ENHANCING THE LEARNING ENVIRONMENT USING CLASSROOM RESPONSE SYSTEMS

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ABSTRACT
Classroom response systems (CRS) offer a management tool for engaging students in the classroom. These systems have been used in a variety of fields and at all levels of education. Typical goals of CRS questions are discussed, as well as the advantages to both students and instructors as a result of using them. These systems are especially valuable as a means of introducing and monitoring peer learning methods in the large lecture classroom. But the efficacy of using these systems depends strongly on the quality of the questions used. The integration of a CRS in an introductory physics module is discussed along with examples of questions used and the student assessment carried out.

INTRODUCTION
The simplest classroom response system (CRS), commonly called clickers, look like a basic TV remote control and work using infrared or radio frequency technology to transmit and record student's responses to questions. A small receiver is connected to a personal computer and placed at the front of the class. Each CRS is registered to a student, or can be set as anonymous if preferred, and each unit generates its own identifiable signal. The system allows for active participation by all students and provides immediate feedback to the instructor, and the students if desired, about the understanding/misunderstanding of the material being presented.

Traditional instruction presumes two types of 'knowledge': *Facts and ideas* which are things that can be packaged into words and *Know-how* which can be packaged into words as rules or procedures. These 'packages of knowledge' are then 'told' to the students, but students usually *miss the point* of what we tell them, if they listen at all and key words or concepts do not elicit the same *connections* for students as they do for the instructor. CRS have been used in higher education since 1998 as a mechanism to increase student interaction and transform student learning, particularly in the challenging large lecture environment [1,2]. By engaging their minds in class students become active participants in the learning process. By providing frequent feedback to students about the limitations of their knowledge, CRS-based instruction helps them to take charge of their own learning, seeking out the information and experiences they need to progress. By providing feedback to an instructor about student's background knowledge and preconceptions, CRS-based pedagogy can help the instructor design learning experiences appropriate to the students' state of knowledge and explicitly confront and resolve misconceptions. Many studies have reported positively on student satisfaction with classroom response systems, on whether it made their class more interesting, improved attendance, etc., [3-5]. Other studies have reported on learning outcome related to the use of interactive engagement pedagogical methods in large science courses [6].

A controlled study by Ebert-May et al. shows that student confidence in their knowledge of course materials is significantly increased in courses taught using interactive engagement methods over those taught by traditional lecture: “Results from the experimental lectures at NAU suggest that students who experienced the active-learning lecture format had significantly higher self-efficacy and process skills than students in the traditional course” [7]. A comparison of mean scores from the self-efficacy instrument indicated that student confidence in doing science, in analyzing data, and in explaining biology to other students was higher in the experimental lectures ($N = 283$, $DF = 3, 274$, $P < 0.05$). A large study by Hake [8] of 63 introductory physics courses taught with traditional methods versus interactive engagement (IE) methods, examined student learning outcomes using a commonly applied pre- and post-test design based on the Halloun-Hestenes Mechanics Diagnostic test and Force Concept Inventory. The study, which included 6,542 students, concluded that "A plot of average course scores on the Hestenes/Wells problem-solving Mechanics Baseline test versus those on the conceptual Force Concept Inventory show a strong positive correlation with coefficient $r = + 0.91$. Comparison of IE and traditional courses implies that IE methods *enhance* problem-solving ability. The conceptual and problem-solving test results strongly suggest that *the use of IE strategies can increase mechanics-course effectiveness well beyond that obtained with traditional methods* [original emphasis]." A recent study by Kennedy and Cutts [9] examined actual response data per student over the course of a single semester. In-class questions were of two types, one which asked the student to self-assess their study habits, and the other which focused on course content. These data were analyzed with end-of-semester and end-of-year exam performance results. Their investigation showed that students who more frequently participated in use of the personal response system *and* who were frequently correct in their responses, performed better on formal assessments. Students who infrequently responded, but did so correctly, nevertheless performed poorly on formal assessments, suggesting level of involvement during the class is positively correlated with better learning outcomes. These studies suggest that better learning outcomes are really the result of changes in pedagogical focus, from passive to active learning, and not the specific technology or technique used. Without a focused, well-planned transformation of the large lecture format and pedagogical goals, the technology provides no advantage. If the manner in which the technology is implemented in class is neither meaningful nor interesting to the student, then participation lapses. Ultimately, what these studies demonstrate is that student participation is key to positive learning outcomes.

