the degree of student engagement are likely to exist. Digital technologies seem to improve the outcomes of student learning (Benson et al., 2002).

Kenneth Green, director of the Campus Computing Project, noted that students come to university campuses expecting to learn about, and learn with, technology (Green, 1999, 2000a, 2000b). The Campus Computing Project surveys about 600 2- and 4-year public and private colleges and universities in the United States each year. The Campus Computing Survey focuses on campus planning and policy issues that affect the role of information technology in teaching, learning, and scholarship. Rhee, Verma, Plaschka, and Kickul (2006) studied the technology readiness of students in e-learning environments. They found that students were overall more likely to place a higher utility on enrolling in e-learning classes where the students were more technology ready. The use of clicker technologies requires very little technology readiness on the part of the student. More technology readiness is required, in our view, on the part of the instructor.

In their latest book, *Revolutionary Wealth*, Alvin and Heidi Toffler (2006) point out that one of the slowest changing components in U.S. society is the educational system. If the United States is going to retain its world economic and social status, it is imperative that the educational system in this country make some significant changes. Finding more effective teaching technologies, for example, methods to provide instantaneous feedback to students, may provide the path to improving the educational process from one of the slowest changing in our society to one of its fastest.

Questioning Paradigms: Sociolinguistic & Process-Product

Carlsen (1991) has identified two paradigms in his research on questioning. The sociolinguistic paradigm of questioning is concerned with the interdependency of language and situation. According to Carlsen (1991), a sociolinguistic approach will emphasize the role of social context in the interpretation of spoken language. The process-product paradigm of questioning research focuses on student outcomes as a function of instructor behaviors.

The Sociolinguistic Paradigm

The sociolinguistic perspective sheds informative light on the process of questioning. "Analysis focuses on three characteristics of questions: context, content, and responses to reactions by speakers" (Carlsen, 1991, p. 157). Carlsen notes that "the meaning of questions is dependent on their context in discourse" (p. 157). The social context, the question content, and the responses to questions all affect the meaning of a question.

If we accept Carlsen's view on classroom questioning, then it seems plausible that the social context of the digital classroom alters the meaning of questions raised in such an environment. The use of immediate feedback systems with the ensuing discussion has the potential to change the meaning of the questions that are proposed to students. The discussion among the students aids in the interpretation of a question. As students explain the question to each other, they also learn about the subject matter. The clicker system provides immediate feedback to the students on their understanding of the question. The clicker systems allow the instructor to monitor the student responses in real time. Because the clicker system affects the classroom dynamic through directly engaging students in the material presented, the meaning of the question to the student becomes a class-time focus. The question takes on a class-time focus because the student knows that the answer and discussion will follow in a minute or two. In traditional paper-based questioning systems, some of the meaning of the question can become lost over the time that it takes to evaluate and return the quiz result to the student.

A key benefit of the social context of the classroom is the ability to engage students in discussions in small groups. "Participation in small-group discussions primes students to be more attentive and involved in subsequent whole-class discussion. In traditional classes, students tend to ignore questions and comments by other students and only pay attention to the instructor; this tendency is reduced or eliminated in CCS-based instruction" (EDUCAUSE, 2004, p. 5).

The Process-Product Paradigm

Carlsen (1991) also examined the conceptual focus of research in the process-product paradigm. "Process-product research conceptualized the four moves—structuring, soliciting, responding, and reacting—as independent and has striven to describe the effects of each on the product variables like student achievement" (p. 160). Structuring has been defined as a process of establishing a context. An example of structuring would be for an instructor to state, "Last time we discussed the economic order quantity model." A soliciting question would be, "Does anyone recall how this model was developed from the total annual cost equation?" A responding move would be when a student responds, "We can derive the EOQ formula from the total cost equation by the calculus." A reacting move on the part of the instructor might be to say, "Yes, that is correct and we utilize the first and second derivatives to arrive at the optimal order quantity under a certain set of assumptions." The clicker technology enables the instructor to capture summary statistics of each of these four moves during the class time rather than sometime after the class had ended.

