A Student Response System for Increasing Engagement, Motivation, and Learning in High Enrollment Lectures

Richard H. Hall
University of Missouri - Rolla
rhall@umr.edu

Harvest L. Collier
University of Missouri - Rolla
hcollier@umr.edu

Marcie L. Thomas
University of Missouri Rolla
thomasm@umr.edu

Michael G. Hilgers
University of Missouri - Rolla
Hilgers@umr.edu

ABSTRACT

Student response systems (SRS) are devices that allow students to provide categorical and numerical responses to questions embedded within a lecture, and the responses can be tallied and scored in various ways to provide immediate feedback to the students and/or professors. In the fall of 2004 at the University of Missouri – Rolla, questions were systematically integrated into large general chemistry lecture sections, and students used the response system to answer. In order to evaluate the system, students' test scores were compared with previous years, and a survey was administered with the aim of evaluating the system at the end of the course when SRS was used. Test scores indicated substantial improvement from previous years. In addition, survey results indicated that a significant majority of the students found that the SRS made the course more engaging, motivational, and increased learning. Qualitative analyses of students' open-ended responses provided support and additional insights for the quantitative analyses.

Keywords

Student Response System, Classroom Communication System, Leaner Engagement, SMET Education.

MOTIVATION

This research took place at a medium sized Midwestern technological research University with a large percentage of students majoring in science and technology fields. As such, general Chemistry plays an important foundational role in student development. Each semester, hundreds of students take the first course in General Chemistry. This course includes large lecture sections, and much of the important foundational content for the course is presented via the lecture. Despite the fact that undergraduate students come to this University with the highest college entrance exam scores among public higher education institutions in the state, there is a general feeling among instructors in Chemistry and subsequent courses that students are leaving the introductory class without adequate preparation. This problem appears to be, in no small part, due to a disconnect between student and faculty awareness, with respect to perceived and actual learning. This is illustrated by the fact that students rarely ask questions in class, though many clearly do not understand much of the material based on their test performance. In turn, the instructors find it difficult to identify where students are having problems. Two main problems have been identified as major factors in accounting for these difficulties. First, students are simply overconfident, unable to identify when they have learned – a lack of metacognitive awareness (Flavell, 1979). Second, students are not effectively engaged, which is a fundamental problem often associated with the direct-instruction/lecture format (Cooper, 1995; Schank, Berman, & Macpherson, 1999).

As a consequence of these problems the department set out to identify a solution that would increase students' metacognitive awareness and level of engagement in lecture. At the same time the solution had to be logistically practical for large lecture environments. A potential solution was identified in the form of a student response system (SRS). These systems, which are also referred to as electronic response systems (ERS); personal response systems (PRS); audience response systems (ARS); or classroom communication systems (CCS), allow each student to immediately respond to some type of closed ended question (usually multiple choice) via a distinct electronic sending unit. The results are then immediately available to the instructor, who can show them to the class via some type of multimedia presentation (Judson & Sawada, 2002; Ward, Reeves, & Heath, 2003). Such a system could potentially address the problems of metacognitive awareness and engagement via quizzes embedded at strategic points within the lecture. The quizzes could provide feedback to students and faculty on the level of student learning and provide students with extra motivation to be engaged in the lecture. At the same time it would seem that such a system could easily be integrated into the lecture format and allow for collection of responses from a large number of students quickly. Although the advantages of such a system for addressing these issues seems self evident, it is important to first consider previous research that has examined the use of PRS in lecture environments.

RESEARCH ON PERSONAL RESPONSE SYSTEMS

Personal Response Systems in various forms have been used in classrooms since the 1960s. These early systems were hard-wired with a series of knobs or buttons at students' desks and instructor stations provided a series of gauges that indicated the percent of students responding to each multiple choice option (Judson & Sawada, 2002). Thus, although the sophistication of the technology has increased significantly via the use of wireless devices, receivers, and automated integration of results into various software packages, the fundamental method for SRS was basically the same. Early research on the efficacy of these devices was disappointing in terms of learning outcomes (Judson & Sawada, 2002; Ward et al., 2003). However, students consistently reported higher levels of engagement and positive attitudes about the effectiveness of the systems (Judson & Sawada, 2002).

