2012

Classroom Response Systems Have Not "Crossed the Chasm": Estimating Numbers of Chemistry Faculty Who Use Clickers

Mary E. Emenike
Iowa State University

Thomas Holme
Iowa State University, taholme@iastate.edu

Classroom Response Systems Have Not "Crossed the Chasm": Estimating Numbers of Chemistry Faculty Who Use Clickers

Abstract

Results of a national survey of faculty usage of assessment tools are presented and framed within the concept of the technology adoption life cycle. Specifically, the use of classroom response systems as reported by survey participants suggests that the adoption of this technique in chemistry is still at the "early adopters" stage, or perhaps is just beginning to cross into the "early majority" category. This transition is viewed within this model as a chasm to be crossed, and data from this work suggest that transition is not yet fully achieved.

Keywords

interdisciplinary/multidisciplinary, computer-based learning

Disciplines

Curriculum and Instruction | Higher Education | Other Chemistry | Science and Mathematics Education

Comments

Reprinted (adapted) with permission from J. Chem. Educ., 2012, 89 (4), pp 465–469.

JOURNAL OF CHEMICAL EDUCATION

Article

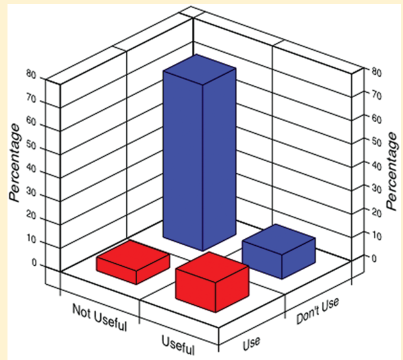
pubs.acs.org/jchemeduc

Classroom Response Systems Have Not "Crossed the Chasm": Estimating Numbers of Chemistry Faculty Who Use Clickers

Mary E. Emenike and Thomas A. Holme*

Department of Chemistry, Iowa State University, Ames, Iowa 50011, United States

ABSTRACT: Results of a national survey of faculty usage of assessment tools are presented and framed within the concept of the technology adoption life cycle. Specifically, the use of classroom response systems as reported by survey participants suggests that the adoption of this technique in chemistry is still at the "early adopters" stage, or perhaps is just beginning to cross into the "early majority" category. This transition is viewed within this model as a chasm to be crossed, and data from this work suggest that transition is not yet fully achieved.



KEYWORDS: *Interdisciplinary/Multidisciplinary, Computer-Based Learning*

■ BACKGROUND

Recent articles describing the use of classroom response systems (CRS) or clickers in STEM (science, technology, engineering, and mathematics) education typically discuss how CRS are used in a specific course, and provide information about the instructor and students' experiences with this technology.[1−11] Most reports describe the use of CRS in large or introductory courses,[5−9] while some reports specifically address small classes or upper-level courses.[9−11] MacArthur and Jones[12] provided a review of the literature related to CRS use in college chemistry classrooms, while Woelk[13] provided a taxonomy of types of CRS use ranging from taking attendance to encouraging out-of-the-classroom engagement.

To place the impact of CRS on learning in college chemistry, it is important to consider the role of clickers in the context of how students learn. According to the theory of meaningful learning,[14] learning occurs in three domains: cognitive, affective, and psychomotor. The most meaningful learning will occur when students learn content through all three domains. Cognitive learning includes the student's thoughts and ideas about some content, affective learning includes the student's attitudes and emotions toward this content, and psychomotor learning includes the student's physical interactions with this content.

For the most part, reports on the use of CRS in STEM education focus on affective measures.[5,6,8−10] Psychomotor learning may be connected to affective learning because inputting responses with clickers requires a more active process than simply thinking about one's answers. However, when CRS are only used for taking attendance, there is likely no psychomotor learning associated with the use of this technology. There have been attempts to measure cognitive learning when using CRS. Hunter et al.[6] provided subscores from concept tests for items related to statistics in an introductory biology course, but there was no comparison to a control class not using CRS. Bunce et al.[7] compared students using CRS and WebCT online quizzes in a general, organic, and biology chemistry course for nursing majors. Their findings suggest that the WebCT quizzes had a significantly positive effect on student achievement on teacher-written exams, but CRS did not, because the WebCT quiz questions were available for students to review and reflect upon outside of class. Ultimately, the effectiveness of clickers should be evaluated from the perspective of all three learning domains.

