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Effect of personal response systems on student perception and academic performance in courses in a health sciences curriculum

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FitzPatrick KA, Finn KE, Campisi J. Effect of personal response systems on student perception and academic performance in courses in a health sciences curriculum. *Adv Physiol Educ* 35: 280–289, 2011; doi:10.1152/advan.00036.2011.—To increase student engagement, active participation, and performance, personal response systems (clickers) were incorporated into six lecture-based sections of four required courses within the Health Sciences Department major curriculum: freshman-level Anatomy and Physiology I and II, junior-level Exercise Physiology, and senior-level Human Pathophysiology. Clickers were used to gather anonymous student responses to questions posed within the class period after individual thought and peer discussion. Students ($n = 293$, 88% of students completing the courses) completed a perceptual survey on clicker effectiveness inserted into the Student Assessment of Learning Gains online instrument. Across courses and years, students uniformly rated several dimensions of clicker use as providing good to great gain in engaging them in active learning, increasing participation and involvement during class, maintaining attention, applying material immediately, providing feedback concerning their understanding, and offering an anonymous format for participation. Within these four sections, quiz grades were compared between clicker and nonclicker years. Significant increases in pre- and posttest scores were seen in Exercise Physiology in clicker years and on some, but not all material, in Anatomy and Physiology I and II based on content quizzes. Human Pathophysiology results were unexpected, with higher quiz scores in the nonclicker year. The results support the hypothesis of increased engagement with clicker use. The hypothesis of increased student performance was not consistently supported. Increased performance was seen in Exercise Physiology. In Anatomy and Physiology I and II, performance improved on some content quizzes. In Human Pathophysiology, performance did not improve with clickers.

clickers

THE VALUE OF ACTIVE LEARNING in science education has been emphasized by many national organizations (1, 2, 26–29). For some time, instructors in our Health Sciences Department have recognized a lack of student involvement, engagement, and participation in the classroom, particularly in larger classes with beginning students. In response, we have implemented active learning methodologies into our classrooms (8, 15). After a discussion among faculty members from our department and the Chemistry Department, as well as research on personal classroom response systems (clickers), some department faculty members chose to adopt clickers as an additional method to address this deficiency. Clickers provide technology that facilitates student engagement in the classroom through a cycle of interactive activities that includes questions interpolated within the class period, with student responses collected

and displayed, followed by immediate feedback, peer interaction, and group discussion of the results. This approach has been described as the question cycle (3), interactive engagement (17), and peer instruction (11). This study reports assessment results from a common set of survey questions on clickers incorporated into the web-based Student Assessment of Learning Gains [SALG (35, 37)], an instrument with a customizable question template. This instrument emphasizes student perceptions of many dimensions of their learning and emphasizes the usefulness of course activities rather than instructor performance. We report here data from four different courses [Anatomy and Physiology (A+P) I and A+P II, Exercise Physiology, and Human Pathophysiology] over 2 yr. Quiz and exam scores within these courses were also used to compare performance in nonclicker with clicker years.

The clicker methodology described here, in combination with the question cycle, is designed to increase active learning. Bransford et al. (4) specifically addressed the value of new technologies like clickers in facilitating active learning. At this point, a large body of literature has been published on various aspects of clicker use. These include general works on the theory and general techniques of clicker use (3, 5) and review articles covering several clicker studies (7, 14, 20, 23). Many studies have addressed student perceptual responses to clicker use in science courses (12, 22, 25, 31, 32, 34, 38). Other studies use quiz/exam scores to assess the effect of clickers on student performance (6, 9, 10, 16, 18, 19, 21, 30). Few studies have examined both perceptual responses and quiz/exam scores in the same cohort of students or investigated the impact of clickers on different levels of students in the same study.

Reflective teaching, informed by the scholarship of teaching and learning, requires that pedagogical innovations be tested. The objective of this study was to conduct an early assessment of the effect of the introduction and use of clicker personal response systems in a variety of major courses, with several levels of students (first to fourth year), within the Health Sciences Department. This unique, cross-sectional approach afforded us the ability to examine clicker effectiveness quantitatively and qualitatively and to compare effectiveness across different levels of students. Effectiveness was assessed by 1) a survey of student perceptions of the effectiveness of the clickers in improving several aspects of learning and 2) comparisons of quiz/exam grades between nonclicker and clicker years. We hypothesized that student perception of clicker usefulness would be positive and that quiz performance would increase in clicker years. Additionally, we hypothesized the clicker effectiveness would be similar among the different levels of students. The perceptual data presented here support the first hypothesis, whereas the quiz data support the second hypothesis in some, but not all, cases. Interestingly, our results

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suggest that clickers were least effective in our senior-level course.

METHODS

Context of the study. Our institution is a small (2,000 students), private, comprehensive college. The course data reported here were drawn from 334 students (36% men and 64% women) enrolled in A+P I and A+P II (freshman level), Exercise Physiology (junior level), and Human Pathophysiology (senior level) from fall 2009 through fall 2010. Additional quiz data were drawn from fall 2007 to fall 2010. A+P I, A+P II, and Human Pathophysiology are required courses for all majors in Health Science, Sports Medicine, and Athletic Training. Exercise Physiology is required for Sports Medicine and Athletic Training majors. These students were almost entirely traditional age students from 18–22 yr old. The distribution of student enrollment across courses is shown in Table 1. The data reported here pertain to the lecture sections of these courses; all courses had associated laboratory sections, which did not use clickers. This study was approved by the Institutional Review Board of Merrimack College.

Personal response system. In fall 2009, after a preliminary investigation and discussion among faculty members, on the basis of cost and ease of use, the Health Sciences and Chemistry Departments selected the Turning Point, Turning Point Anywhere personal response system marketed by Turning Technologies. The system includes no-cost software that can be downloaded on any computer, a radio frequency receiver device with a USB connection to be inserted into the computer, and a credit card-size personal response device (clicker) with alphanumeric keypad for student use (ResponseCard RF). Departments purchased several receiver units for instructor use, and students in the courses reported here were required to purchase clickers at the college bookstore. Freshman students in our majors are all enrolled in both A+P I and General Chemistry I and will eventually take A+P II and General Chemistry II. Students in the fall 2009 courses (A+P I, Exercise Physiology, and Human Pathophysiology) had no previous exposure at the college level to clicker use. Students in A+P II in spring 2010 had used clickers in A+P I and General Chemistry I in fall 2009. Some students in Exercise Physiology in 2010 had used clickers in a previous athletic training course.