In recent years, with more advanced technological devices, researchers have continued to find positive responses in students' views on attitudes towards these responses systems (Judson & Sawada, 2002). In addition, researchers are beginning to find positive effects in learning outcomes as well. For example, using an SRS called a classroom communication system (CCS) (Abrahamson, 1999), Mazur found dramatic increases from pre-post test gains in student's physics knowledge in classes that used this system as compared to those with students who didn't (Mazur, 1997) It's important to note, however, that Mazur used the system specifically to promote peer interaction. In response to professor's questions, students discussed the questions in teams and then responded with an answer. In fact, in a review of electronic response devices Judson and Sawada (Judson & Sawada, 2002), note that the more recent positive learning outcomes are the results of pedagogical changes made possible by these devices; as opposed to the devices themselves. More specifically, according to these authors, collaborative interaction and the use of higher level conceptual questions to enhance discussion in large enrollment classes promote learning.

In perhaps the largest and most comprehensive study of SRS, Poulis and colleagues (Poulis, Massen, Robens, & Gilbert, 1998) examined the effectiveness of an SRS used at Eindhoven University in Physics classes in large lectures. Over the course of a period of years instructors used the system in a relatively consistent and straight forward manner. For example, if more than 30% of the students miss a multiple choice item with three options, or, if there was an inappropriate wait time in student responses (based on complexity of the question), the instructor reviews the material step-by-step and asks an additional question to re-check understanding. In addition, at the end of the lecture the instructor quizzes students about their opinions on the speed of the lecture (e.g., "Who thought the lecture was too slow/too fast etc…"). Based on the response to this question, instructors made an effort to modify future lectures. The researchers note that the typical lecture consisted of approximately 20 minutes of SRS functions interspersed with approximately 25 minutes of conventional lecture. To examine the effectiveness of their technique they examined lecture sections over the course of 13 years (1979 – 1992), comparing the sections that used the SRS with those that did not. They found that the pass rate for students in SRS sections (n = 2550) was significantly higher than those in the non-SRS sections (n = 2841), with a pass rate of almost 50% higher for the SRS sections. The researchers also note that the standard deviation was substantially lower in the SRS group, indicative of more consistent understanding among the students.

Particularly relevant to this research is a report on a web-based SRS system called Numina II especially designed for large lecture sections and labs in Chemistry at the University of North Carolina (Ward et al., 2003). Instructors use the system in numerous ways, including: a) asking content questions during lecture and lab; b) checking understanding of procedures and techniques prior to starting lab exercises. Instructors observed a number of positive consequences associated with the use of the devices, such as increases in student participation in class and increases in student-instructor interactions. A more formal evaluation of the system focused on logistical concerns that instructor's off-task behaviors, technical problems, and distributing/collecting of the devices would interfere with lecture. Results indicated that these issues were minimal.

RESEARCH QUESTIONS

The fall of 2004 served as the pilot implementation of a student response system in Chemistry lectures. The purpose of this research was to conduct an initial evaluation of the system. More specifically, the research questions addressed were:

1. Did test grade distributions differ significantly between semesters when the student response system was used vs. semesters when it was not?

2. Did students perceive that the student response system
    a. made the course more challenging?
    b. made the course more engaging?
    c. enhanced learning?
    d. made the lecture more motivational?
    e. made the lecture more relevant to "real world" problems?
3. What additional issues will impact the effectiveness of the system?

METHOD

Participants

One thousand two hundred and twenty one undergraduate students in General Chemistry courses at a medium sized Midwestern technological University took part in this experiment. Course grades were considered for 651 students for the Fall 2003 and 570 students for the Fall of 2004 when the student response system was used. In addition, 348 students in the 2004 course completed end-of-semester surveys.