Four of these reports specifically discuss the challenges to CRS adoption.[3,9,10,12] Koenig[3] investigated physics faculty members' use of CRS and found that (ref 3, p 47),

> *Some expressed concern regarding the time it would take to (1) get the clicker hardware and software running, (2) develop effective clicker questions and create presentation slides, (3) learn the software for posing clicker questions and tracking students, and (4) rewrite current lectures to allow time for clicker use.*

Sevian et al.[9] and Milner-Bolotin et al.[10] also reported challenges related to time and effort and the need to "cover material". While CRS technology is not applicable to every course or every classroom, faculty members likely benefit from the opportunity to make an informed decision about whether or not to adopt CRS technology. Such information should include knowledge about the different ways to use CRS in the classroom and findings from research that investigate the effects of CRS technology on cognitive, affective, and psychomotor learning.

Published: February 7, 2012

In the December 2010 issue of the *Journal of Chemical Education*, Towns[15] described the "technology adoption life cycle" (TALC)[16,17] and how it could be used to explain the adoption of classroom response systems. According to this model, the number of users of a new technology can be described by a normal distribution, where each standard deviation away from the mean represents a group of adopters with different psychographic profiles. Figure 1 represents this concept, where the percentage of the population for each group of adopters was added to Towns' representation.[15] Technology adoption does not occur seamlessly across these groups, and a "chasm" exists between the early adopters and the early majority. Studies of technology adoptions find that not all technology is able to cross this chasm and be adopted by a majority of users.

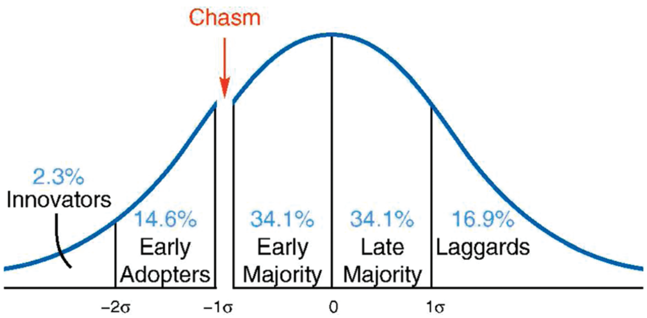


Figure 1. Percentage of members in each group of the technology adoption life cycle as adapted from ref 16.

MacArthur and Jones[12] claimed "Although clickers appear to be widespread in chemistry classrooms, publications of results of clicker use are few in comparison to those in physics" (ref 12, p 192). Yet the term "widespread" is ambiguous; it could be referring to a large number of classrooms that use CRS, or to a large variety of classrooms. Furthermore, it is not obvious how the term "widespread" fits with the groups of adopters described in the TALC model (Figure 1). Has clicker adoption "crossed the chasm" and moved past innovators and early adopters? If so, does CRS technology appear to be adopted by only the early majority or by the late majority as well? The data reported herein address the prevalence of clicker use by current chemistry faculty members across the country. The findings from this analysis support the need for additional, in-depth research into the use of clickers so that the chemistry education community can better evaluate the effects of CRS and possibly improve the use of this technology as a pedagogical tool.

RESEARCH QUESTIONS

As part of a recent needs assessment survey,[18] information was collected on the use and perceived usefulness of clickers. This set of data provides a snapshot of the current state of clicker use among a national sample of chemistry instructors. Specific questions of interest include: (i) What is the prevalence of clicker adoption by chemistry faculty members and how does this compare to the TALC model? (ii) For the following subgroups of chemistry faculty members (institution type, sex, years teaching chemistry, and discipline), are certain subgroups more likely than others to use clickers or find clickers useful?

METHODOLOGY

A needs assessment survey was developed from data collected during focus groups at four regional chemistry conferences in fall of 2009. This online survey was piloted in the spring of 2010, and the revised survey was implemented in the summer of 2010. A database of chemistry faculty members was developed using information available on departmental and institutional Web sites. Institutions within the United States were classified as two-year (at most associate degrees awarded in chemistry or physical science), four-year (at most master degrees awarded in chemistry), or doctoral (granting doctorate degrees in chemistry). Contact information was collected for individual faculty members at each institution from Web sites, where *chemistry faculty member* is defined as an instructor of college chemistry at any faculty-level standing (tenured, tenure-track, or nontenure-track). Participation in the national online survey was enabled by e-mail communication to all contacts in the database (approximately 15,000 contacts). Demographic data collected from participants at the end of the survey including sex, years teaching chemistry, and chemistry discipline.

While the survey probed a wide range of aspects related to assessment, of interest to this report was a question that asked survey participants to indicate with check boxes which tools they "use" and which tools they "find useful". "Student response systems/Clickers" was one of the nine tools listed. Types of homework, laboratory reports, writing assignments, types of exams, and student evaluations (surveys) were among the other tools listed. Logistic regression[19,20] was used to determine whether relationships existed between or among subgroups of chemistry faculty members and their use of clickers or their perceived usefulness of clickers.