During the course of 50- to 75-min lectures, instructors posed four to six multiple-choice questions in the context of their lectures. Clicker questions were drawn from previous quizzes, textbook ancillary materials (24), and clinical scenarios and were created by the instructors specifically for their courses. Questions ranged from the basic knowledge level to application and analysis (Table 2). Once the question was posed to the class, students were given time to read and consider the answers and, in some cases, to discuss with peers. When all students had responded, the instructor closed voting, and a percent frequency histogram of student responses was displayed on the screen. The instructor and students then discussed the correct

and incorrect answers given in the context of the lecture. At the end of the lecture period, all responses were saved for later recording. This allowed instructors to track individual student participation and understanding as well as keep attendance. In Exercise Physiology, students received a grade based on student participation, regardless of whether the answer was correct (5% of lecture grade). In the other courses, clicker participation was recorded but not graded.

Assessment. At the end of the term, students were given instructions and due dates, during the week before the final exam, to complete the SALG (35, 37), a web-based instrument developed for assessing the effectiveness of college-level science courses. This instrument assesses student perceptions of the degree to which various course aspects improved their learning. Instructors can modify the standard SALG survey template to add questions specific to each course. In this case, faculty members developed 10 additional numerical questions pertaining to clicker use (Table 3); these were added to the class activities section of the survey. The instrument uses a five-point Likert scale, such as in the following question: "As a result of the use of clickers, what gains did you make in each of the following?" (where 1 = no gains, 2 = a little gain, 3 = moderate gain, 4 = good gain, and 5 = great gain). Text box questions for narrative responses to clicker use were also added (such as "Please comment on how the class activities helped your learning" and "Please provide any additional comments on clickers"). After the submission of final course grades, the survey data were downloaded for analysis.

To assess possible changes in course performance resulting from clicker use, quiz/exam grades from years before clicker use (2007 and 2008) were compared with years with clicker use (2009 and 2010). The course instructor, textbook, and segments of material covered on the compared quizzes/exams were constant across nonclicker and clicker years.

Data analyses. One-way ANOVA was performed to compare quiz data from three or more nonclicker years with clicker years. Where appropriate, post hoc analyses were conducted using Tukey's multiple-pairs comparison test with two-tailed α set at $P < 0.05$. Student *t*-tests were used to compare quiz data involving 2 yr with two-tailed α set at $P < 0.05$. In Exercise Physiology, pre- and posttest data from the same 15-item test instrument were available for 4 yr, 2 previous nonclicker years and 2 clicker years. In this case, percent normalized gain from pre- to posttest scores was calculated for each student as $100 \times (\text{posttest} - \text{pretest}) / (15 - \text{pretest})$ (17). In all figures, values are shown as group means (SD). Data from the SALG survey were downloaded from the SALG website. The analysis anonymously reports *n*, mean, SD, and distribution of responses as percentages for each survey question as well as all responses to narrative questions. All 168 narrative comments were read, and several recurring themes that appeared with some frequency were noted. Comments were rated as positive or negative, classified into these categories, and counted, and percentages were then calculated as percent = number of comments of a type/total number of positive or negative comments.

Table 1. Distribution of student enrollment across courses

	A+P I (HSC1122)		A+P II (HSC1123)	Exercise Physiology (SME3311)		Human Pathophysiology (HSC3336)
	Fall 2009	Fall 2010	Spring 2010	Fall 2009	Fall 2010	Fall 2009
Level of students	Freshman	Freshman	Freshman	Junior	Junior	Senior
Number of students who completed the SALG survey	72	84	54	26	25	32
Number of students who completed the course	80 (30 men and 50 women)	96 (37 men and 59 women)	68 (22 men and 46 women)	27 (8 men and 19 women)	31 (13 men and 18 women)	32 (10 men and 12 women)
Survey response rate, %	90	88	79	96	81	100

A+P, Anatomy and Physiology; SALG, student assessment of learning gains.

Table 2. Sample clicker questions

Question
<i>A+P I</i>
You have difficulty with pressing down on the accelerator when driving and with going up on your toes. You could have injured all of the following muscles EXCEPT: A. Gastrocnemius B. Soleus C. Tibialis anterior* D. Peroneus brevis
<i>A+P II</i>
Predict the outcome of an overdose of the hormone erythropoietin (24). A. Blood viscosity increases to levels that may induce heart attacks or strokes.* B. Oxygen-carrying capacity remains unchanged despite elevated red blood cell counts. C. Red blood cell counts remain unchanged, but the number of reticulocytes increases. D. Blood viscosity levels decrease, where oxygen-carrying capacity increases.
<i>Exercise Physiology</i>
Which of the following statements is <u>not</u> true regarding the increase in SV that occurs during exercise? A. SV is generally higher during upright exercise than during supine exercise.* B. Increases in ventricular filling (due to the Frank-Starling relationship) and ventricular contractility contribute to increased SV during exercise. C. The increase in SV seen in exercise contributes to the increase in cardiac output. D. In normal recreational athletes, SV probably plateaus after work intensity exceeds 60% of maximal.
<i>Human Pathophysiology</i>
A government agency proposes a pilot program to screen a population for a disease by means of a blood test. Characteristics of the disease and the screening test are listed. Which of these indicate that the proposed screening is <u>not</u> likely to be worthwhile? A. Disease occurs with some frequency (1 per 1,000 persons screened) B. Disease progresses slowly in afflicted persons. C. Sensitivity and specificity of the test are unknown.* D. The test can detect the disease in its early stage and is relatively inexpensive.

SV, stroke volume. *Correct answer.

