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ABSTRACT

Student response systems (SRS) are keypad devices that allow students to provide responses to questions embedded within a lecture, which can then be used to provide real-time feedback. In the fall of 2005 a second stage pilot implementation of these devices was carried out at a Midwestern technological research University, with 417 students in large enrollment chemistry and calculus courses. The purpose of this study was to conduct an evaluation of this implementation. The research methodology included qualitative field observation and quantitative analysis of students' responses to surveys. The results indicated that: a) Overall, the devices had a strong positive impact on student ratings; b) All instructors used the devices actively, and encouraged collaboration; though they differed in quizzing and collaborative practices; c) Though all instructors' student ratings were high, there were significant differences that may have been mediated by these differences in practices.

Keywords

Student Response Systems, Multi-method evaluation, SMET education.

MOTIVATION

This project constitutes the second stage evaluation of a learning technology system pilot-implementation carried out at a medium-sized Midwestern technological research university. The initial impetus for the implementation of this system was problems identified within introductory level Chemistry courses. Due to the technological emphasis a large percentage of the University's students major 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 some of the highest college entrance exam scores among public higher education institutions in the Midwest, there was a general feeling among instructors in Chemistry and subsequent courses that students were leaving the introductory class without adequate preparation. The problem appeared to be, in no small part, due to a disconnect between student and faculty awareness, with respect to perceived and actual learning. This was illustrated by the fact that students rarely asked questions in class, though many clearly did not understand much of the material based on their test performance. In turn, the instructors found it difficult to identify where students were having problems. Two main problems were identified as major factors in accounting for these difficulties. First, students were simply overconfident, unable to identify when they had learned – a lack of metacognitive awareness (Flavell 1979). Second, students were not effectively engaged, which is a fundamental problem often associated with the direct-instruction/lecture format (Cooper 1995; Schank et al. 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 et al. 2002; Ward et al. 2003). It was thought that 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. In, fact, an evaluation of the first stage of the pilot implementation of the system in Chemistry courses, indicated that such a system did appear to have the potential to address all these problems (Hall et al. 2005). Before, discussing this initial evaluation and its relationship to the current research, 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 et al. 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 et al. 2002; Ward et al. 2003). However, students consistently reported higher levels of engagement and positive attitudes about the effectiveness of the systems (Judson et al. 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 et al. 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 et al. 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 et al. 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 straightforward 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 the initial evaluation 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.

INITIAL PILOT IMPLIMENTATION

The initial pilot-implementation of this system, which preceded the research reported here, was carried out in the fall of 2004 within all the lecture sections of General Chemistry. The appropriate hardware and software was set up in the lecture halls, and the software that was used (described in the materials section below) allowed instructors to easily integrate quizzes within *Microsoft Power Point©* slides. The instructors were encouraged to include quizzes over reading materials, and periodically during lectures to ascertain student understanding, and to modify lectures accordingly.

The evaluation (Hall et al. 2005) consisted of a questionnaire administered on the last day of the course, and an examination of students course grades from previous semesters. 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.

CURRENT RESEARCH

Bolstered by these positive results, the University made the decision to extend the scope of the implementation. A number of additional instructor volunteers were solicited, and, as a result, the SRS system was implemented in additional disciplines, beyond chemistry. The scope of the evaluation was also broadened. In addition to replicating the end of the semester survey in Chemistry, two sections of Calculus were added. Further, the second stage evaluation included an examination of instructors' usage patterns via field observation within the courses.

This second-stage evaluation study addressed the following questions:

1. Did students perceive that the student response system enhanced outcomes such as learning, engagement, and the quality of collaboration?
2. In what ways did instructors' differ in their patterns of use of the SRS system in their courses, especially with respect to quizzing and collaborative practices?
3. How did student perceptions differ as a function of these instructor usage patterns?

METHOD

Participants

Four-hundred and seventeen undergraduate students in General Chemistry (247) and Calculus II (170) at a medium sized Midwestern technological research University took part in this experiment. In addition, four tenured faculty, two in Chemistry and two in Mathematics were the instructors for the four observed courses. All instructors were male.