In brief, analyzing binary data (e.g., "use clickers" = 1, "do not use clickers" = 0) with logistic regression enables the prediction of the probability of an outcome based on a logit-function logistic curve (s-shaped curve). The prediction can be described using the probability of the outcome (nonlinear) or the odds of the outcome (linear). The odds of the outcome is the ratio of the probability of success for that outcome divided by the probability of failure for that outcome. The nonlinear regression equation can also be transformed into an odds ratio or ratios, which are easier to understand based on their linear relationships to the independent variable(s). The odds ratio describes the odds of success based on a one-unit increase in the variable. For example, an odds ratio of 1.6 would be interpreted as: *the odds of observing the outcome is 1.6 times greater for every one-unit increase in the variable*. Similarly, the interpretation could also be phrased: *a one-unit increase in the dependent variable increases the odds of observing the outcome by 1.6 times.*

DATA AND FINDINGS

Over 1500 chemistry instructors responded to the needs assessment survey (10% response rate). Overall, the sample of participants contained more men than women (sex: 63% male, 35% female, 1% prefer not to say, <1% other); however, the discrepancy between participation among men and women was related to institution type. Specifically, participants were more likely to be men at doctoral institutions than at four-year (p = 0.001) and two-year institutions ($p < 0.001$). Rigorous demographics for instructional staff across all possible locations for chemistry teaching are unavailable. Considering the

dx.doi.org/10.1021/ed200207p | J. Chem. Educ. 2012, 89, 465−469

comparison of this sample to published demographics for top doctoral programs[21] that finds 14% women in chemistry departments, the current work has 28% women from doctoral schools and suggests the responses to this survey may have oversampled women. Furthermore, based on the sales of ACS Exams, responses have indicated oversampled instructors using ACS Exams (71% in our sample). This situation is not surprising given the fact that these instructors are familiar with the Exams Institute and would therefore be more likely to respond to a survey from us, given our association with the Exams Institute. It is also important to keep in mind that the needs assessment survey was focused on assessment in general, rather than innovative practices or the use of technology in chemistry education. The two questions on the use and perceived usefulness of clickers represent a small fraction of the total number of questions in the survey.

While 18.6% of the participants reported using clickers, only 12.8% reported that they used clickers *and* found clickers useful (Table 1). Conversely, 71% of the participants reported that they did not use clickers *and* they did not find clickers useful. The percentage of faculty members who reported that they find clickers useful (23.2%) was larger than the percentage of faculty members who reported using clickers (18.6%). The design of the survey allowed participants to indicate that they find clickers useful regardless of whether or not they indicated that they use clickers. It is difficult to analyze the implications of the 76.8% of faculty who reported they do not use clickers and they do not find clickers useful because the two facets of the analysis were asked as a single question; it is possible that a large percentage of the faculty members who did not report using clickers did not even consider whether they find clickers useful or not.

Table 1. Overall Reported Clicker Use and Perceived Usefulness of Clickers

		Use Clickers, %	Do Not Use Clickers, %
	Total, %[a]	18.6	81.4
Find Clickers Useful	23.2	12.8	10.4
Do Not Find Clickers Useful	76.8	5.8	71.0

[a] N = 1546.

Other data collected from the needs assessment survey shed light on the demographics of the chemistry instructors who use clickers (Table 2). Similar to Table 1, Table 2 also shows a higher percentage of faculty members reporting that they find clickers useful than that they use clickers for each demographic subgroup. Using logistic regression,[20] no statistically significant differences were found between male and female faculty members' use of clickers or their perceived usefulness of clickers. While the number of years teaching chemistry was not related to the use of clickers, an increase in the number of years teaching chemistry decreased the probability of a faculty member finding clickers useful (p = 0.010). The effect size of this difference was quite small (odds ratio: 0.9828), however, which suggests that the change in the probability between faculty teaching one more or one fewer years is quite minimal compared to the change across the entire range of years teaching. It may be that younger faculty members are more comfortable with technology, but additional research would be needed to explain this finding.