RESULTS

SALG survey. Of the 334 students completing the courses, 293 students completed the SALG for an overall response rate of 88%. Student perception of clicker effectiveness was quite positive. Table 3 shows SALG survey numeric data by course and semester for the clicker-related questions. The mean values fell from the midrange of moderate to good gain (3.5) to the midrange of good to great gain (4.3). Of the 55 question items reporting a single mode, 98% were scored as 4 and 5. The three questions regarding attendance, exam preparation, and promoting discussion were consistently rated a bit lower than the other items (3.3–4.0). The different courses did not seem to vary greatly in responses. When clickers were used in a course for a second time (A+P I and Exercise Physiology in fall 2010), mean ratings were slightly higher in the second year. These responses support the conclusion that students feel that the use of clickers encourages active learning, participation, application, and feedback about their understanding.

Table 4 shows clicker narrative comments, pooled from all four courses, which reinforced the positive numeric ratings. Of the 168 total comments on clickers, 139 comments were classified as positive in tone, for an overall positive rate of 83%. The positive rate ranged from 65 (A+P I in 2010) to 100% (Exercise Physiology). A content analysis of positive comments is shown in Table 5. Most commonly, students commented positively on clickers as encouraging participation and engagement (29% of positive comments), checking their level of understanding of material (17%), and being generally helpful (27%). At lower frequencies (<10%), students identified anonymity, encouraging deeper thinking, and promoting

discussion as positive traits. Some comments were positive but not easily classifiable into these categories. A sample of positive comments is shown in Table 6.

An analysis of negative comments is also shown in Table 5, with 29 negative comments of 168 total comments and an overall negative rate of 17%. For the purposes of this analysis, comments that clickers were not used enough or could have been used differently were taken as negative and made up 55% of the total negatives. General comments that clickers were not useful (28%) and cost (17%) were also found. These latter two are definitively negative, whereas the 55% indicating that clickers were not used enough could be taken as a positive endorsement of their use. In this interpretation, overall positive comments would constitute 92% and negative comments 8% of the total. A sample of the negative comments is shown in Table 6.

Quiz/exam performance analysis. Student responses to the use of clickers were clearly quite positive; however, these data do not address whether student performance improved in courses that use clickers. Student quiz/exam grades for these courses were compared for nonclicker and clicker years. In some cases, performance improvements were found.

In the freshman-level A+P I course, quiz scores were compared among 2008 ($n = 93$, nonclicker) and 2009 and 2010 ($n = 80$ and 96 , clicker). In all 3 yr, five quizzes were given on the same chapter topics with the same instructor, textbook, and organization of material (Fig. 1). When each topic quiz was compared across the 3 yr with ANOVA, significant differences were found for the terminology/cells ($P < 0.0001$) and tissue/

Table 3. Results of the class activities section of the survey

	A+P I		A+P II		Exercise Physiology				Human Pathophysiology			
	Fall 2009		Fall 2010		Spring 2010		Fall 2009		Fall 2010		Fall 2009	
	Mean (SD)	Mode	Mean (SD)	Mode	Mean (SD)	Mode	Mean (SD)	Mode	Mean (SD)	Mode	Mean (SD)	Mode
How much did each of the following aspects of the class help your learning?												
Use of the clicker personal response system.	4 (1.1)	4	N/A	N/A	N/A	N/A	4.4 (0.8)	5	4.2 (0.9)	4	3.7 (0.8)	4
As a result of the use of clickers, what gains did you make in each of the following?												
Engaging you in active learning	3.9 (1.0)	4	4 (1.1)	5	3.9 (1.1)	4	4.2 (0.9)	5	4.1 (0.8)	4	3.9 (0.8)	4
Increasing your participation and involvement in class	4 (1.0)	4	4.1 (1.0)	5	3.9 (1.1)	5	4.2 (1.1)	5	4.2 (0.9)	5	4.1 (0.8)	4
Maintaining your attention during class	3.8 (1.0)	4	4 (1.1)	4	3.9 (1.1)	4	4.2 (1.1)	5	4.1 (1.1)	5	3.9 (0.8)	4
Applying material immediately during class	4 (1.0)	4	4 (1.1)	5	4 (1.0)	4	4.3 (0.9)	5	4.4 (0.9)	5	4.2 (0.8)	4
Providing feedback about understanding of material	4.1 (0.9)	4	4 (1.0)	4	4 (1.0)	4 and 5	4.2 (1.0)	5	4.2 (0.9)	5	4 (0.8)	4
Encouraging participation through an anonymous format	4.1 (1.0)	4	4.2 (1.0)	5	4 (1.0)	5	4.2 (1.1)	5	4.3 (0.7)	5	4 (0.9)	5
Encouraging class attendance	3.6 (1.2)	5	4 (1.2)	5	3.6 (1.2)	4	3.6 (1.3)	4	3.8 (1.4)	5	3.3 (1.1)	3
Providing a way to study for exams	3.7 (1.1)	4	3.5 (1.3)	5	3.6 (1.2)	4	3.7 (1.2)	4 and 5	3.6 (1.4)	5	3.6 (1.0)	4
Promoting discussion/collaboration with others	3.8 (1.2)	4	3.6 (1.3)	5	3.7 (1.1)	3 and 4	3.8 (1.2)	4	3.7 (1.2)	4	3.9 (0.7)	4

$n = 293$ total respondents. Results were scored with a five-point Likert-type scale, where 5 = great gain, 4 = good gain, and 3 = moderate gain. N/A, not applicable.

muscle physiology content areas ($P = 0.0002$). Tukey's test indicated that for terminology/cells, mean scores in both 2009 ($P < 0.0001$) and 2010 ($P < 0.0001$) clicker years exceeded those in the 2008 nonclicker year. The clicker years 2009 and 2010 did not differ ($P = 0.8681$). In tissue/muscle physiology, Tukey's test showed that 2010 scores (clicker) exceeded both 2009 (clicker, $P = 0.0222$) and 2008 (nonclicker, $P = 0.0002$) scores but did not differ between 2008 (nonclicker) and 2009 (clicker, $P = 0.4263$) scores. ANOVA showed no differences across years for upper extremity ($P = 0.2886$), lower extremity ($P = 0.9723$), or nervous system ($P = .0587$) content areas. Here, clickers appeared to be associated with improved performance in one subject area (terminology/cells), some effect in tissues/muscle physiology, and no effect in other subject areas. As a first-term freshman course, no college grade point average/performance data were available to compare the student cohorts for the 3 yr. None of the data indicated any statistically significant reduction in performance associated with clicker use.