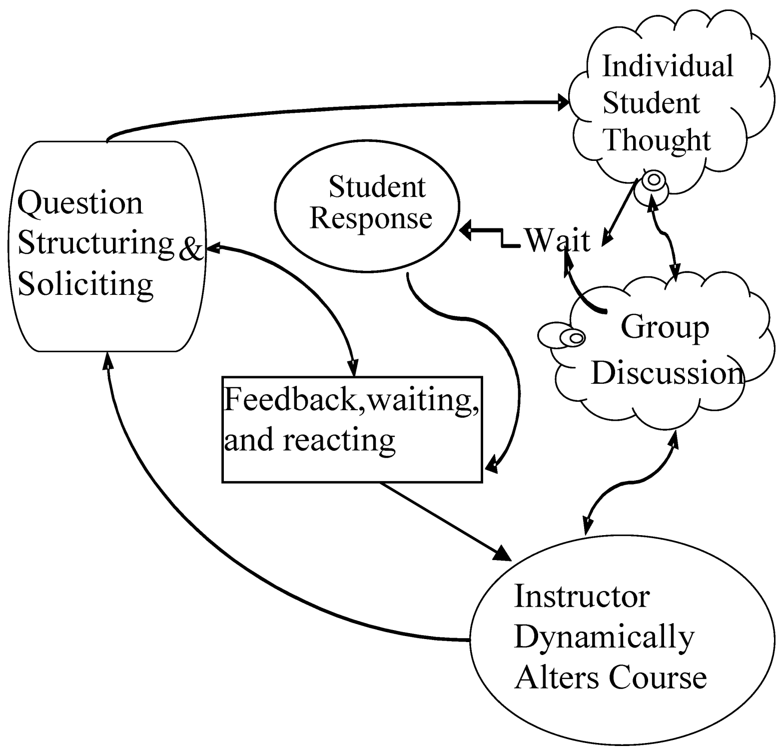
A QUESTIONING MODEL FOR IMMEDIATE FEEDBACK SYSTEMS

The Social Context of the Classroom

We have developed a model of the learning system in the classroom when clickers are used. Figure 1 illustrates the process of questioning when clickers are used in the classroom. The dynamic of the classroom changes when immediate feedback systems such as clickers are used. Figure 1 attempts to describe in a graphical fashion the classroom dynamic that is present with the clicker technology and other technologies that can give immediate feedback to both student and instructor during the class time.

A question is structured and soliciting for responses takes place. The question is displayed on a large screen in the classroom. The instructor structures the questions and solicits answers. The answers are delivered with a handheld clicker device by each student within a set amount of time allotted for the question. Individual student thought may be engaged with group discussion if the instructor wishes to allow that. The individual and the group can shape the individual student response to the question. In light of the student response, the instructor then engages in feedback to the entire class. The feedback can be the correct answer only. The feedback can also be how many in the class selected the correct answer and perhaps other incorrect answers. In a class that is using clickers for questioning, the individual student is also engaged in feedback because each knows during class time whether or not he or she has answered the question correctly. Clearly this could still be accomplished without the use of clickers, albeit at a much slower pace and with more time-consuming data collection across students. The instructor uses the immediate feedback provided by clickers to dynamically alter the class in reaction to the

Figure 1: The context of questioning with immediate feedback systems.



nature and the distribution of answers given by the class. This alteration in the class process can then lead to modifications in the structuring and soliciting of further questions as well as ensuring that the material being presented was understood. The sociolinguistic paradigm suggests that the social context alters the meaning of the questions. Blending the sociolinguistic paradigm and the process-product paradigms suggests that the feedback and reacting phases are affected by the social context as well because the correct answer to the question is given in a feedback discussion with the class during class time. This class-time feedback seems to enhance the cognitive level of the students. The amount of time that elapses in each of the questioning stages also appears to make a difference in student learning. Fine tuning the use of immediate response questioning systems can be done through attention to the wait time involved in the process. Prior research suggests that wait time is a variable that affects student learning.

Wait Time

Tobin (1987) and Rowe (1974) have found that increasing the time between posing a question to a class and responding to answers from the class led to a higher cognitive level of questions formulated by instructors. Tobin (1987, p. 89) concluded, "Wait-time probably affects higher cognitive level achievement directly by providing additional time for student cognitive processing, and indirectly by influencing the quality of instructor and student discourse." Rowe (1974) defined two wait-time periods in the process-product view of questioning. Wait-Time 1 is the time from giving the question to the students until the students respond to the question. Wait-Time 2 is the time from student response to the time at which the instructor begins speaking again. Tobin (1987) and Rowe (1974) both found that increasing instructor wait time from its typical length of less than 1 second to over 3 seconds had a number of significant effects, including (1) a decrease in the amount of instructor talk, (2) fewer student verbal patterns repeated by the instructor, (3) fewer instructor questions, (4) fewer chained questions, (5) fewer low-cognitive-level questions, (6) more high level questions, and (7) more probing questions.