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. The scale consisted of fourteen Likert Items. Students responded to each item on a 6-point scale with 1 representing strongly disagree and 6 representing strongly agree. The fourteen items were:

1. The "clickers" made the class lectures more engaging.
2. The "clickers" increased the degree to which I collaborated with classmates.
3. The "clickers" made my collaboration with classmates more effective.
4. The "clickers" increased my motivation to attend class.
5. Class was more organized as a result of using the "clickers".
6. The instructor was more aware of student understanding as a result of the "clickers".
7. The instructor modified his or her teaching to meet the class needs as a result of the "clickers".
8. Class objectives were more clear as a result of the "clickers."
9. I learned more foundational facts and concepts as a result of the use of the "clickers".
10. My ability to solve problems associated with class material increased as a result of my experience with the clickers.

11. My ability to understand the connections between concepts and the “big picture” increased as a result of my experience with the clickers.
12. The “clickers” helped the instructor to better achieve class goals.
13. I believe I will remember the material better as a result of the “clickers.”
14. In the future, I will be more likely to enroll in classes that use the “clickers” than those that do not.

Procedure

Implementation

In the fall of 2005 the student response systems were piloted in a number of sections, on a voluntary basis. Four of these were included in this research. Instructors were encouraged to: a) provide quizzes over homework and reading assignments; b) provide quizzes periodically throughout lecture; c) modify the lecture, if necessary, based on student comments; and d) encourage collaboration/discussion associated with the use of the SRS quizzes.

Field Observations

The four instructors who were observed agreed to serve as participants in this research at the beginning of the semester, and arrangements were made with the experimenter for an appropriate observation period. The experimenter sat in the class for the entire period, observed and noted his observations in the form of field notes. The intention was to focus, in particular on: a) the number and nature of the quizzes; and b) the nature of the collaboration that occurred in conjunction with the quizzes.

Survey

On the last day of lecture in the semester, students completed the survey 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

Question 1: Students Perception of Response System

In order to address the first experimental question, which focused on student’s overall evaluation of the system, 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 fifteen questionnaire items. These frequencies are displayed in Table 1 with indication of statistically significant differences, based on Chi-Square analyses of frequency differences.

Item	No	Yes
Made Class More Engaging***	45	372
Increased degree of collaboration***	74	343
Increased Effectiveness of Collaboration***	96	318
Increased Motivation to Attend Class***	60	356
Class more organized***	106	310
Instructor more aware of student understanding***	83	330
Instructor modified teaching to meet class needs***	110	298
Class objectives were more clear***	130	284
I learned more foundational facts and concepts***	149	267
Ability to solve problems increased***	112	302
Ability to understand concept connections and the “big picture” increased***	136	278
Helped Instructor to achieve course goals***	107	305
I will remember material better***	141	273
In the future, more likely to enroll in classes that use “clickers”**	172	232

**** $p < .01$; *** $p < .001$**

Table 1. “Disagree” vs “Agree” Frequencies on Survey Items

Question 2: Instructors Usage Patterns

Analysis

In order to examine instructor usage patterns, the field notes were examined and categorized with the focus on quizzing techniques and course collaboration. From this examination, the following classification categories were derived in association with quizzes: a) Number of quizzes as a function of material covered; b) Average quiz score and ; c) Instructor lecture modification based on quiz scores. With regard to collaboration, it was determined that such a categorization system did not accurately capture the behavior, so a narrative summary was developed, based on the field notes for each instructor. Table 2 displays the instructor key, including the course and number of students in the section.

	Course	Number of Students
Instructor A	Chemistry	125
Instructor B	Chemistry	122
Instructor C	Calculus	81
Instructor D	Calculus	89

Table 2. Instructor Information

Quizzes

Metrics associate with the different quiz categories are displayed in Table 3. The number of quizzes of each type refers to the number of quizzes that were administered via the SRS system during the day when the experimenter observed the course. These are demarcated based on whether they covered the reading/homework assignment for class, previous lectures, or the current lecture. The average quiz score is the combined student average quiz score for these quizzes. The lecture modification column refers to whether or not the instructor noticeably modified the quiz based on students' scores on quiz items.

Instructor	Number of Quizzes			Quiz score mean %	Lecture modification
	Reading/ Homework	Previous Lecture	Current Lecture		
A	3	0	1	91	no
B	1	4	2	89	no
C	1	1	1	61	yes
D	2	0	2	83	yes

Table 3. Quiz Metrics

Collaboration

The following are narrative summaries of the collaboration activities associated with each instructor/class.

