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We explored whether a new pedagogy using personal response systems (clickers) along with case study teaching improved students' perceptions of their understanding of science in large introductory biology classrooms. Twelve faculty from nine institutions and 1,457 students across the United States and Canada participated in this study. Faculty taught six to eight topics in biology by lecture or clicker case method, alternating the methods within the same course. Data include student responses to a survey questionnaire. Results indicated that students, especially women and nonscience majors, were generally positive toward the use of both clickers and cases.

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Large classrooms reduce peer interactions among undergraduates (DeCaprariis 1997; Tobias 1990), limit opportunities to check students' understanding (Geski 1992; Trees and Jackson 2007; Wulff, Nyquist, and Abbott 1987), and diminish learning results (Mayer et al. 2009). By using personal response systems or *clickers*, professors are able to answer students' questions instantly, and students report being more engaged when instruction centers on the discussions of these questions (Duncan 2005). However, research is mixed concerning student perceptions of the effective use of clickers (MacGeorge et al. 2008), depending on how instructors use them (Mun, Hew, and Cheung 2009; Trees and Jackson 2007). Student perceptions of instruction have been linked to student persistence, motivation, and attitudes (Ames and Archer 1988; Kardash and Wallace 2001; Seymour and Hewitt 1997; Tinto 1993; Tobias 1990); thus, it is critical to understand student opinions of proposed technologies before they are implemented on a broad scale. In this study, we investigate whether clicker cases, stories about real-life problems related to biology that use clickers, affect student perceptions of instruction.

Achieving student interaction in large lecture classrooms with clickers

Social interactions in the classroom help students learn (Mayer and Wittrock 2006; Vygotsky 1978). Researchers extrapolated this theory to personal response systems, which provide immediate, real-time feedback to students in even the largest lecture hall, directly influencing student learning (e.g., Guthrie and Carlin 2004; Mayer et al. 2009). The successful use of clickers is associated with several educational theories, such as generative learning (Mayer et al. 2009), the importance of feedback (Cain, Black, and Rohr 2009; Yourstone, Kraye, and Albaum 2008), and student motivation (Trees and Jackson 2007).

Cognitively engaged students learn more (Mayer and Wittrock 2006). When students feel involved, they are more apt to create linkages between existing knowledge and the material taught (Mayer et al. 2009). Clickers generate student engagement by allowing immediate feedback to flow from students to professors (e.g., Guthrie and Carlin 2004), thus providing students with a tool to influence instruction. In past studies, students have indicated that they believe the effective use of technological tools can help them learn material better and make abstract or esoteric ideas more concrete; however, poor or improper use of technology can have the exact opposite results (Davies, Lavin, and Korte 2009; Savery 2002). Because clickers are a relatively new technology, we know little about how to combine this technology with strong instructional practice.

Motivating students through the use of cases

Case-based learning is a promising practice in science, technology, engineering, and mathematics (STEM; Lundeberg 2008) that has increased student interest, participation, and understanding of science material (Bell 2004; Bergland et al. 2006; Kumar and Sherwood 2007; Rybarczyk et al. 2007; Yadav et al. 2007). Case-based instruction allows students to make a personal connection to material by presenting it in a context that is relevant to them (Levin 1999; Savery 2006). When students discuss real-world problems in situated learning contexts, material becomes more engaging and students become more motivated to learn (Bergland et al. 2006; Prince and Felder 2006). Although some benefits of case-based instruction in science education have been documented (e.g., Herreid 2006a), implementing this pedagogy in large (100+ students) classrooms is difficult. The combined use of clickers and cases can transform a large class into an interactive experience (Herreid 2006b), according to faculty perspectives. It is also imperative to know what students think about the use of clicker cases.

Most researchers surveyed students' perceptions of using clickers in large classes without distinguishing learner differences, with the exception of Trees and Jackson (2007), who found that freshmen and sophomores were more positive than juniors and seniors who used clickers. However, there are other potential variables, such as gender, major, and types of clickers that could influence student perceptions. This study was designed to measure students' perception of using clicker cases in large (100+ students) undergraduate introductory biology classes and to explore potential variables that might influence students' perceptions of using clicker cases.

Thus, we investigated the following research questions:

1. What are students' perceptions of using clickers in large undergraduate introductory biology classes?
2. What variables, if any (including learner characteristics such as gender, major, class status, and types of clicker systems used in classrooms) influence students' perceptions of using clickers?

Methods

Research context

We collaborated with 12 instructors who teach introductory biology classes at nine different institutions (research, comprehensive, private liberal arts, and community college) throughout the United States and Canada. At the end of the semester, students completed a survey to measure their perception of using clicker cases.