Increasing instructor wait time has also been found to increase student participation during the class time (Honea, 1982; Swift & Gooding, 1983; Tobin, 1986). Honea studied high school students. Swift and Gooding studied middle school science students. Tobin studied students in grades 6 and 7 in mathematics and language arts classes. Even though these researchers were not examining the college classroom, it seems reasonable to propose that the same effect is likely to be taking place in the college classroom. Increasing the instructor wait time is easier to implement when using the clicker system because the classroom focus is not on a particular student-to-instructor interaction. The classroom focus is on the entire class-to-question interaction. The benefits of using clickers in the classroom accrue to the instructor and student.

Potential Benefits to the Instructor

Through the use of clickers, the instructor benefits from the fact that he or she can measure during the class time the degree of learning that is taking place. The instructor also can modify his or her presentation during class time in response to the immediate student feedback from the clicker system. The clicker system provides the instructor with an immediate summary of the class response to a question. "Although lecturing may be efficient, it may not result in effective learning for many students" (Benson et al., 2002, p. 143). Another benefit to the instructor is a reexamination of how we interpret student responses to our questions during class time. With the use of clickers, we can poll the entire class to check on their comprehension of topics and pieces of each topic. We also capture the proportion of the entire class who understands, does not understand, and who is absent from the class responses.

Potential Benefits to the Student

The student appears to benefit through the immediate feedback about the correct answer. A question posed today but with feedback given some days later seems to lose some relevancy in the student's mind. With traditional time-delayed methods of feedback, the thoughts that the student had at the time that the question was first posed may not be as clear or even remembered when the student receives delayed feedback on that same question. With a clicker system, the student knows that the clicker will be used in every class session. That knowledge may lead to students being better prepared for class. The same effect is clearly possible with traditional paper-based quizzes.

HYPOTHESES

The focus of the present study was to measure in a quantitative way the difference in learning outcomes between classes that were taught using clickers and classes that were taught using traditional paper quizzes. The prior research discussed above leads to the following hypothesis to be tested:

> H_1: Students will learn more, as measured by examination scores, using immediate electronic response feedback than those students that receive delayed paper feedback.

Given the general nature of classroom instruction, a question can be raised about the impact of the instructor on student performance, independent of mode of instruction. Thus, we also hypothesize the following:

> H_2: There is no significant difference in effectiveness of the immediate electronic response feedback technique compared to a traditional feedback system, due to the instructor.

METHODOLOGY

The study was conducted as a randomized block experimental design where the manipulated variable is clicker or nonclicker and the blocking variable is instructor. The study, which was conducted during the spring 2006 semester, started with the testing of four sections of undergraduate introductory Operations Management involving a total sample of 190 students. Each of the four class sections was given the same two-part entrance examination over the course material that would be presented during the semester. One part of the entrance examination focused on quantitative knowledge that required some mathematical computations (19 questions). The other part of the entrance examination focused on concepts and definitions (75 questions). The entrance examination was given to all students in the study in traditional paper format.

The examinations were given over two class periods and students had 1 hour and 15 minutes to complete each examination. Students were not given the results of their entrance examination for 2 weeks and were only given their raw scores on both examinations. The examinations were not returned to the students. All questions on both of the entrance examinations were multiple choice and each question had four possible answers. The examinations given to all four sections in the study contained identical questions, but the order was randomized between the sections.

Students in each class section attended classes 2 days a week for 75 minutes during the 16-week semester. Instructor A taught two classes on Monday and Wednesday and Instructor B taught two classes on Tuesday and Thursday. Both A and B used the same textbook, *Operations Management for Competitive Advantage* (11th edition) by Chase, Jacobs, and Aquilano (2006). The two instructors standardized their lecture materials to ensure that the same material was covered each class period in all four class sections. In addition to the entrance examination, during the semester, each of the four classes were given the same midterm and final examinations and 21 multiple-choice quizzes averaging 10 questions per quiz. The final examination was also a two-part paper examination for all four classes. The final examination was a 2-hour in-class examination and was composed of a subset (4 fewer quantitative questions and 11 fewer concept questions for some material that was not covered during the semester) of the same concept and quantitative questions that were given on the entrance examinations, arranged in a different order. The entrance examination had 19 quantitative questions and 75 concept questions. The midterm examination had 15 quantitative questions and 24 concept questions, and the final examination had 15 quantitative questions and 64 concept questions.

The purpose for giving the same final and entrance examinations was to have a benchmark to measure quantitatively student learning within and across each of the four classes. Students were not given back their copy of the entrance examination or told that the final examination would consist of the same questions as were on the entrance examination. Copies of the midterm examination were returned to each student to use for study purposes. The midterm examination contained similar concept and quantitative questions to the entrance examination but with different values and answer choices.