The benefits of teaching by questioning are now widely recognized and the technique is becoming widely used. A recent *Harvard* survey indicated over 700 instructors use the technique, with about 400 using a variation called *Peer Instruction.* Peer Instruction (PI) is a student-centered instructional approach developed at Harvard by Eric Mazur [10-12]. This method has been welcomed by the science community and adopted by a large number of colleges and universities due, among other reasons, to its common sense approach and its documented effectiveness. The reasons for posing questions in class include: To assess background knowledge; To test if what has been taught has been understood; To provoke a class discussion; To emphasize or reinforce a point; To introduce a new topic; To see if students can combine past material to reach an understanding of present material; To see if students have read the textbook; To see if they understood what was done in the lab; To test student's physical intuition before a demonstration or before teaching a subject; After a demonstration to evaluate student's interpretation of what happened and to correct a misconception or to lead students to a better understanding.

The efficacy of CRS depends strongly on the quality of the questions used. Creating effective questions is difficult, and differs from creating exam and homework problems. Every CRS question should have an explicit pedagogic purpose consisting of a content goal, a process goal, and a metacognitive goal. Questions can be engineered to fulfil their purpose through four complementary mechanisms: directing students' attention, stimulating specific cognitive processes, communicating information to instructor and students via CRS-tabulated answer counts, and facilitating the articulation and confrontation of ideas [13]. Several literature reviews have recently been published on the use of CRS in the classroom and provide an overview of current research and best-practice tips [14-18].

RESOURCES AND METHODS

The CRSs used in this study are the Quizdom Q4 (http://www.qwizdom.co.uk/) used in conjunction with Microsoft PowerPoint. There are several forms of questioning available on these units, i.e. multiple choice-Conceptual or Numeric, True/False, Yes/No, Rating Scale, Sequencing questions and numerical input. A schematic of the Quizdom Q4 classroom response system is presented in Figure 1. During lectures, there are six basic steps that an instructor follows when using a CRS:

1. The instructor presents a question, problem or information.
2. The instructor sends a question
3. The students think about and/or discuss the question and respond
4. The instructor displays the responses
5. The instructor analyses the results
6. The instructor provides feedback to the students and uses information for tests and grading.

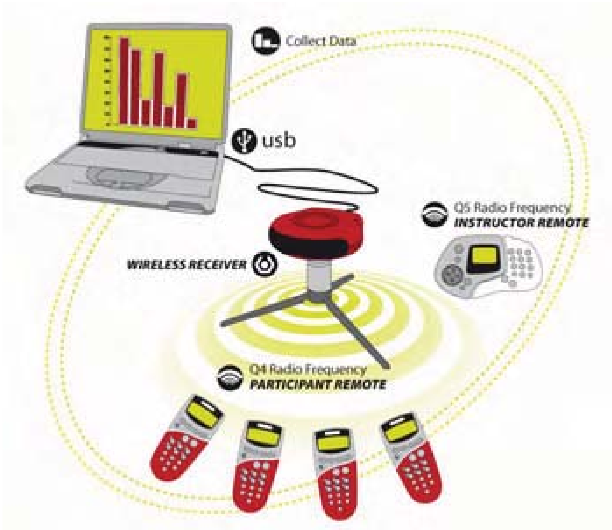

Figure 1. Schematic of Quizdom classroom response system.

The module chosen to pilot the use of a CRS system is an introductory physics module on waves and optics delivered to 22 first year University physics students. This module consists of 24 lectures and 12 tutorial sessions, with a 20% weighting on continuous assessment (CA) and 80% weighting on the end of module examination. During the module, CA was carried out on four separate occasions, in the form of a test consisting of 20 Multiple Choice Questions (MCQ), with the CRSs used twice and two paper-based tests. A range of question types were posed in both CA and in final examination questions, including: recall, calculation, interpretation, reasoning and application.