Materials

The TurningPoint® system by Turning Technologies was the student response system used in this research. The system includes handheld key pads for students, a receiver, and software. The software allows for integration of the results with Microsoft Office® so the results can be automatically displayed within a PowerPoint ® presentation; responses can be tracked and recorded via Excel® or Microsoft Word®; or the results can be communicated and shared via Outlook® (http://www.turningtechnologies.com).

A survey was used to collect evaluation data. Five Likert items were relevant to this research. Students responded to each item on a 10 point scale with 1 representing strongly disagree and 6 representing strongly agree. The five items were:

1. The student response system made the class lectures more challenging.
2. The student response system made the class lectures more engaging.
3. The student response system enhanced my learning in the class lectures.
4. The student response system made the lectures more motivational.
5. The student response system helped me to better understand how the course material related to "real world" problems.

In addition, students responded to the following open-ended items:

1. Please list and explain the strengths and weaknesses of the student response system as a tool for enhancing the effectiveness of the lectures.
2. Please list and explain additional suggestions you have for improving the effectiveness of the student response system.

Procedure

In the fall of 2004 the student response systems were piloted in all lecture sections of General Chemistry. They were used in the following ways: 1) Students were required to respond to questions regarding reading assignments before lectures; 2) Students were required to respond to questions periodically throughout lecture. With respect to questions embedded in the lectures, students were often allowed to discuss the answers with a group of peers before responding. Lectures were modified accordingly based on student understanding as represented by the accuracy of their responses.

On the last day of lecture in the semester students completed the questionnaire as a part of their regular class evaluations. It was emphasized that the questionnaire responses were completely confidential, such that those scoring the data would not see the student's name associated with their data, and the instructors would have no knowledge of student's individual responses.

RESULTS

Grade Distribution Comparison

Course Grades for the fall 2004 semester (n = 574), when the student response system was used, were compared to course grades in the fall semester of 2003 (654) when the system was not used. For each grade level (A, B, C, D, F, and Withdraw) a Chi-Square test was computed comparing the two semesters on the total number of grades at each level. For these Chi-Square tests the expected value was calculated for each year by multiplying the total number of grades by the proportion of total students represented for each year (.47 for 2004 and .53 for 2005). For example, the total number of A's for both years was 381, so, if the years were equivalent, the expected value for 2004 would be 179.07 (381 * .47) and 201.93 for 2003 (381 * .53).

The frequencies for each grade (expressed as a percentage of total grades for that year) as a function of year, with significant Chi-squares noted, is presented in Figure 1.

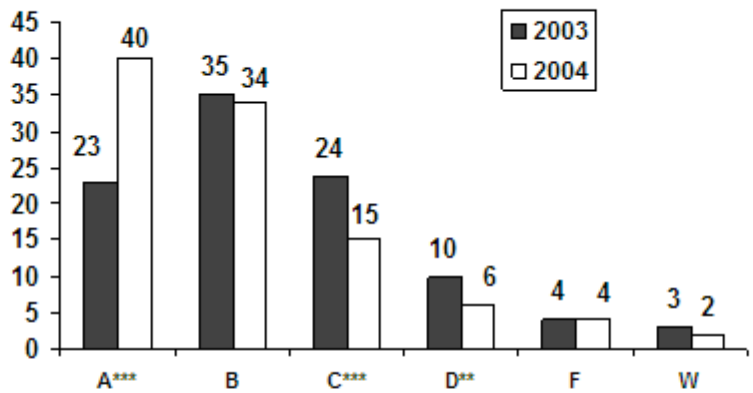

Figure 1. Grade Distribution Percentages as a Function of Year (p < .01; ***p < .001)**

Quantitative Survey Analysis

In order to address the first experimental question, students' responses were dichotomized based on their response to each item. Responses of 1, 2, or 3 were classified as "do not agree" and responses of 4, 5, or 6 were classified as "agree". A series of Chi-square tests were then performed on frequencies of responses for "agree" vs. "disagree" for each of the five questionnaire items. These frequencies are displayed in Figure 2, with statistically significant differences indicated.