One of A's and one of B's classes took the quizzes using an eInstruction clicker to respond, while their other two sections were given traditional paper quizzes. For both the clicker and traditional classes, each quiz contained 7–14 multiple-choice questions, with the average quiz having 10 questions. The shorter quizzes had more computational questions and the longer quizzes had more conceptual questions.

The clickers were only used for the 21 quizzes and not on the entrance, midterm, or final examinations. The classes were chosen randomly for either clicker or nonclicker technology use. The quizzes accounted for 15% of a student's grade in class. The midterm and final examinations accounted for 65% of a student's grade, and 20% of the student's grade came from written problem assignments. The same written problem assignments were given to both the clicker and traditional sections. The students in both the traditional and clicker classes were told and understood the percentage that their quiz grades contributed to their final grade in the class. In all four sections, the quizzes were given in the last 15–20 minutes of the class period.

How the Clickers Were Utilized

The questions were displayed on an overhead projection screen with typically four possible answers. For each question, the instructor would set a timer in the software to cut off accepting responses from students after a designated period of time. The amount of time remaining on each question was displayed on the projection screen. Also the number of students who have responded at any point in time was also displayed on the projection screen. Students were given 1–3 minutes to answer the question using their clicker. The amount of time was determined by the nature of the question. Some questions were purely definitional, while other questions required computations and table lookups. For questions that required computations, students were given 2–3 minutes depending on the complexity of the computation. For conceptual questions, students were given 1 minute to respond using their clicker. At the end of the allotted time for each question, the number of students who chose each multiple-choice response was shown along with an indication of the correct answer. The software assigns a unique number to each student's clicker and shows when that student has responded to the question. If a significant number of students did not respond with the correct answer, the instructors could then engage the class in a discussion of why the other answers were not correct. To minimize the possibility of sharing of quiz information across the four class sections, two different versions of quiz questions (i.e., the order of the questions were shuffled) were used in the clicker and nonclicker classes. So the questions were the same, but not the order, between the clicker and the nonclicker sections. The amount of time spent discussing an individual quiz question in the clicker sections depended on how many students missed the question and student responses.

How Traditional Classes Operated

Students in the two traditional class sections were given a hard-copy quiz during the last 15–20 minutes of the class period. These students were then able to answer the questions in any order and to allocate their own time to each question. The clicker and traditional sections were always given the same total time to finish a quiz. Even though the traditional classes had 15–20 minutes to answer all the questions, they were not limited to a certain amount of time per question as the clicker classes were. More important, there was no discussion following each question during the class time. The traditional quizzes were machine graded and returned the following week. If a student taking the traditional quiz had a question about an answer to a question on the quiz, it was answered at the time the quizzes were returned.

RESULTS

As previously stated, the major overall hypothesis tested is that Operations Management students will learn more, as measured by examination scores, using electronic classroom feedback than those that receive delayed paper feedback. Several specific analyses were conducted to examine the results on the quizzes, the entrance examination, the midterm examination, and the final examination.

As shown in Table 1, the mean values for the entrance examination score comparisons of clicker versus traditional sections for both Instructors A and B

Table 1: Mean values of entrance examination scores.

	Percentage Points		
	Nonclicker	Clicker	p
Instructor A[a]	33.2	32.2	$<.39$
Instructor B[b]	33.6	34.1	$<.76$

[a]Sample size for nonclicker is 52; sample size for clicker is 46.
[b]Sample size for nonclicker is 45; sample size for clicker is 47.

Table 2: Mean values of midterm and final examination scores.

	Percentage Points		
Examination	Nonclicker	Clicker	p
Midterm examination			
Instructor A[a]	66.7	72.6	$<.03$
Instructor B[b]	74.2	81.0	$<.005$
Final examination			
Instructor A[a]	60.9	64.2	$<.02$
Instructor B[b]	58.3	62.0	$<.06$

[a]Sample size for nonclicker is 52; sample size for clicker is 46.
[b]Sample size for nonclicker is 45; sample size for clicker is 47.

did not differ significantly. Overall, the entrance examination scores for the four classes did not differ ($F = .69$, $p < .56$, $df = 3$).

Analysis is based on two measures. First, mean examination scores for the midterm and final examinations were used to compare mode of instruction effects for each instructor. Second, so-called improvement scores, the difference between entrance examination and final examination scores, are presented for each instructor.

Table 2 shows scores for the two instructors for both the midterm and final examinations. In all cases, scores for the clicker treatment classes were higher than for those where clickers were not used. All of the differences are significant at $p \leq .10$ (one-tailed test). Using raw examination scores as the measure of effect, it appears that H_1, cannot be rejected at $p < .10$ (one-tailed test). Students will learn more, as measured by examination scores, using immediate electronic response feedback than those students that receive delayed paper feedback.