In A+P II, scores on seven chapter quizzes were compared between 2009 ($n = 84$, nonclickers) and 2010 ($n = 68$, clickers) using Student t -tests. The instructor, textbook, and

organization of material were the same in both years. Data from 2008 were not used as the textbook, organization, and presentation of material and quiz coverage were different from the 2 later years. While the class averages were slightly higher (Fig. 2) in 2010 on six of seven quizzes, the differences were significantly higher only for the vascular system ($P = 0.033$) and digestion ($P = 0.005$). These two quizzes had the lowest class averages for the term (<70% in 2009). For the chapter quizzes on blood ($P = 0.191$), the heart ($P = 0.373$), lymphatics ($P = 0.152$), respiration ($P = 0.292$), and the kidney ($P = .552$), no differences between years were found. When student averages for all 10 quizzes were compared for 2009 [$n = 84$, mean: 75.5 (7.9)] and 2010 [$n = 67$, mean: 78.7 (6.8)], grades were slightly, but significantly, higher in the 2010 clicker year ($P = 0.010$). The difference in mean scores represents the difference between a C and C+ grade. Analysis of the quiz averages in the preceding course, A+P I, showed no significant difference in the cohorts entering A+P II in the 2009 nonclicker [$n = 93$, mean: 76.6 (9.0)] and 2010 clicker [$n = 80$, mean: 78.6 (8.3), $P = 0.148$] years. None of the data indicated any

Table 4. Clicker narrative comment evaluation

	A+P I		A+P II	Exercise Physiology		Total
	Fall 2009	Fall 2010	Spring 2010	Fall 2009	Fall 2010	
Number of positive narrative comments on clickers	45	31	32	18	13	139
Number of negative narrative comments on clickers	9	17	1	2	0	29
Total number of comments on clickers	54	48	33	20	13	168
Positive comments, %	83	65	97	90	100	83
Negative comments, %	17	35	3	10	0	17

$n = 168$ respondents total.

Table 5. SALG narrative comments from 2009 to 2010

	Number	%
Pooled positive comment themes	139	
Encouraging participation and engagement	41	29
General (helpful, good, like, etc.)	37	27
Checking level of understanding	24	17
Aiding quiz preparation	11	8
Anonymity, reducing risk of being wrong	6	4
Encouraging deeper thinking	5	4
Promoting class discussion	4	2
Other	11	8
Pooled negative comment themes	29	
Not used enough	16	55
General (little help, etc.)	8	28
Cost	5	17

statistically significant reduction in performance associated with clicker use.

In the Exercise Physiology course, a pretest and posttest have been administered for several years. The instrument contains 15 multiple-choice questions with 1 or 2 questions drawn from each chapter covered during the course. Students take the pretest on the first day of the class; it is scored but not returned, nor does it count in the course grade. The same posttest questions were incorporated in the final exam and were graded and counted toward the overall score, but were not returned. Figure 3A compares performance on the same pre-post instrument from 2007–2008 (nonclicker years, $n = 57$) to 2009–2010 (clicker years, $n = 58$). ANOVA indicated a significant difference ($P < 0.0001$) among the four groups. Tukey’s multiple-pairs comparison test indicated that pretest mean scores between clicker [6.7(1.9) of 15, or 45%] and nonclicker [6.3 (1.8) of 15, or 42%] years did not differ ($P = 0.5922$), indicating that the background preparation of the two groups was similar. Posttest scores for the clicker years [11.6 (2.0), or 77%] exceeded posttest values for nonclicker years [10.5 (1.9), or 70%, $P = 0.0117$]. Within both nonclicker and clicker years, posttest values increased from pretest values ($P < 0.0001$). The percent normalized gain from the pretest to posttest was calculated for each student and pooled for the two nonclicker years and for the two clicker years (Fig. 3B). The mean gain achieved by

students in the clicker years [57% (26)] was higher than that for the nonclicker years [47% (23), $P = 0.0372$].

In the senior-level Human Pathophysiology course, average quiz/exam grades were compared between 2008 ($n = 27$, no clickers) and 2009 ($N = 32$, clickers) using t -tests. Average grades on all quizzes and exams in this senior-level course exceeded 80%. In no case did performance improve significantly in the clicker year; in fact, average grades were significantly higher in the 2008 nonclicker year on 8 of 10 quizzes/exams on comparable material (P values ranged from <0.0001 to 0.0454), with the same instructor, textbook, and coverage of material. Quiz 2 ($P = 0.7913$) and exam 3 ($P = 0.6059$) showed no differences between years. Figure 4 shows a comparison of the class average grades on the four quizzes and four exams. t -Test results showed a significant difference between years for both quizzes [2008 nonclicker: 87.8 (6.7) and 2009 clicker: 79.9 (6.4), $P < 0.0001$] and exams [2008 nonclicker: 87.9 (6.8) and 2009 clicker: 82.9 (4.9), $P = 0.002$].

In summary, there is evidence in some courses on some material that supports performance improvement in clicker years. In one senior-level course, grades were lower in the clicker year; however, these grades were $>80\%$ in both years analyzed. In other comparisons, clicker use had no effect on performance, as measured by quiz grades, in either direction.

DISCUSSION

General comments. The objective of this study was to evaluate the effect of the introduction and use of clickers in a variety of courses, with several levels of students, within the Health Sciences Department. We hypothesized that student perception of clicker usefulness would be positive and that quiz/exam performance would increase in clicker years. The perceptual data presented here support the first hypothesis, whereas the quiz data support the second hypothesis in some, but not all, cases. Clickers were least effective in the highest-level course, in which, compared with the other two classes, students performed best on quizzes/exams. Overall, these data are consistent with our previous studies (8, 15) indicating that incorporating active learning strategies into the classroom is viewed positively by students and results in enhanced learning.