Survey instrument

The 35-question instrument used in this study was developed from Duncan's (2005) instrument, measuring the use of clickers in large lecture classrooms and Yadav et al. (2007) survey measuring the use of cases. The instrument was revised multiple times by faculty and researchers both individually and as a group. Additional testing and refinement occurred as part of a pilot study during spring semester 2007. Items were organized into two sections. The first section contained seven demographic items: gender, class status, major/nonmajor, type of clicker system used, experience with cases, experience with clickers, and initial reason for taking the course—required or elective. The second section included 35 items that addressed students' perceptions of using cases and clickers using a 5-point Likert scale (4 = *strongly agree*, 3 = *agree*, 2 = *neutral*, 1 = *disagree*, and 0 = *strongly disagree*). A factor analysis performed on the 35 items identified five factors. Cronbach's alpha was determined for the set of items that constituted each of the five subscales. Overall test validity was high ($\alpha = 0.94$). Varimax rotation of factors was used in principle component analysis with items loading higher than 0.3 selected. The first scale included nine items measuring students' general attitudes toward using clickers to help them learn in classrooms ($\alpha = 0.92$; e.g., "I learned more using clickers"). The second scale contained four items that measured students' comfort level with the ease of using clickers ($\alpha = 0.83$; e.g., "I was comfortable answering questions in class using the clicker"). The third scale included six items ($\alpha = 0.87$) that measured students' perception of the impact of cases in learning science (e.g., "Case-based learning improved my ability to understand science"). The fourth factor ($\alpha = 0.82$) included five items that measured the effects of clicker cases on classroom interaction. Finally, the fifth scale (two items) measured whether students attended class more regularly when they knew they were using clicker cases ($\alpha = 0.61$). This low number is probably due to the small item set. Because we do not have strong evidence of internal consistency among these items, results from the fifth scale are not reported.

Participants

One thousand four hundred fifty-seven (1,457) students voluntarily participated in this study as part of their introductory biology class and completed the survey by the end of fall semester 2007. The majority of participants were nonscience majors (N = 1,097; 75.3%) and women (N = 933; 64%). Most (78.6%) were in their first (N = 537; 36.9%) or second year (N = 608, 41.7%) of instruction. Participants used one of three common North American clicker systems in this study: Interwrite (PRS), Turning Point (TP), and Classroom Performance Systems (CPS).

Data analysis

To examine whether learner characteristics influenced students' perceptions of using clickers, we ran multivariate analysis of variance (MANOVA) with five scales' composite scores as dependent variables and all variables of learner characteristics (gender, major, class standing, types of clickers, experience with cases, experience with clickers, and initial reason for taking the course—required or elective) as independent variables. Among these independent variables, student major was categorized as science or nonscience major. Class standing included four categories: freshman, sophomore, junior, and senior. Finally, we examined if the three different clicker systems impacted students' perceptions.

TABLE 1

Multivariate analysis of variance (MANOVA) results.

Multivariate	MANOVA results with Pillai's criterion				
	Hypothesis *df*	Error *df*	*F*	Sig. (*p*)	η²
Gender	2	1,445	4.66	0.010*	0.006
Major	2	1,445	7.72	0.000**	0.011
Clicker type	4	2,892	48.998	0.000**	0.063
Class standing	6	2,892	9.065	0.000**	0.018
Initial reason	2	1,445	1.95	0.143	0.003
Case experience	2	1,445	2.82	0.060	0.004
Clicker experience	2	1,445	0.917	0.400	0.001

Note: Sig. = significance.
*p < .01 **p < .001

TABLE 2

Clickers univariate tests.

	n	General attitudes			Ease of use		
		Mean	*F*	η²	Mean	*F*	η²
Gender Male Female	 524 933	 17.71 18.77	6.58**	0.005	 10.93 11.47	7.83**	0.005
Major Science Nonscience	 360 1,097	 17.25 19.23	15.36***	0.011	 10.92 11.48	5.81*	0.004
Clicker type PRS CPS TP	 843 275 339	 18.48 15.92 20.315	22.08***	0.030	 12.29 8.97 12.35	93.02***	0.114
Class standing Freshman Sophomore Junior Senior	 537 608 258 54	 20.53 17.52 18.79 16.12	13.60***	0.027	 12.03 10.83 10.81 11.13	10.61***	0.022

Note: Maximum scores possible: general attitudes = 45, ease of use = 20. PRS = Interwrite; CPS = Classroom Performance Systems; TP = Turning Point.
*p < .05 **p < .01 ***p < .001

Results and discussion

Perceptions of clickers

Students had neutral attitudes toward using clickers overall (M = 2.14, SD = 0.86), even though most students felt comfortable using clickers in class (M = 3.00, SD = 0.90). According to the MANOVA results shown in Table 1, student attitudes were influenced by gender, $F(3, 1{,}446) = 4.66$, $p < .01$; major, $F(1, 1{,}446) = 7.72$, $p < .001$; type of clicker system used, $F(3, 1{,}446) = 48.99$, $p < .0001$; and class standing, $F(1, 1{,}446) = 9.065$, $p < .0001$. However, reasons for taking the class, previous experience with cases, and previous experience with clicker systems were not significant.

