Jl. of Interactive Learning Research (2010) 21 (3), 343-365.

Examining the Use of Audience Response Systems in Secondary School Classrooms: A Formative Analysis

ROBIN KAY, ANN LESAGE AND LIESEL KNAACK
University of Ontario Institute of Technology, Canada
robin.kay@uoit.ca
ann.lesage@uoit.ca
liesel.knaack@uoit.ca

To date, extensive research has been done on the use of Audience Response Systems (ARSs) in colleges and universities, but not in secondary schools. The purpose of this study was to conduct a detailed formative analysis on the benefits, challenges, and use of ARSs from the perspective of 659 secondary school students. Key benefits reported were increased levels of engagement and motivation, the effective use of formative assessment, and a better quality learning environment. Key challenges included a perceived decrease in learning performance when an ARS was used for summative assessment, technological malfunctions, resistance to using a new method of learning, and increased stress due to perceived time constraints. Finally, students consistently rated the use of an ARS significantly higher when it was used for formative as opposed to summative assessment.

Overview

An Audience Response System (ARS), also known as a personal response system (Hinde & Hunt, 2006), electronic voting system (Kennedy & Cutts, 2005), student response system (Kaleta & Joosten, 2007 and clickers (Bergtrom, 2006), permits students to respond to multiple choice questions using a remote control device. After students click in their responses, the results are instantly aggregated and displayed in chart form for the entire class to review. Responses are often anonymous but the teacher can assign an ARS remote device to specific students for evaluation purposes. Once the feedback is displayed, a teacher can change the course of instruction accordingly or students can work out misconceptions and difficulties through peer

or classroom discussion. While the use of ARSs started in 1966 (Judson & Sawada, 2002), mainstream use of this tool in secondary schools and higher education is a relatively new phenomenon beginning in 2003.

Several research reviews have been completed examining the use of ARSs (Caldwell, 2007; Fies & Marshall, 2006; Judson & Sawada, 2002), however only one paper could be found examining the use of ARSs in secondary school classrooms (Penuel, Abrahamson, & Roschelle, 2006). The purpose of the current article was to conduct a detailed formative analysis of the potential benefits, challenges, and use of ARSs from the perspective of secondary students.

Literature Review

A detailed review of the ARS literature revealed four key areas of focus: (a) overall attitudes toward ARSs, (b) student involvement, (c) assessment, and (d) learning. Each of these areas will be discussed in detail.

Overall Attitudes Toward Using an ARS

Prior to 1992, overall student acceptance of ARSs was quite high (Judson & Sawada, 2002), although much of the evidence presented was judged to be anecdotal (Fies & Marshall, 2006). However, more recent studies have reported considerable quantitative and qualitative evidence to suggest that higher education students have positive attitudes toward using ARSs (Caldwell, 2007; Carnaghan & Webb, 2007; Draper & Brown, 2004; Judson & Sawada, 2002; Kaleta & Joosten, 2007; Paschal, 2002; Prezler, Dawe, Shuster, & Shuster, 2007; Reay, Bao, Li, Warnakulasooriya, & Baugh, 2005; Sharma, Khachan, Chan, & Byrne, 2005; Slain, Abate, Hidges, Stamatakis, & Wolak, 2004).

Student Involvement and ARSs

Engagement. Engagement is a precursor to student-centered learning. If a student is actively constructing knowledge, overall engagement should be higher. Students who used an ARS reported being more interested or engaged in the content presented (Bergtrom, 2006; Preszler, et al., 2007; Simpson & Oliver, 2007).

Participation. Another essential element for student-centred learning is participation—students need to be part of the learning process. There is considerable evidence to suggest that students participate more when an ARS is used in the classroom (Caldwell, 2007; Draper & Brown, 2004; Greer & Heaney, 2004; Jones, Connolly, Gear, & Read, 2001; Siau, Sheng, & Nan, 2006; Stuart, Brown, & Draper, 2004; Uhari, Renko, & Soini, 2003; Van Dijk, Van Den Berg, & Van Keulen, 2001).

Attention. There is some evidence to suggest that student attention wanes after about 20 minutes in a classroom environment (d'Inverno, Davis, & White, 2003; Jackson, Ganger, Bridge, & Ginsburg, 2005). Consequently, offering ARS questions at 20 minute intervals is one technique of segmenting a long lecture and allowing students to shift their attention and actively participate in the learning process. Numerous studies have reported that higher education students are more attentive when an ARS is used (Bergtrom, 2006; Burnstein & Lederman, 2001; Caldwell, 2007; d'Inverno et al.; Draper & Brown, 2004; Jackson et al.; Jones et al., 2001; Latessa & Mouw, 2005; Siau, et al., 2006; Slain, et al., 2004).