Table 2. Subgroups of Faculty Members' Use and Perceived Usefulness of Clickers

Categories	Subcategories	Responses, N	Use Clickers, %	Find Clickers Useful, %
Institution Type	Two-year	328	13.1	21.0
	Four-year	792	17.4	21.1
	Doctoral	426	25.2	29.0
Sex	Male	969	17.4	21.9
	Female	547	20.7	26.0
Years Teaching Chemistry	1−5	278	20.9	29.9
	6−10	330	17.6	23.9
	11−15	260	17.7	20.4
	16−20	229	22.7	25.3
	21−25	162	17.9	21.6
	26−30	86	17.4	19.8
	>30	179	15.3	17.3
Discipline	Analytical chemistry	198	17.7	28.3
	Biochemistry	133	16.5	18.8
	Chemistry education	147	25.9	25.9
	Inorganic chemistry	283	18.4	23.3
	Organic chemistry	430	16.5	21.9
	Physical chemistry	262	19.8	24.0
	Other	93	19.4	21.5

Faculty members from a doctoral institutions were 2.2 times more likely to report using clickers than faculty members from two-year institutions ($p < 0.001$) and 1.6 times more likely to report using clickers than faculty members from four-year institutions (p = 0.001). No statistically significant difference was found between faculty members from two-year and from four-year institutions in their reported use of clickers. Furthermore, faculty members from doctoral institutions were 1.5 times more likely to report finding clickers useful than faculty members from both two-year institutions (p = 0.014) and from four-year institutions (p = 0.002).

Most pairwise comparisons of faculty members between different disciplines were not statistically different for the use of clicker or for finding clickers useful. However, faculty members who identified their discipline as "chemistry education" were 1.6 times more likely to report using clickers than faculty members who did not identify their discipline as "chemistry education" (p = 0.019). Furthermore, faculty members who identified their discipline as "chemistry education" were 1.8 times more likely to report using clickers than faculty members who identified their discipline as "organic chemistry" (p = 0.014). Finally, faculty members who identified their discipline as "analytical chemistry" were 1.7 times more likely to report finding clickers useful than faculty members who identified their discipline as "biochemistry" (p = 0.050).

DISCUSSION

While Towns[15] discussed "crossing the chasm" in the TALC model from a theoretical basis, the data from the needs assessment survey suggests that, in fact, the adoption of clickers is essentially at the chasm for chemistry faculty. In the simple model of TALC, innovators and early adopters comprise 16.9% of adopters and survey results indicate that 18.6% of chemistry faculty members are using clickers. For the sample obtained,

dx.doi.org/10.1021/ed200207p | J. Chem. Educ. 2012, 89, 465−469

the 95% confidence interval is ±2.5%, so these two values are not distinguishable. It is quite clear that the TALC model suggests that the early majority adopters, the group of users immediately after the chasm, are not yet strongly engaged in the new technology. Moreover, not every subgroup of chemistry faculty appears to adopt clicker technology to the same degree. For example, faculty members from two-year institutions report a use of clickers that is apparently below the chasm cutoff (13.1%). The only two identifiable subgroups in the sample that appear to be well into the early majority category are faculty members from doctoral institutions (25.2% adoption) and faculty who identify as specializing in chemistry education (25.9% adoption.)

The findings that faculty at doctoral institutions are more likely than faculty at two-year and four-year institutions to use clickers and more likely to find clickers useful is not surprising given the typical class sizes at these institutions. If chemistry class sizes at two-year and four-year institutions are small, instructors may be more confident that they can interact with their students at a more individual level. These interactions are able to provide instructors with insights to their students' ideas about chemistry concepts. For large chemistry classes, typically found in doctoral institutions or in introductory courses, individual interactions between students and the instructor are less prevalent. Classroom response systems could be used in these instances to provide information to instructors about their students' ideas. Additional research would be needed to determine whether clickers are being used in larger classes to provide information to instructors about their students' ideas or for other purposes, such as a means to record attendance.

It is also likely that the largest classes at any institution tend to be general chemistry and organic courses. People who teach these courses are more likely to identify themselves as specialists in chemistry education, so they may have a higher adoption rate because of their teaching environment, or potentially because they are more aware of the utility of CRS as a pedagogical tool. The upper-level courses (analytical chemistry, biochemistry, inorganic chemistry, and physical chemistry) are likely to have smaller class sizes, even in doctoral institutions, and the faculty from these disciplines reported lower levels of clicker use. However, organic chemistry faculty members reported the lowest use of clickers and they are not likely to have small classes, especially in doctoral and even four-year institutions. This suggests that although general chemistry and organic courses may have many students in a class, other factors may discourage the use of clickers for organic chemistry faculty members. Additional research would be needed to understand *why* clickers are not used as often in organic as in general chemistry, even though they both have large classes sizes.