Table 6. Sample student comments

Positive Comments	Negative Comments
<ul style="list-style-type: none"> •The clicker questions made me really understand the material right after we learned it which made it stick in my brain better •Clickers were fun and easy to use. I loved testing myself on what I knew or thought I knew. Any easy way of finding out what I need to spend more time studying and what I can spend less time on. •The clickers were a nice advantage in class because even if we didn’t know the answer we could still try and not feel bad if we got the answer wrong. •The clickers are a helpful tool that promote paying attention and using what you learned that same day on the spot. •Clicker questions allowed us to discuss the answers of the questions immediately after which helped me a lot. •The clicker questions allowed me to work with the people around me to find the right answers. 	<ul style="list-style-type: none"> •I feel as though they should be used more in this class. When used they inform me on what I need to focus more on. They should be used after we learn the material rather than before. •More clicker questions would increase participation. •I do not think the clickers did much of anything. •Clickers are overpriced and impractical. •They’re kind of expensive. I don’t think they’re completely necessary.

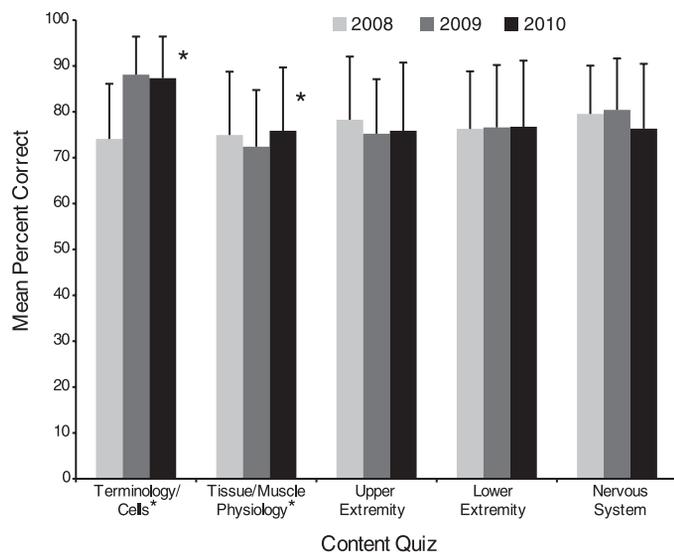


Fig. 1. Class mean scores on content quizzes in Anatomy and Physiology (A+P) I from 2008 to 2010. Class enrollment was 93 students for 2008, 80 students for 2009, and 96 students for 2010. Error bars = 1 SD. Clickers were used in 2009 and 2010. *ANOVA showed a significant difference among areas of terminology/cells ($P < 0.0001$) and tissue/muscle physiology ($P = 0.0002$). For terminology/cells, Tukey's multiple-pairs comparison test indicated differences between 2008 and 2009 ($P < 0.0001$) and between 2008 and 2010 ($P < 0.0001$). For tissue/muscle physiology, Tukey's test showed differences between 2008 and 2010 ($P = 0.0002$) and 2009 and 2010 ($P = 0.0222$). ANOVA indicated no significant differences among years for content areas of the upper extremity ($P = 0.2886$), lower extremity ($P = 0.9732$), and nervous system ($P = 0.0587$).

Perceptual data. The survey results for the 293 students (88% of students enrolled in the courses) that completed the survey both quantitatively (Table 3) and qualitatively (Tables 4–6) supported the hypothesis that students viewed clickers quite positively across class years and across courses. Question means were generally around 4, with virtually all modes of 4 or 5, indicating that students perceived good to great gains as a result of clicker use in the areas of increased engagement, participation, application of material, useful feedback about understanding, and anonymous risk free participation. Responses did not vary greatly across courses or levels of students, and the narrative comments were quite consistent with the numeric ratings; positive comments predominated and expanded on the same features in the numeric questions. Clearly, these students felt more engaged and active within their classes when clickers were used. Although not surveyed formally, the three instructors involved in the reported courses are committed to the continued use of clickers, as a result of their own observations of increased student involvement. Thus, in the opinion of both students and instructors, clickers allow students to 1) actively engage in classroom lecture (instead of just passive listening); 2) apply course content to practical questions; 3) check the students' level of understanding; 4) respond anonymously, which avoids the feelings of being "wrong" or "called out;" and 5) work collaboratively with peers to answer questions.

Performance data. Instructors provided quiz/exam score information for the clicker years and for the years immediately before clicker use. The number and format of quizzes varied across courses, but within a course across time, the instructor, syllabus, content coverage, textbook, and quiz format and

coverage were the same. The evidence for performance improvement in these courses is mixed. In the case of Exercise Physiology, the evidence supported the hypothesis of improved student performance during clicker years. In A+P I and A+P II, improvement was seen on some, but not all, material in clicker years. On other material, the use of clickers had no effect on performance. In the Human Pathophysiology course, grades were lower in the clicker year; however, performance in both years was quite high ($>80\%$ on quizzes/exams). Indeed, the performance of students in this course was higher than in the two introductory courses. This is not surprising as students typically perform better in senior-level courses than introductory courses (A+P I and A+P II). Taken together, these results might suggest that clickers are more effective in lower-level courses, which tend to be larger in size and where students tend to be less engaged.

Advantages. The advantages of the present study include sampling of multiple courses with multiple instructors at several levels of progression within our major curriculum over 2 yr of clicker use. The perceptual survey instrument was developed by faculty members to assess the goals that we had hoped clickers would help achieve. By inserting these items within the SALG template, students could rate and assess clicker use in the context of many other course activities and learning approaches. As an online survey, SALG is easily used by both instructors and students, provides the possibility of extensive narrative responses as well as numerical data, and provides a downloadable analysis of the data collected. The site also archives data from all of an instructor's courses over time. The 88% overall response rate to the survey was quite good, considering that it was not administered in class and students were asked to complete it online on their own time. The faculty members involved in the courses reported here all used the clickers in a similar manner, with group discussion and peer interaction as essential elements of the process. Instructors found that this approach created a much more interactive classroom. Students appreciated that they could attempt an-