Discussion. Several researchers have observed that an ARS promotes increased discussion, particularly when used with a peer instruction strategy (Beatty, 2004; Brewer, 2004; Draper & Brown, 2004; Jones et al., 2001; Nicol & Boyle, 2003). With this strategy, students felt they were better able to discuss and calibrate their understanding of specific concepts (Draper & Brown, 2004). In addition, students noted they were more engaged and animated when peer discussions were occurring as a result of ARS feedback (Jones et al.; Nicol & Boyle).

Assessment and ARSs

Feedback. An ARS improves the feedback cycle between instructor and students by the rapid, anonymous, collection and presentation of all student responses (Abrahamson, 2006; McCabe, 2006; Pelton & Pelton, 2006). In addition, with an ARS students are required to think about a question or problem and then commit to an answer. This commitment to a response is particularly important when students are required to articulate and defend their answers in a peer-instruction situation (Abrahamson; Beatty, 2004; Pradhan, Sparano, & Ananth, 2005).

Compare with other students. When an ARS is used, all responses from the class are publicly presented, so students are able to compare their individual understanding with their fellow classmates. There is some evidence to suggest that students like to see how well they are doing relative to their peers (Burton, 2006; Caldwell, 2007; Draper & Brown, 2004; Hinde & Hunt, 2006; Simpson & Oliver, 2007).

Formative assessment. There are two common forms of assessment that can be used in a class. Summative assessment involves tests and assignments that count toward a student's final grade. The vast majority of assessment in higher education is summative. Formative assessment, on the other hand, is used to determine student understanding of concepts without grades, to identify misconceptions, and alter classroom instruction accordingly (Donovan, Brown, & Cocking, 1999). Regular use of an ARS can offer

formative feedback to both instructors and students as to how well concepts are being understood. Students can gauge and discuss their understanding of concepts as they are being presented. There is considerable evidence to suggest that an ARS is an effective tool for providing formative assessment (Beatty, 2004; Bergtrom, 2006; Brewer, 2004; Caldwell, 2007; Draper & Brown, 2004; Dufresne & Gerace, 2004; Greer & Heaney, 2004; Jackson et al., 2005; Siau et al., 2006; Simpson & Oliver, 2007; Stuart et al., 2004).

Summative assessment. While it has been suggested by Fies & Marshall (2006) that ARSs have been used primarily for summative assessment, little research has been done on the impact of using an ARS for formal test situations. There is some indirect evidence to suggest that higher education students do not like using ARSs for "participation" credit (Caldwell, 2007). More research is needed to examine the impact of summative assessment on classroom learning.

Learning and ARSs

Quality of Learning. Numerous studies have asserted that higher education students report increased learning when an ARS is used (Greer & Heaney, 2004; Nicol & Boyle, 2003; Pradhan et al., 2005; Preszler et al., 2007; Siau et al., 2006; Slain et al., 2004; Stuart et al., 2004; Uhari et al., 2003). Some students like hearing explanations about ARS questions from their peers who have a similar language and therefore can explain misconceptions more effectively than the instructor (Nicol & Boyle, 2003; Caldwell, 2007). Other students report that using an ARS helps them think more deeply about important concepts (Draper & Brown, 2004; Greer & Heaney).

Learning performance. A number of researchers have provided descriptive data to suggest that learning performance increased as a direct result of using an ARS (Brewer, 2004; Caldwell, 2007; Carnaghan & Webb, 2007; Kennedy & Cutts, 2005; Latessa & Mouw, 2005; Schackow, Milton, Loya, & Friedman., 2004). In addition, many experimental studies have reported that ARS-based classes significantly outperform traditional lectures (Fagan, Crouch, Mazur, 2002; Kaleta & Joosten, 2007; Kennedy & Cutts, 2005; Pradhan et al., 2005; Preszler et al., 2007; Schackow et al.; Slain et al., 2004).

Challenges Associated with Using an ARS

Technological challenges.Two main technological difficulties were reported when an ARS was used. When students were responsible for buying their own remote devices, they didn't always bring them to class or they lost them. Because of the dependence on technology, students without remote devices were unable to fully participate in an ARS-based class (Caldwell,

2007; Reay et al., 2005). A more critical issue was when remote devices did not work or the signal was not received by the instructor's computer. This was a particularly stressful experience when students were being evaluated for marks (Sharma et al., 2005; Siau et al., 2006).