We now turn to improvement in examination scores as the measure of effect. Table 3 shows these results. For both instructors, the clicker-treatment class had a significantly greater increase in examination scores than did the nonclicker class ($p < .10$, one-tailed test). This finding supports the previous finding for H_1 that students will learn more, as measured by examination scores, using immediate electronic response feedback than those students that receive delayed paper feedback.

Table 3: Mean values of differences between final examination and entrance examination scores.

	Percentage Points		
	Nonclicker	Clicker	p
Instructor A[a]	27.6	32.0	$<.008$
Instructor B[b]	24.7	28.0	$<.075$

[a]Sample size for nonclicker is 52; sample size for clicker is 46.
[b] Sample size for nonclicker is 45; sample size for clicker is 47.

The final analysis is that of assessing whether there was a so-called instructor effect. We hypothesized (H_2), the null hypothesis, that there would be no such effect regarding the use of clickers. The measure of effect used is the improvement in examination scores. To assess the existence of such an effect, we looked at the interaction between instructor and feedback system in analysis of variance. The interaction is not significant ($F = .322$, $p < .58$, $df = 1$). Therefore, H_2 cannot be rejected (two-tailed test).

We examined the differences in the quiz scores between the clicker and traditional sections. The null hypothesis was that there was no statistically significant difference in quiz scores ($p < .6$). Therefore, there is no statistically significant difference between the clicker and traditional sections on quiz scores.

DISCUSSION

Our results provide statistically significant evidence that the use of clickers can have an impact on student learning as measured by test scores. The clicker technology itself may not be the reason why learning outcomes were higher with the use of clickers. It may be that other systems that can provide immediate feedback to the student as well as the instructor would provide a statistically significant learning benefit. So, it may not be so much the particular technology but rather the feedback time. We compared only two levels of feedback and did not examine the time dimension closely. Future research on the effect of time itself would provide more insight. Perhaps varying the feedback time from a few minutes to a few hours to a few days would be a worthwhile study. The clicker technology also provides a software record for both the instructor as well as the individual student.

We did not expect to find that quiz scores were higher for one group versus the other. At the point in time at which a quiz was given, both groups had been exposed to the course information in identical ways. There were also more student absences from quizzes than from the entrance, midterm, and final examinations. We did not consider the quizzes to be highly representative of the classes as compared to the examinations. We also allowed students to drop up to three quizzes or simply to pass on taking them.

Even though we found no statistically significant instructor effect, there were some differences between the two instructors. Clearly, personal styles of delivery of identical material as well as experience with the clicker system of questioning can affect the classroom experience. Instructor A had used the clicker system for two semesters and five class sections prior to this study. Instructor B used the system for the first time during this study. The instructors worked closely with each other to remedy any technical problems in the clicker section delivery. Instructor A wrote all clicker and hard-copy quizzes and all examinations for all four sections.

Instructors A and B worked very hard to coordinate their lesson plans, delivery methods, and approach to teaching in the classrooms. A and B had team taught this same course a year earlier, so in addition to the rigorous coordination, they had significant personal experience observing and working with each other.

The findings of this research provide some evidence that the use of immediate feedback using a technology like clickers can have an impact on student learning as measured by test scores. Whether the improvement can be tied directly to the clicker has not been clearly demonstrated. While the material covered in each section was identical, the way the clicker versus nonclicker classes were taught may have been a contributing factor. Both instructors worked very hard to coordinate their lesson plans, delivery methods, and approach to teaching in the classrooms. Every effort was made to ensure that all four class sections covered all material in an identical way with the exception of the quizzing method.

It may be that the results that we found are not related to the specific technology of clickers per se. It may be that other systems that can provide the same amount of feedback in the same class period would work as well. The ability of the students and the instructor to engage in a dialogue around each question seems to be very beneficial. There appears to be much more involvement of the students during the class time.

Future research should explore the use of other technologies in the classroom. Wireless laptops make it possible to access Web-based resources such as electronic grading of quizzes, assignments, and examinations during the class time. Online quizzes, assignments, and examinations are also available. Podcasting is another emerging technology for use during and after class time. Future research on clickers should explore their use in areas outside of introductory Operations Management. Future research into the outcome measures would be very enlightening. Perhaps, as one reviewer suggested, the benefits of using clickers might be stronger in one area such as concept formation versus identification problems. Each one of the digital technologies contributes in a unique way. Future research should investigate each one more closely for differences in learning outcomes.

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