Instructor A. Collaboration was verbally encouraged, as students were told they could work in pairs. With time, larger groupings of students began collaborating and encouraged smaller groups to do likewise. As time progressed, even students sitting by themselves were drawn to join nearby groups. This joining of the larger group occurred in the quizzes at the end of the lecture. In earlier quizzes, group work rarely exceeded two students. The instructor walked through the lecture hall and discussed the problems as the time allotted expired.

Instructor B. Collaboration was not verbally encouraged, but occurred naturally in a ripple effect; students in the middle of the lecture hall began discussing the problem first, and more engagement spread to the outlying students. The amount of discussion significantly increased as time went on. In quizzes given after the day's lecture, students were much more prone to collaboration, and genuine group work was observed. The instructor did not discuss or work the problem during the time allotted.

Instructor C. Collaboration was not verbally encouraged, but occurred naturally in a ripple effect; students in the middle of the lecture hall began discussing the problem first, and more engagement spread to the outlying students. Collaboration increased significantly as the instructor began working the question (equation) on the chalkboard and discussing to himself what he was doing (his reasoning). The instructor worked the quiz questions openly as the time allotted expired.

Instructor D. Collaboration was slow to begin but increased exponentially with time. The starting point for this, I believe, was the point in time that most students had worked out the problem; after 2-3 minutes, collaboration increased significantly. Of all the classes observed, this class included the least "genuine" collaboration. It seemed that students were merely relaying answers to one another, and less centered on genuine group work. The instructor gave very limited explanations of the problems afterward-especially in comparison to the other classes observed.

Question 3. Differences in student perception as a function of instructor usage patterns

Data Reduction and Relationship

As a first step in addressing the third experimental question, a factor analysis was carried out on the survey items, in order to examine the relationship among the items and reduce the number of items for subsequent analysis. A principal components analysis with a Varimax rotation was used. A five factor solution was selected, due to the logical nature of factor loadings, and differentiation of factors. Items associated with basic learning and class goals loaded on the first factor, so this factor was labeled "learning" (eigen value = 7.20; 32% of variance accounted for); the second factor consisted of items associated with instructor flexibility, so was labeled "flexibility" (eigen value = 1.30, 15 % of variance accounted for). Note that the "engagement" item loaded approximately equally on both of these factors, so is attributed to both. The third factor consisted of the two collaboration items, so was labeled "collaboration" (eigen value = .901; 14% of variance accounted for). The fourth and fifth item factors consisted of single items. The fourth was the motivation to attend item, labeled "attendance" (eigen value = .79; 9% of variance accounted for). The fifth factor consisted of the likelihood of taking another SRS course, labeled "enrollment" (eigen value = .66, 8% of variance accounted for). Table, 4 displays the factors and loadings for each item on each factor, with the factor items that were attributed to each factor in bold.

	Learning	Flexibility	Collaboration	Attendance	Enrollment
Made Class More Engaging	**.41**	**.46**	.31	.27	.27
Increased degree of collaboration	.11	.16	**.92**	.08	-.01
Increased Effectiveness of Collaboration	.31	.10	**.83**	.12	.15
Increased Motivation to Attend Class	.15	.13	.18	**.92**	.06
Class more organized	**.57**	.28	-.05	.43	.09
Instructor more aware of student understanding	.39	**.70**	.04	.26	.01
Instructor modified teaching to meet class needs	.32	**.80**	.22	.03	.15
Class objectives were more clear	**.65**	.50	.14	.05	.12
I learned more foundational facts and concepts	**.76**	.29	.17	.16	.07
Ability to solve problems increased	**.79**	.21	.17	.10	.12
Ability to understand concept connections and the "big picture" increased	**.83**	.20	.22	.07	.15
Helped Instructor to achieve course goals	**.72**	.40	.18	.12	.14
I will remember material better	**.79**	.19	.18	.13	.23
In the future, more likely to enroll in classes that use "clickers"	.26	.13	.08	.07	**.94**

Table 4. Factors and Item Loadings (Items in Bold Attributed to Factors)

Factor scores were then created for the next stage of analyses. The factor score consisted of the mean score of the items that were attributed to that factor (items in bold above). The "engagement" item, which loaded on two factors, was weighted as half (.5) for each of the two factors to which it was attributed. Of course, for the final two factors, the single item score was used as the "factor score".