Example 1: A mass on a spring undergoes SHM. When the mass passes through the equilibrium position, its instantaneous velocity is: A) is maximum. B) is less than maximum, but not zero. C) is zero. D) cannot be determined from the information given.

Example2: You drop a stone into a deep well and hear the splash 2.5 s later. How deep is the well? A) 25 m, B) 27 m, C) 29 m, D) 31 m .

Example3: The figure is a "snapshot" of a wave at a given time. The frequency of the wave is 120 Hz. What is the wavelength in metres?

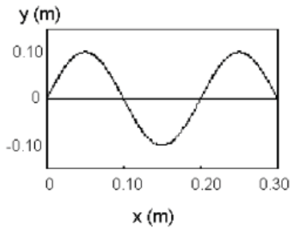

Figure 2. "snapshot" of a wave at a given time.

RESULTS

Figure 3 presents an overview of the individual performances in all aspects of assessment, CRS-based MCQ assessment, paper-based MCQ test and the final end of module examination.

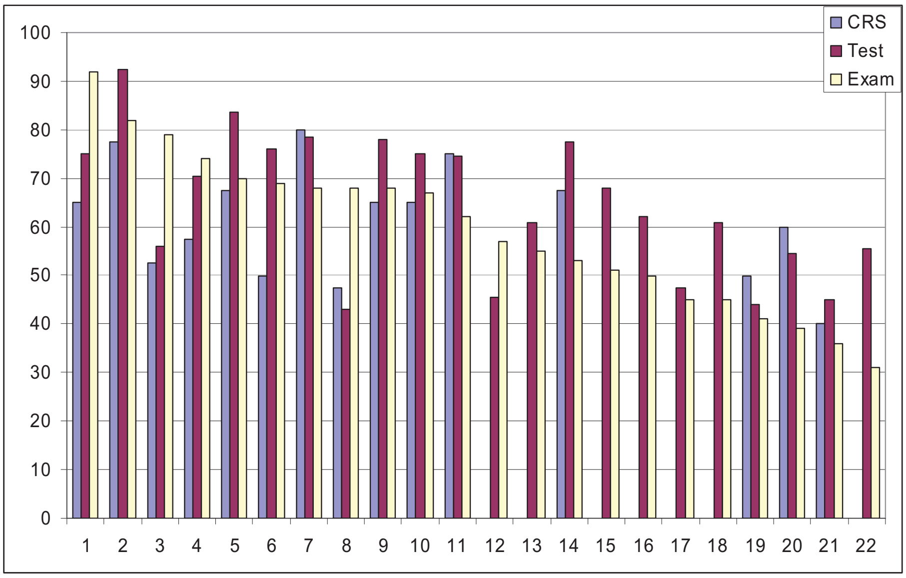

Figure 3. Students' performance in Continuous Assessment (CRS and Test) and Final Exam.

The results show that only 68% of the students participated in the CRS assessment, and the average difference in grades between exam-CRS was 3%, exam-test was 6% and test-CRS was 7%. These results do not show any statistical significance of the effect of the form of assessment on the student's performance. Unsurprisingly, the top 60% of students were consistently those that attended lectures and tutorials and actively participated in class. When students were asked about the use of CRS in their module:

- 95% of the students agreed that the CRS were easy to use
- 85% agreed that the questions required a deep understanding of lecture material
- 96% agreed that the questions were directly related to material covered in lectures
- 80% agreed that the CA element was an advantage to their learning
- 78% agreed that they liked questions where they could demonstrate that they understood core concepts
- 92% agreed that the CRS should be continued in the same module next year.

DISCUSSION AND CONCLUSIONS

The benefits of using CRS in Higher Education have been well documented and the integration of these systems across all disciplines has been successfully implemented for a variety of uses [19]:

- Assessment **-** as a substitute for a paper test.
- Instant feedback on learning - with this, the lecturer can discover which points have already been understood by the students and which may need some further clarification.
- Instant feedback to the lecturer on their teaching **-** particularly lecturers could ask what the best and worst aspects of his/her teaching were, and attempt to correct them immediately.
- Peer assessment -students who are giving presentations could be graded instantly by their peers on the quality of their work.
- Community building - general questions, for example why students chose this particular class, would create a sense of mutual awareness within the group.
- Demonstrating human response experiments- when illustrating conformity, for example, the responses to early questions could be faked in order to see whether the class would change their answers later.
- Encouraging debate - students who have had to commit privately to a definite opinion are much more likely to feel the need to justify their answer in peer