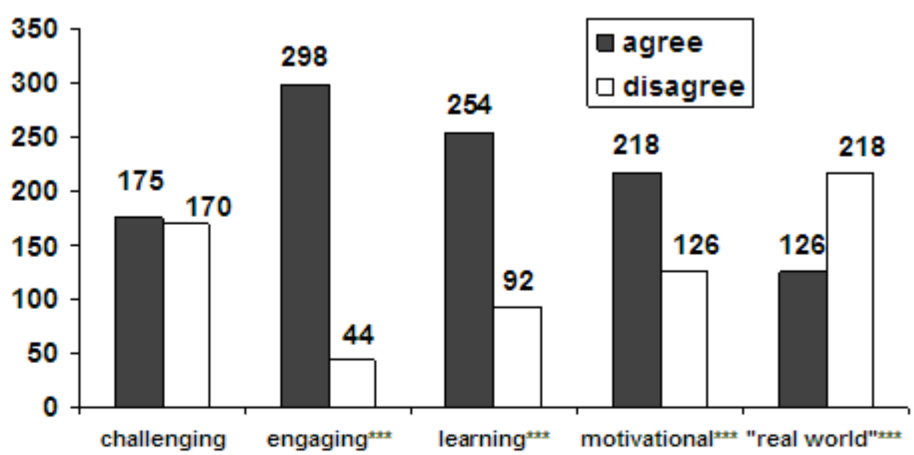

Figure 2. Frequency of "Agree" vs. "Disagree" responses for questionnaire items. (*p < .001)**

Qualitative Survey Analysis

Students' responses to the open-ended items were reduced to a series of canonical quotes, such that each quote represented one statement or concept. These items were then examined, six major themes were identified, and items were categorized according to these themes. The themes and representative quotes follow:

1. **The SRS lead to more efficient use of class time and materials**
    - They allow more time b/c you don't have to pass out quizzes.
    - They are good way to collect large amounts of data without having to grade thousands of quizzes.
    - They're a lot more efficient than paper & pencil.
2. **The SRS increased student engagement**
    - They help to engage the students and keep us awake.
    - The clickers helped me pay attention and get involved with the problem solving.
    - They helped you pay attention in class because you knew you had a question coming.
3. **There were technical issues that hampered the effectiveness of the SRS**
    - Better color contrast on the screen. More unobstructed receivers. Battery checks.
    - Have more receivers so that the answers can be put into the computer faster, or don't have timed problems.
    - The sensor to inquire the IR signal is weak so that students have to wait long to answer using clickers.
4. **The SRS facilitate group work**
    - The clickers allowed for group discussion.
    - They let you discuss strategies with the people around you.
    - Through the use of the clickers you interact more
5. **The PRS provided incentive for students to attend class prepared.**
    - They encourage you to go to class …
    - Our row found the clickers helpful to learn what the professor was wanting us to get out of the reading.
    - They forced you to read the chapters which, in turn, helps your understanding and, therefore, your grade.
6. **The PRS enhanced metacognitive awareness**
    - … you can see the areas you need to go back and look at when you get questions wrong.
    - I like the clickers because I feel it's a good way to know if you understand that material and might need to go over it again.
    - Strengths - useful for … helping see if I understand.

DISCUSSION AND CONCLUSIONS

With regard to the first experimental question, an examination of the grade distributions between the semester when the SRS was used and a control semester when it was not used, indicates that grades were substantially better during the semester when SRS was used. More specifically, significantly more students received an A when the SRS was used and significantly less students got a grade of C or D when the system was used. Of course, it's important to note that, although the department makes an effort to grade equivalently from year to year, we do not have any specific control to assure this was the case. Further, we cannot be sure that the students were equivalent in ability for the two years. However, these are the type of distributions that would be expected if the SRS had a positive and significant impact on performance, and the results certainly provide support for this contention, particularly when considered in combination with the analyses of the end-of-the-semester questionnaire administered to the students who were exposed to the SRS system.