Comparion of Instructors

The second stage of the analysis intended to address the third experimental question, consisted of a series of five, one-way between-subjects analyses of variance (ANOVA) with instructor as the independent variable, and each of the factor scores serving as the dependent variable. All ANOVAs were significant, so Tukey's post hoc tests were carried out for each. Table 4 displays the means, significance, and post-hoc results.

Factor	Instructor				Post Hoc
	A	B	C	D	
Learning***	4.21	4.14	3.60	4.31	A,B,D > C
Flexibility***	4.57	4.46	3.87	4.77	A,B,D > C
Collaboration*	4.75	4.35	4.31	4.55	A > B,C
Motivation to Attend Class*	4.65	4.84	4.57	5.17	D > A,C
Likely to enroll in future SRS courses***	4.02	3.92	2.91	3.77	A,B,D > C

***p < .05; *** p < .001**

Table 4. Factor Scores as a Function of Instructor

DISCUSSION AND CONCLUSIONS

With respect to the first experimental question, these results clearly replicate the initial pilot study (Hall et al. 2005) and demonstrate that the results can be extended to a foundational course (calculus) in another discipline (mathematics), based on student responses. Across all sections, substantially and significantly more students agreed that the "clickers" made the class more engaging, facilitated collaboration, enhanced student and instructor awareness, and motivated them to attend class. They even reported that they were more likely to enroll in courses that used these devices in the future.

In terms of professors' usage patterns, there appeared to be more consistency than might be anticipated, based on experimenter observations. All instructors used the devices actively, in that they gave at least three quizzes during the class period. However, there was certainly some variance in number of quizzes in that it ranged from three all the way to seven quizzes administered during the class time. There was even more variance in the focus of the quizzes in that one instructor focused more on the previous lecture, one on the current lecture, while the other two had a more balanced approach. For the most part, the quizzes were at a level that students performed relatively well, with the exception of one class where the average was close to 60% correct. It's interesting to note that the instructors also varied in the way that they responded to the quizzes, in that two modified their lectures noticeably, and two did not. The two that modified their lecture also had students with the lowest quiz grades, so they had more motivation to cover the material again.

Another focus of the observational analysis was to examine the nature of collaboration in the class. In all four courses the students engaged in some sort of collaboration associated with the clickers. Although it was only explicitly encouraged in one course, it was not discouraged in any course. The collaboration tended to increase over the course of the class and, in one class, the collaboration demonstrated a "ripple effect' where it radiated out from the collaboration which began literally in the middle of the lecture hall. The instructors exhibited some differences in their behavior during the quizzes. One instructor walked through the class answering questions, one worked on the problems on the board, while two left the students on their own until the quiz was completed. With the exception of one course, where the collaboration was mainly a matter of students sharing answers, the bulk of the collaboration appeared to be "genuine" in that students discussed the concepts and worked together to solve problems in order to arrive at a solution.

The final experimental question focused on the relationship between these instructor practices and students perceptions. The first step in addressing this question was to reduce the survey items through a factor analysis, which identified, five factors: a) basic learning, such as instructor organization and ability to meet course goals, and student's reported level of learning; b) Instructor flexibility, which included the instructors' response to student feedback and awareness of students' level of understanding; c) Collaboration, which included items that asked students to rate the degree and quality of their collaborative experience; d) Attendance, which was a single item regarding students motivation to attend the class; and e) Enrollment, which was the reported likelihood that students would enroll in another class that used the SRS devices.

Although a series of analyses of variance indicated that instructors differed significantly on each of these factors, that pattern was somewhat complex, and partly confounded by the fact that all instructors clearly used the devices actively, encouraged collaboration, and generally performed well. This is, in no small part, due to the fact that instructors who participated in the pilot project were volunteers. Having said that, there were still some interesting differences. The most pronounced of these was one instructor who scored significantly lower on the learning, flexibility, and likelihood to take SRS course factors. An examination of this instructor's usage practices indicates that the instructor gave the least number of quizzes and gave substantially more difficult quizzes as indicated by average scores well below the other three instructors (61%). This score is particularly low given that students were allowed to work together to come up with the solution. During the quizzes this instructor worked the problems on the chalkboard and reported aloud his thought processes. Of course student perception of the value of the clickers could be influenced via a number of factors, so, it's difficult to ascertain if any of these factors accounted for the significantly lower scores. However, it is still interesting to note these differences, and we can speculate that it may be better for instructors to think of the quizzes as learning tools where students will learn best if they are more likely to succeed. However, for now this will have to remain a speculation, which future research can address.

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