Adjusting to a new method. Some students may react adversely to the use of an ARS because the learning "game plan" has been changed. They are used to a lecture format and a switch of methods can lead to stress, frustration, and resistance at first (Beatty, 2004; Fagan et al., 2002). Other students are distracted by the use of an ARS (Siau, et al., 2006). Still others doubt their ability to direct their own learning using an ARS (Allen & Tanner, 2005).

Effort. Trees & Jackson (2007) noted that using an ARS requires more cognitive energy and cooperation from students. This kind of extended effort may not suit all students, especially those who are more accustomed to passive lectures. More research is needed, though, to determine whether students adapt to and accept the extended effort required when using an ARS. The popularity of ARSs and their positive impact on learning suggest that the additional effort required may not be a significant barrier (Caldwell, 2007; Fies & Marshall, 2006; Judson & Sawada, 2002; Simpson & Oliver, 2007).

K-12 Investigation of an ARS

Penuel et al. (2006) have done the only comprehensive study involving the use of ARSs with K-12 teachers. Teachers used an ARS for two main reasons: (a) to improve learning and instruction (formative assessment) or (b) for evaluating students (summative assessment). Frequent users of an ARS had positive perceptions about using this tool in the classroom. Overall, the impact of the ARSs in K-12 was to increase motivation and improve student learning.

Summary and Purpose of Study

Previous research on ARSs has been conducted almost exclusively in the domain of higher education. Reported benefits include greater student involvement, positive reaction to regular assessment of knowledge during a class, and improved quality of learning. Key challenges include ensuring that the technology functions properly and helping students adjust to a new way of learning. Since the use of ARSs is increasing rapidly in secondary schools (Abrahamson, 2006), it is prudent to broaden the scope of current ARS research. Therefore, the purpose of the current study is to examine benefits and challenges of using ARSs in secondary schools. Three questions were addressed:

1. What were the perceived *benefits* of using an ARS?

2. What were the perceived *challenges* in using an ARS?; and

3. How did *teaching strategy* influence the use of ARSs? (summative vs. mixed vs. formative assessment).

METHOD

Sample

Students. The student sample consisted of 659 Canadian students (327 males, 327 females, 5 missing data), enrolled in grades 9 (n= 71), 10 (n=233), 11 (n=149), and 12 (n= 206). Subject areas where an ARS was used included accounting, biology, business, chemistry, civics, computer engineering, English, law, mathematics, marketing, physics, technology, and world issues. Eighty-seven percent (87%) of the students claimed that they were comfortable or very comfortable with technology (n=572). Sample population data was collected from 23 classrooms in 15 different secondary schools located within an urban population of 400,000 people. All students were selected through convenience sampling and had to obtain signed parental permission to participate.

Teachers. The teacher sample consisted of 23 teachers (16 males, 7 females), with 1 to 26 years of teaching experience (M = 15.9, SD = 7.9). Almost all teachers reported that they were comfortable or very comfortable with technology (n=22, 96%).

Procedure

Teachers were emailed by an educational coordinator and informed of the ARS study. Participation was voluntary and subjects could withdraw from the study at any time without penalty or prejudice. Each teacher received two half days of training in November and February on how to use the ARS software and possible strategies for using an ARS in the classroom. Teachers were then asked to use an ARS in their regular classrooms for one month, although frequency of use was controlled by the individual teacher. In pairs, teachers shared a laptop computer, an LCD projector, and one ARS system (32 clickers and a receiver) from E-Instruction (see http://www.einstruction.com/ for details of the specific ARS brand used). E-Instruction did not fund nor was it affiliated in any way with this study. All teachers used the ARSs for a three month period, however, data collected for this study focused on the last month. During the final month in which ARSs were used, 94% (n=617) of secondary students reported using an ARS one to two times. Only, 6% (n=41) of the students used an ARS once a week.

Data Sources

Student survey. Based on the final month in which an ARS was used, students completed the ARS Attitude Survey for Students (Kay, 2008a). This survey consisted of 11, 7-point Likert scale items that focused on the four key areas reported in previous ARS research: (a) overall attitudes, (b) student involvement, (c) assessment, and (d) learning. Since this was a formative analysis of student attitudes toward ARS and its use, reliability and construct validity were not calculated. Instead, each item was analyzed individually to glean as much information as possible.

Student comments. Students were asked the following open-ended question: "What was the impact of clickers on your learning in the past month?" A coding scheme was developed to categorize 714 student comments made by 526 students (Kay, 2008b). Some students made more than one comment when they filled in their survey, while other students offered no response. Each comment was then rated on a 5-point Likert scale (-2 = very negative, -1 = negative, 0 = neutral, 1 = positive, 2 = very positive). Two raters assessed all comments made by students based on category and rating value. After round one, inter-rater reliability was 83% for categories and 93% for ratings. Comments where categories or ratings were not exactly the same were shared and reviewed a second time by each rater. After round two, an inter-rater reliability of 98% was reached for categories and 99% for the rating values.