In terms of the second experimental questions posed, students who used the SRS system indicated that the system increased the degree of engagement, learning, and motivation significantly. These results were anticipated, largely consistent with research discussed above, and encouraging with respect to the use of the SRS. The qualitative analysis of student comments largely supported these findings. In particular, students referred to an increased level of engagement. It's important to point out, however, that these positive results can not be attributed simply to the system, since SRS is a tool. It is the pedagogical practices that the tool affords that accounted for these results. Therefore, it's important to consider the tool in context. In particular, we will consider the ways in which the tool was used, as well as students' views on the factors that made it effective.

Class periods began with students completing quizzes over the materials they were to read before class. Students' comments indicate that this served as a powerful motivator not just for attendance, but class preparation as well. Also, students indicated that it aided them in understanding what was important in the reading and the degree to which they understood the reading material. These factors would strongly encourage engaged and strategic reading for the students, which would likely generalize beyond this particular course. Of course quizzes that encourage all of these activities could be given without this system, in a paper and pencil format, but professors would not have real time access to student performance to aid them in modifying the lecture accordingly. Moreover, there are a number of logistical difficulties associated with the paper and pencil quizzes, which was something students noted in their comments.

In addition to serving as a tool for pre-lecture quizzes, questions were interspersed throughout the lecture simply for the purpose of making the degree of student understanding explicit to the instructor and students. This also presumably led to the high ratings of student engagement, motivation, and learning; as well as the significant improvement in grades vs. the year before. Student comments indicate that the questions inserted into the lectures periodically, encouraged engagement throughout the lecture period. It is quite possible that students' performance on these questions improved as their engagement and metacognitive awareness improved, which would in turn increase motivation. Students were also often allowed to interact with peers before responding to lecture questions. The importance of this type of collaborative interaction, afforded by such a system, is one of the greatest strengths of a student response system (Judson & Sawada, 2002). Student comments reflect this fact, with several identifying this as an important factor associated with the use of this system. High levels of engagement, motivation, and learning were most likely influenced by the presence of this collaboration.

Although overall the results were positive, the analyses also identified problematic issues and unanticipated results. With respect to the quantitative analyses, the most striking unexpected finding was the fact that significantly more students disagreed with the statement that "the student response system helped me to better understand how the course material related to 'real world' problems." This seems to demonstrate that the degree to which a student is encouraged to pay attention and engage with the lecture, does not necessarily enhance the degree to which the student will see the content as relating to "real world" problems. In fact, if the applicability of the content is not made clear in the lecture, additional learner engagement may make this more evident. Thus, this finding may be indicative of the nature of the content and presentation, rather than a statement about the nature of the SRS. Of course, we can not know to what extent the content influenced this result without examining students' response to different types of content and presentation, so it is simply a speculation until explored further.

The qualitative results also pointed to technical and usability issues. First, a number of students noted that the response of the receivers was less than optimal and sluggish in responding at times. This was apparently particularly frustrating when timed responses were required. One student also indicated that the screen was difficult to read due to poor color contrast, and batteries sometimes went unchecked. Clearly, these technical issues will need to be addressed if the system is to be implemented in the future.

In summary, this research served as an initial evaluation of the use of student response systems within large enrollment Chemistry classes at a technological research University and the results are encouraging overall with respect to continuing the project. However, there are still many ways that this research can be extended, with a plethora of issues still to be examined. The most obvious extension on this work is a more controlled efficacy study using control groups during the same semester, identical measures of learning, and controls for ability differences. A more thorough exploration of factors that account for the systems success may be even more important, since previous controlled efficacy studies have been conducted, and the underlying pedagogy associated with the tool's use will provide more fundamental and generalizable information. More specifically, from an observational/qualitative perspective, detailed observation of lectures, and more thorough interviews with students would provide rich and meaningful data on the ways in which the tool is used and understood. With respect to more controlled quantitative explorations, varying methods of using the tool and systematically examining their impact on various outcomes in interaction with other types of measures, such as individual differences, would also yield a more complex detailed understanding of the impact of the SRS.

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