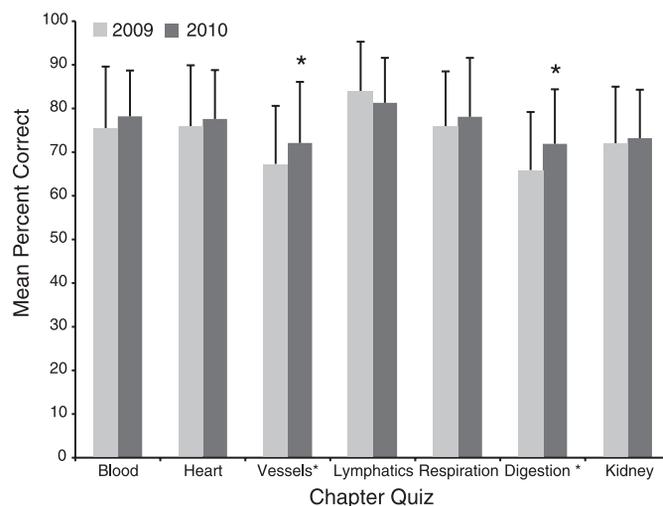


Fig. 2. Class mean scores on content quizzes in A+P II from 2009 to 2010. Class enrollment was 84 students for 2009 and 68 students for 2010. Error bars = 1 SD. Clickers were used in 2010. *Student's t -test comparing the 2 yr showed a significant difference for vasculature ($P = 0.033$) and digestion ($P = 0.005$). Student's t -test indicated no significant differences among years for content areas of blood ($P = 0.191$), the heart ($P = 0.373$), lymphatics ($P = 0.152$), respiration ($P = 0.292$), and the kidney ($P = 0.552$).

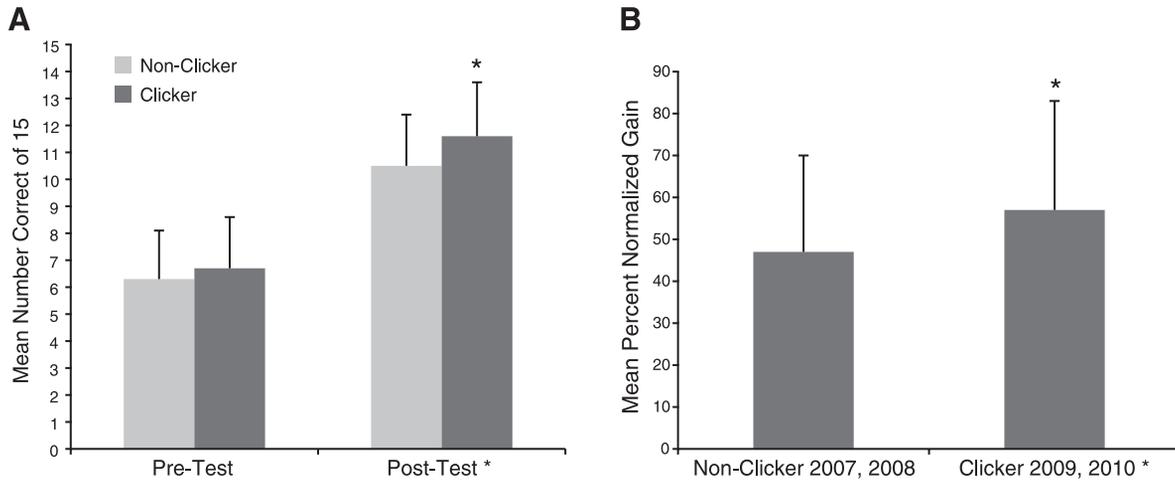


Fig. 3. A: class mean scores on 15-item pre- and posttests in Exercise Physiology from 2007–2008 (nonclicker years, $n = 57$) and 2009–2010 (clicker years, $n = 58$). Error bars = 1 SD. *ANOVA indicated a significant difference ($P < 0.0001$) among the four groups. Tukey’s multiple-pairs comparison test indicated that pretest mean scores did not differ ($P = 0.5922$) between clicker versus nonclicker years. Posttest scores for the clicker years exceeded posttest values for nonclicker years ($P = 0.0117$). Within both nonclicker and clicker years, posttest values increased from pretest values ($P < 0.0001$). B: class mean percent normalized gain scores. Gain = $100 \times (\text{posttest score} - \text{pretest score}) / (15 - \text{pretest score})$. *Student’s t -test indicated a significant difference ($P = 0.0372$) between nonclicker and clicker years.

swers without the risk of answering incorrectly in public but at the same time could assess their own level of understanding individually and relative to peers. This could then allow them to focus more on areas that were unclear by asking followup questions. Instructors appreciated the information gained from responses as to which points were unclear to students. Subsequent class time could then focus on clarifying those areas rather than repeating material that students understood well. It can often be surprising to an instructor that areas that seemed obvious and that students had not asked questions about previously turned out to be unclear to a large proportion of the

class. The feedback gained by both students and instructors with this method is considerable. Our current digital native generation of students responded very positively to this technology, but the technology is only a means to the end of stimulating deeper thought. It is essential that the questions posed address multiple levels of Bloom’s taxonomy of learning and that peer interaction is a key feature of the process.

All of the classes and sections reported here responded similarly to the perceptual survey. The quiz comparison performance assessment yielded more variable results. The strongest evidence for improvement was seen in the junior-level Exercise Physiology course. Pre- and posttest data were used to compare two nonclicker years and two clicker years, with a significant improvement seen in clicker years, as measured both by raw scores and by normalized gain from pre- to posttest scores. Comparison of pretest scores across years indicated no statistical difference in the level of background that students brought to the class. A subset of about half the students in this class in 2010 had used clickers in a previous sophomore-level athletic training class, whereas the rest had no clicker experience. The fact that clicker participation contributed 5% to a student’s course grade may have increased the motivation of these students to engage with the material and participate more, resulting in better quiz performance in clicker years. In contrast, the other courses did not grade clicker participation. The first-year A+P I and A+P II courses yielded mixed results, with improvement in quiz performance on some, but not all, material. While these two classes had pre- and posttest data from the most recent clicker year, these were not done in prior nonclicker years. We did not include 2007–2008 data in this study as it was the first year for the course; the text, syllabus, coverage, and order of presentation and quiz format were different from subsequent years. Since fall 2008, these factors were revised and have been constant across the following years. As this was a freshman course, we can assume that students in the first term had no prior clicker experience, whereas those in the second term had used the clickers in the