To examine the specific impact that each significant independent variable exerted on the dependent variables, post hoc univariate tests were conducted. Table 2 shows that all four variables significantly influenced both general attitudes and perceptions of ease of use. Women had more positive opinions of clickers, $F(1, 1{,}446) = 6.58$, $p < .01$, and were more comfortable adopting clickers, $F(1, 1{,}446) = 7.83$, $p < .01$, than were men, although effect sizes were small (η^2 = .005), indicating that gender accounted for only half a percent of variance. It is surprising that women responded more positively toward clickers than men. Literature associated with gender and technology has suggested that males are more frequently engaged and excited by technology (Hakkarainen and Palonen 2003; Heemskerk et al. 2005; Volman and van Eck 2001), but that women are more drawn toward discussions and emotionally engaging situations (Kang and Lundeberg 2010). Female students tend to prefer cooperative learning environments (Grossman and Grossman 1994; Sadker and Sadker 2003), whereas male students generally respond better to competitive learning environments. Thus, women are more oriented toward group rather than individual goals; however, group-oriented goals are rarely achieved in lecture-based, large undergraduate classrooms because of the limited opportunities for social interactions. Given the overall small gender effect size, one interpretation of this result is that the technology itself is not important, but rather it is the discussions that the technology facilitates that are making an impression on the students.

Table 2 shows that nonscience majors liked using clickers more than students majoring in science, $F(1, 1{,}446) = 15.36, p < .001$. These results indicate that using clickers may have more positive effects on student learning and participation in the classes with nonscience majors and freshman, such as introductory courses.

Moreover, the kind of clicker system used influenced students' general attitudes toward clickers, $F(2, 1{,}446) = 22.08, p < .001$, as did class standing. Students rated two systems, PRS and TP, significantly higher than CPS, $F(2, 1{,}446) = 22.08$, $p < .001$. They also rated PRS and TP significantly easier to use than CPS, $F(2, 1{,}446) = 93.02, p < .0001$. Clicker type has the largest effect in both MANOVA and univariate analyses, with a moderate size effect from MANOVA ($\eta^2 = .063$) and a large effect from univariate testing (attitude, $\eta^2 = .03$; ease, $\eta^2 = .114$). Freshmen responded more favorably to clickers than did upperclassmen.

TABLE 3

Cases univariate tests.

	F	*df*	Sig. (*p*)	η^2
Gender				
Impact on science*	9.431	1, 1,773	.002	0.005
Classroom interaction	3.645	1, 1,773	.056	0.002
Attendance	0.396	1, 1,773	.529	0.000
Major				
Impact on science	0.984	1, 1,773	.321	0.001
Classroom interaction**	10.468	1, 1,773	.001	0.006
Attendance	0.868	1, 1,773	.352	0.000

Note: Sig. = significance.
*$p < 0.01$ **$p < 0.001$

Clearly the type of personal response system used matters. Although colleges are beginning to institutionalize clicker systems throughout their campuses, many still allow professors to choose their own system, resulting in a potential scenario in which students may be forced to buy three or more clickers for a single semester with no guarantee that they will be used in future courses. Informal discussions with students have revealed frustration with this and may help explain why upperclassmen have a poorer opinion of clickers than do underclassmen.

Perceptions of cases

A pattern similar to that for clickers was found in students' attitudes toward cases. Multivariate tests show that gender, $F(3, 1{,}446) = 3.349, p < .05$, and major, $F(3, 1{,}446) = 5.997$, $p < .001$, significantly influenced students' perceptions of using cases. According to univariate tests (see Table 3), female students had more positive perceptions that using cases influenced their understanding of science than did male students, $F(1, 1{,}446) = 9.431, p < .01$. Nonscience majors were more likely to believe that using cases can improve classroom interaction than science majors, $F(1, 1{,}446) = 9.431, p < .01$. It may be that science majors, who are comfortable with content and lecture situations, do not see as much need to use alternative pedagogical approaches. Another possible explanation is that the real-world scenarios presented within the case studies allowed nonmajors to relate the material to their own lives and to contextualize the information (Herreid 1994, 2006b; Wolter, Kang, et al. 2009; Wolter, Lundeberg, and Bergland 2009).

Conclusion and implications

We explored whether a new pedagogy using personal response systems (clickers) along with case study teaching improved students' perceptions of their understanding of science in large introductory biology classrooms. Results indicated that students were generally positive toward the use of both clickers and cases, especially women and nonscience majors. The results also suggested that the type of personal response system used matters in students' perception.

Our findings demonstrate that using clickers may be particularly beneficial to nonscience majors, women, and freshmen. In other words, the increased student interaction and engagement achieved by incorporating clickers and cases can be particularly beneficial to students who are not typically represented in science classrooms. This study also suggests that instructors need to be more careful in selecting the type of clicker systems. Each system has different merits, but students showed different preferences toward different personal response systems. Instructors need to be mindful of the fact that the type of clicker system may result in the variation at the level of student perception associated with using clickers.

In summary, the use of clicker cases has the potential to increase classroom interactions, although their efficacy depends largely on instructional strategies. Research has shown that using clickers can improve student performance by facilitating peer discussion (Smith et al. 2009) and promoting cognitive engagement (Mayer et al. 2009), whereas cases engage and motivate students (Bergland et al. 2006; Wolter, Kang, et al. 2009). Although the incorporation of clicker cases into large lecture halls presents challenges, this data suggests that doing so can access the benefits of both clickers and cases (Herreid 2006b; Wolter, Kang, et al. 2009). ■

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