In this pilot study, the CRS was used with a small cohort of students which a view to gaining experience in the technology and determining if this form of evaluation provided a appropriate measure of student engagement and performance. As discussed above, there is no indication that the evaluation of student's performance is enhanced or diminished by this format of questioning and certainly this type of system benefits an instructor in terms of being a convenient way of determining knowledge of the lecture content at any time, being easy to use and take up little time from the lecture. However, the design and development of suitable questions remain key to its effective implementation.

REFERENCES

1. Banks, D. A. (Ed.) *Audience response systems in higher education: Applications and cases*. Hershey, PA: Information Science Publishing, 2006.
2. Beatty, I., Transforming student learning with classroom communication systems, EDUCASE Centre for Applied Research Bulletin, 2004, Issue 3, p1-13.
3. Steven R. Hall, Ian Waitz, Doris R. Brodeur, Diane H. Soderholm, Reem Nasr, *Adoption of Active Learning in a Lecture-based Engineering class*, IEEE Conference, 2005 Boston, MA, USA.
4. SW Draper and MI Brown, Increasing Interactivity in Lectures Using an Electronic Voting System, *Journal of Computer Assisted Learning*, 20 (2004): 81-94.
5. Ernst Wit, Who Wants to be... The Use of a Personal Response System in Statistics Teaching", *MSOR Connections* 2003, Vol. 3(2).
6. Duncan, D., *Clickers in the classroom: How to enhance science teaching using classroom response systems*. San Francisco: Pearson Education, 2005.
7. Diane Ebert-May, Carol Brewer and Sylvester Allred, Innovation in Large Lectures--Teaching for Active Learning, *BioScience* , 1997, Vol. 47 p601-607.
8. Richard R. Hake, Interactive-engagement Versus Traditional Methods: a Six-thousand-student Survey of Mechanics Test Data for Introductory Physics Courses, American Journal of Physics 1998, Vol. 66 p 64-74.
9. GE Kennedy, QI Cutts, The Association Between Students' Use of an Electronic Voting System and their Learning Outcomes," Journal of Computer Assisted Learning, 2005 Vol. 21(4), p260-268.
10. Eric Mazur, Peer Instruction: A User’s Manual, Prentice Hall, Upper Saddle River, NJ, 1997.
11. C.H. Crouch and E. Mazur, “Peer Instruction: Ten years of experience and results,” Am. J. Phys. 2001, Vol. 69, p.970–977.
12. A. Fagen, C.H. Crouch, and E. Mazur, “Peer Instruction: Results from a range of classrooms,” Phys. Teach. 2002, Vol. 40, p.206–209.
13. Ian D. Beatty, William J. Gerace, William J. Leonard, and Robert J. Dufresne, *Designing effective questions for classroom response system teaching*, Am. J. Phys. 2006, Vol 74(1), p31-39.
14. Caldwell, J.E., *Clickers in the large classroom: Current research and best-practice tips.* Life Sciences Education*,* 2007, 6(1), p9-20.
15. Fies, C., & Marshall, J., *Classroom response systems: A review of the literature.* Journal of Science Education and Technology, 2006, 15(1), p101-109.
16. Judson, E., & Sawada, D., *Learning from past and present: Electronic response systems in college lecture halls*. Journal of Computers in Mathematics and Science Teaching, 2002, 21(2), p167-181.
17. Roschelle, J., Penuel, W.R., & Abrahamson, L., *Classroom response and communication systems: Research review and theory*. Paper presented at the Annual Meeting of the American Educational Research Association, 2004, San Diego, CA.
18. Simpson, V., & Oliver, M. (2007). *Electronic voting systems for lectures then and now: A comparison of research and practice,* Australasian Journal of Educational Technology, 2007, 23(2), p187-208.
19. Steve Draper, *Electronic Voting Systems*, http://www.psy.gla.ac.uk/~steve/ilig/