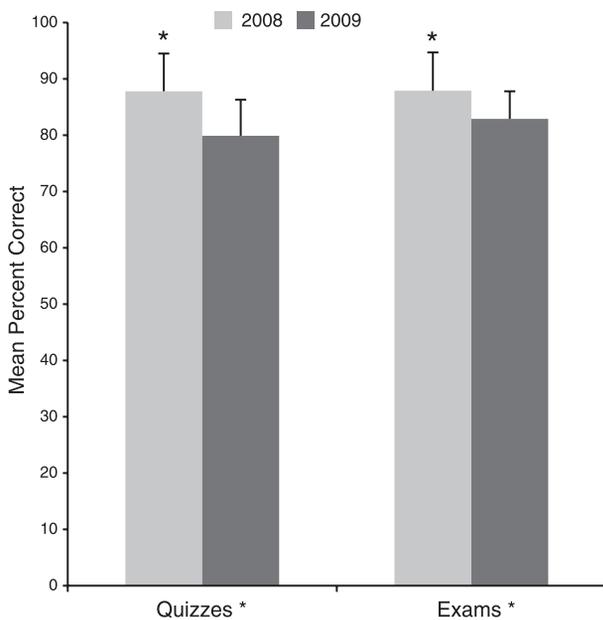


Fig. 4. Class mean scores on four quizzes and four exams in Human Pathophysiology in 2008–2009. Class enrollment was 27 students for 2008 and 32 students for 2009. Error bars = 1 SD. Clickers were used in 2009. *Student’s t -test comparing the 2 yr showed significant differences between years for both quizzes ($P < 0.0001$) and exams ($P = 0.002$).

first term and in General Chemistry I. The instructor in A+P II had used multiple-choice questions in class in the nonclicker year, but without the technology. Polling by a show of hands was used and was not especially successful, as many students did not respond at all, probably due to the nonanonymous nature of the response; counting of responses was time consuming, and no visual representation of response distribution was available. It is interesting that the material on which performance improved in the clicker year was that with the lowest quiz averages, indicating that students found this material more challenging and were perhaps aided in learning this material by the clicker method. In the A+P I course, with all students new to clickers, the same pattern was seen of improved performance on some quiz areas in clicker years. Interestingly, in the second clicker year in this class, for various reasons, the clickers were used less, and students clearly identified in the survey a desire to use them more.

Limitations. In studies such as these, it is difficult to control for the many independent variables that affect student performance. As previously discussed, the level of student (freshman vs. senior) and number of students enrolled in the course might impact the utility of clickers in the classroom. In addition, each year's class enrolls a different student cohort; this is perhaps the most significant uncontrolled variable. For example, the grades in the Human Pathophysiology class decreased in the clicker year, although these students responded very positively in the survey. Examination of the academic records of students in Human Pathophysiology indicated that 59% of the students in the 2008 class graduated with honors (3.25 and above), including 22% summa cum laude (3.75 and above). In contrast, in the 2009 class, 41% graduated with honors, with only 6% summa cum laude. This would seem to indicate that the 2008 class was an academically much stronger class. In such a small sample, the excellent performance of only a few students can significantly alter the mean. It is unlikely that using clickers resulted in students performing worse on quizzes/exams, especially in light of the positive perceptual response.

Most courses did not have students take pretests to determine student knowledge of the content before the course. Even if the background of students on entering the course is similar, pretests cannot quantify intangibles such as work habits, study skills, and commitment, which can vary greatly across students both within a given class and across classes. Other factors were clearly at work in the posttest, since, incredibly, there were examples of a few students who score lower on the posttest, as seen in the fairly large variability in normalized gain shown in Fig. 3B. The posttest questions were generally incorporated in the final exam; it is often the case that final exam scores tend to be lower than quizzes given during the term, perhaps due to the stress and scheduling of multiple finals packed into a few days for all the students' courses. The inclusion of grade point average data, where available, might serve to address the differences in prior academic success. To have a controlled experiment, where some students use clickers and others do not in the same lecture, would not be practical or ethical, if we believe that clickers have a positive effect. A crossover design, using clickers for half the term for some students and switching groups at midterm, would not control for the different material covered in the two halves. Here, we compared different years and assumed that the students had similar knowledge, work habits, and academic ability. In the Human Pathophysiology

course, the assumption about similar previous academic performance was not supported.

While the Exercise Physiology results were based on the same pre- and posttest instrument administered over several years, the quiz comparisons in the other courses introduced another variable. The quizzes compared covered similar material but were not identical in the specific questions asked. Instructors strive to make quizzes of equivalent challenge across years, but short of giving exactly the same quiz (not advisable since former students do save and share returned quizzes with current students), it is difficult to insure that each year's quizzes are exactly equivalent. This emphasizes the importance of comparing performance on standard pre- and posttests, administered across years, but not returned to students. Ideally, national standard exams, such as the Force Concept Inventory used in physics (11, 17), would also allow comparisons with students from other institutions. Pre- and posttests can provide data to assess any number of classroom learning techniques, not just clickers. An additional variable is the nature of the clicker questions used by different instructors. Here, the instructors used the clickers similarly, but we could not control for the nature of the questions asked. While each instructor used the same clicker questions across the 2 yr described, they varied in nature across the different courses, as shown in Table 2. For deeper learning, it is important that questions represent several levels of Bloom's taxonomy, not simply knowledge and memorization. The exact amount of peer interaction and discussion were also not quantified within and across courses. In the Exercise Physiology course in 2010, 5% of a student's lecture grade was based on clicker participation, a proxy for attendance, but was not graded in the other classes, and this may affect student motivation.

We did observe a low level of negative comments on clickers, mostly around cost and general perceptions that clickers were not useful. When clickers are used in multiple courses over 4 yr, the cost per course drops to quite reasonable levels. We did not experience any technical problems with the system, which was quite easy to use and required minimal instructor time to learn.