IMPLICATIONS FOR FUTURE RESEARCH

Findings from this needs assessment survey provide a snapshot into chemistry faculty members' current practices related to using clickers. The fact that a minority of chemistry faculty members (18.6%) reported using clickers does not imply any need to convince all other faculty members to use clickers. As noted above, clicker technology is not applicable to every course, or every classroom. A qualitative investigation into how clickers are used by a range of chemistry faculty (institution type, class size, course level, discipline) would likely provide insightful information related to Woelk's[13] taxonomy of clicker use. Further in-depth quantitative and qualitative investigation could shed light on the prevalence of clicker use in chemistry education based on the kinds of clicker questions instructors find useful and why. Findings from such research could provide additional insights into chemistry faculty members' current practices, the nature of the gap in CRS technology adoption, and potential areas for pedagogical improvements using CRS technology.

Any new technology establishes a profile among possible adopters. Because of the growing literature base about CRS,[1−15] it would seem prudent to identify information that would assist any interested faculty member to make an informed decision about whether or not this technology would be useful in his or her classroom. Research designed to investigate the effects of clicker use on cognitive and psychomotor learning (to complement the current research on affective learning) may provide the most convincing evidence to instructors who want evidence that their time investment will result in improved student learning.

It may also be interesting to investigate faculty members who find clickers useful, but for whatever reason do not use them. A mixed-method investigation could be designed to identify the challenges of clicker use and quantify the prevalence of such challenges. This information may provide a foundation for the chemistry faculty who currently use clickers (innovators and early adopters) to address these issues, communicate the benefits of clicker use to these faculty members, and ultimately help CRS technology "cross the chasm" into the early majority group of adopters.

AUTHOR INFORMATION

Corresponding Author

*E-mail: taholme@iastate.edu.

ACKNOWLEDGMENTS

Funding for this research was provided by NSF DUE #0920266.

REFERENCES

(1) Ribbens, E. *J. Coll. Sci. Teach.* **2007**, *37* (2), 60−62.
(2) Hatch, J.; Jensen, M.; Moore, R. *J. Coll. Sci. Teach.* **2005**, *34* (7), 36−39.
(3) Koenig, K. *J. Coll. Sci. Teach.* **2010**, *39* (3), 46−50.
(4) Keller, C.; Finkelstein, N.; Perkins, K.; Pollock, S.; Turpen, C.; Dubson, M. *Phys. Educ. Res. Conf.* **2007**, *951* (1), 128−131.
(5) Herreid, C. F. *J. Coll. Sci. Teach.* **2006**, *36* (2), 43−47.
(6) Hunter, A.; Rulfs, J.; Caron, J. M.; Buckholt, M. A. *J. Coll. Sci. Teach.* **2010**, *40* (2), 19−25.
(7) Bunce, D. M.; VandenPlas, J. R.; Havanki, K. L. *J. Chem. Educ.* **2006**, *83*, 488−493.
(8) Bjørn, J. K.; Wolter, B. H. K.; Lundeberg, M. A.; Kang, H.; Herreid, C. F. *J. Coll. Sci. Teach.* **2011**, *40* (4), 14−19.
(9) Sevian, H.; Robinson, W. E. *J. Coll. Sci. Teach.* **2011**, *40* (3), 14−18.
(10) Milner-Bolotin, M.; Antimirova, T.; Petrov, A. *J. Coll. Sci. Teach.* **2010**, *40* (2), 14−18.
(11) Ruder, S. M.; Staumanis, A. R. *J. Chem. Educ.* **2009**, *86*, 1392−1396.
(12) MacArthur, J. A.; Jones, L. L. *Chem. Educ. Res. Pract.* **2008**, *9*, 187−195.
(13) Woelk, K. *J. Chem. Educ.* **2008**, *85*, 1400−1405.
(14) Bretz, S. L. *J. Chem. Educ.* **2001**, *78*, 1107.
(15) Towns, M. H. *J. Chem. Educ.* **2010**, *87*, 1317−1319.
(16) Moore, G. A. *Crossing the Chasm*; Collins Business: New York, 2002.

(17) Rogers, E. M. *Diffusion of Innovations*, 4th ed.; Free Press: New York, 1995.
(18) Reviere, R.; Berkowit, S.; Carter, C. C.; Graves Ferguson, C. *Needs Assessment: A Creative and Practical Guide for Social Scientists*; Taylor Francis: Washington, DC, 1996.
(19) Pampel, F. C. *Logistic Regression Analysis*; Sage: Thousand Oaks, CA, 2000.
(20) Long, J. S. *Regression Models for Categorical and Limited Dependent Variables (Advanced Quantitative Techniques in the Social Sciences)*; Sage: Thousand Oaks, CA, 1997.
(21) Nelson, D. J. *Nelson Diversity Surveys*; Diversity in Science Association: Norman, OK, 2004. http://faculty-staff.ou.edu/N/Donna.J.Nelson-1/diversity/top50.html (accessed Jan 2012).