Context of other studies. When students are surveyed about their perceptions of the usefulness of clickers in science, the results are fairly uniformly positive, and these results across a variety of courses, enrollment sizes, and levels of students are quite consistent with what we report here for our courses. The same themes of engagement, feedback, anonymity, confidence, peer interaction, etc. appear regularly in individual studies and in reviews. Clickers are rated as useful and effective learning tools by students in classes of all levels and sizes in health professions (12, 32), biology (39), chemistry (6, 34), and physics (22, 25, 38). There are several factors that may influence response to clicker use. Trees and Jackson (38) found that students with a higher preference for engagement as a learning style had a more positive reaction to clickers, freshmen/sophomores had perceptions of greater learning than juniors/seniors, attendance grading had little effect on perception, perception increased with greater clicker use, perception of learning with clickers did not vary on the basis of whether students were graded or not on correctness of response, and students who expected a higher course grade had a more positive perception of the usefulness of clickers. A study of clickers in combination with the case study method of teaching in biology

found that women and nonscience majors were more positive about the case study/clicker method. The clicker system used and class standing also affected perception, but prior experience with clickers did not. These students were generally positive or neutral about clickers (39). Review articles (7, 14, 20, 23, 33) have described many other studies with similar findings. The perceptual response to clickers is highly positive, and, interestingly, the student narrative responses have a remarkable consistency in the features that they identify as important aspects of clicker use. When negative responses appear, they generally relate to cost and to a general lack of a sense of any positive effect. This may highlight that it is important, as many have noted, for instructors to explain up front their pedagogical rationale for the use of clickers. In early studies, there was a considerable negative perception of clickers based on technical difficulties that consumed class time, interrupted the flow of the class, and generally served as distractions (20). The current generation of clickers has evolved to be fairly free of these problems.

While the perceptual data on student response to clicker use are highly positive and consistent across class type, size, level, subject matter, etc., the data on effect on student performance, as in the results we report, are much more mixed. It is important to note that clickers represent a technology, not a pedagogy. The essential feature that characterizes the clicker studies summarized is the question cycle (3). The instructor poses a question on screen, usually multiple choice; students are given time individually, with a partner or group, to consider the alternatives. Students are polled and respond; responses are gathered and a histogram or record of response distribution is displayed as feedback. Discussion then follows among groups or the class as a whole, concerning the rationales for correct and incorrect answers. In some cases, the correct answer may not be revealed, and further discussion is followed by a revote. This method can be used with or without clickers, using a show of hands, raised response cards, etc. In a survey of 6,542 students in 62 introductory physics courses, Hake (17) referred to this question cycle method as interactive engagement (IE) and the posed questions as ConceptTests, analogous to clicker questions. Comparison of the IE method with traditional lecture found a much higher normalized gain in the IE group from pre- to posttest scores using a standardized Force Concept Inventory instrument. Crouch and Mazur (11) referred to this same method as peer instruction. In 10 yr of use in introductory physics courses, they describe improved performance on standardized physics tests with peer instruction relative to traditional lecture. Since clickers were not used to gather responses in these studies, it appears that the IE/peer instruction method with concept tests is the key feature, and the authors cite the value of hands-on engagement with immediate feedback and interaction with peers in improved performance.

Several studies have examined performance outcomes associated with clicker use. In introductory biology sections, clickers used in either graded or nongraded format reduced the student failure rate and increased class attendance (9). Crossgrove and Curran (10) compared achievement in nonmajor and major classes in introductory biology and genetics and found very positive student response to clicker use as well as significantly increased test performance on material taught with clickers, with a larger increase for nonmajors. These authors found improved retention for clicker taught material in intro-

ductory biology 4 mo after the course ended, but no difference in retention for genetics. This supports the contention of some studies that clickers are more effective with beginning students, whereas we observed a stronger effect in a junior class than with freshman. In an upper-level developmental biology class, traditionally taught sections were compared with those using interactive techniques with clickers (21). Assessment was based on a 15-item pre-/posttest comparison, with the posttest score composing 2% of the final exam grade. The study noted significantly higher normalized gain from the pre- to posttest with the interactive class. No differences in pretest scores were seen between groups. Our results in exercise physiology are very similar to these. In an extensive study of 175 second-year students in physiology, Gauci et al. (16) noted that students who regularly answered clicker questions had better exam results than those who did so less frequently. Students who had lower grades for prerequisite courses had more improvement with clicker use. Significant improvement was noted on midterm and final exams compared with prior years when clickers were not used. In a systems physiology class, a traditional instruction group was compared with a group taught with modified instruction with clickers. While exam scores were higher in the clicker group, the difference was not significant. There were fewer low scores in the clicker group, and no differences were seen in the academic standing of the two groups. Other factors in addition to clickers, such as reading quizzes, differed across groups (30). Clickers did not improve performance in a general, organic, and biochemistry course, although student reaction to their use was positive (6). The review articles mentioned above cite many other such studies. As in our results, improvement was noted in some cases but not in others. For the future, it seems that standardized pre- and posttesting, with comparisons of classes or sections that differ in as few other variables as possible, is the preferred approach to continue to investigate the value of clickers in improving student performance. Additional information about demographics, student experience with clickers, prior academic record, and other factors may be useful to gather to interpret performance results. From instructors, it would be useful to have more details about the way in which clickers were used in a given class, such as the number of questions per class meeting, some rating of question type and level, degree of peer interaction, etc. It could also be helpful to develop a standardized perceptual survey to gather information on student reactions. The surveys described here differed in length, questions, context of administration, and other details. Our study embedded the clicker assessment in a much larger SALG survey; the context of survey administration is not always described in other studies, but it appears to be a stand alone focused on clickers in many cases. Given these differences, the consistently positive student responses seen across studies and the identification of the same positive themes in narrative comments strongly support clicker use. As with any tool or pedagogy, it is important that instructor practice be informed and guided by best practices developed through consistent and frequent assessment. There are many ways to encourage active learning; clicker technology has great potential to facilitate the interactive engagement and peer instruction inherent in the question cycle approach.

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DISCLOSURES

No conflicts of interest, financial or otherwise, are declared by the author(s).

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