Teacher questions. Teachers were asked to indicate gender, years of teaching experience, their comfort level with technology, and whether they used an ARS for formative and/or summative assessment.

RESULTS

Benefits to Using an ARS

Student survey results are presented in Table 1 including percent of students who disagreed (selected Strongly Disagree, Disagree or Slightly Disagree) or agreed (selected Strongly Agree, Agree or Slightly Agree) with an item, mean score (based on a 7-point Likert scale) and standard deviation. In addition, a summary of students comments about ARSs is presented in Table 2 and includes mean rating score (ranging from -2 to +2 – see Appendix B for more details), standard deviations, and number of negative and positive comments.

Table 1
Summary of ARS Quantitative Student Survey Questions (*n*=659)

Question	n	Disagree1	Agree2	M	SD
Overall Attitude					
1. I would prefer to use clickers.	653	15%	69%	5.3	1.8
2. When clickers were used, the class was better.	659	16%	52%	4.7	1.5
Student Involvement					
3. I was more engaged in the lesson when clickers were used.	657	10%	75%	5.3	1.5
4. I was more motivated when clickers were used.	656	11%	70%	5.2	1.5
5. I participated more than I normally would when clickers were used.	659	15%	55%	5.1	1.6
6. Using clickers generated more class discussion.	657	18%	55%	4.6	1.5
Assessment					
7. Using clickers was a good way to test my knowledge.	655	9%	77%	5.4	1.4
8. I liked seeing what other students in the class selected for answers.	656	14%	57%	4.8	1.5
9. I DID NOT feel bad when most students got an answer right and I didn't.	658	26%	47%	4.6	1.7
10. I liked using clickers for tests.	636	21%	54%	4.7	1.8
Learning					
11. I learned more when clickers were used.	656	23%	44%	4.4	1.5

1 Combining "Slightly Agree", "Agree" and "Strongly Agree" responses

2 Combining "Slightly Disagree", "Disagree" and "Strongly Disagree" responses

Overall attitudes. Students were relatively positive about using ARSs with 69% agreeing that they preferred to use an ARS (M = 5.3, SD = 1.8, possible range was 1 to 7) and 52% indicating that their class was better when an ARS was used (M = 4.7, SD =1.5). General comments offered from the open-ended survey question also indicated that students were either neutral or accepting of ARS use in their classroom. Although many comments were neutral (n=41 out of 70), 22 comments were positive. The following were typical comments made by students in favour of ARSs.

Loved the clickers—they were radical

I thought that they were a great addition to the class

They helped me with some things I was not sure about.

Table 2

Summary of Student Comments about Audience Response Systems (n=526)

Category	Mean	SD	No. Negative Comments	No. Positive Comments	Total Comments
Overall Attitude					
General comments	0.30	(0.89)	7	22	70
Different methods used	0.43	(1.03)	12	30	46
Student Involvement					
Engagement	1.23	(0.43)	0	111	111
Participation	1.04	(0.35)	0	49	49
Paid attention more	0.93	(0.38)	1	27	28
Discussion	1.11	(0.33)	0	9	9
Stress	-1.00	(1.05)	23	5	28
Assessment					
Formative Assessment	0.94	(0.41)	1	49	53
Compare with others	0.88	(0.34)	0	14	16
Feedback	0.86	(0.53)	1	3	14
Wrong answer - Reaction	-1.00	(0.00)	2	0	2
Learning					
Learning process	0.81	(0.78)	4	72	104
Review previous concepts	1.13	(0.44)	0	51	53
Memory	0.86	(0.73)	1	19	21
Teacher explained better	1.00	(0.00)	1	5	5
Learning performance	-0.26	(1.16)	45	30	80
Technology Issues	-0.48	(1.05)	16	7	25

Of the 46 comments made about student reaction to using a different method of teaching, 30 were positive. Sample positive comments were as follows:

> I enjoyed it because it was a new form of lesson that we all benefited from.

> It is better than reading questions out of a textbook.

> It was more interesting with the clickers rather than just raising your hand.

Student involvement. Students indicated that they were substantially more involved when an ARS was used. Based on the survey, 75% of the students agreed that they were more engaged (M=5.3, SD = 1.5), 70% agreed they were more motivated (M=5.2, SD = 1.5) 55% agreed that they participated more than they normally would (M=5.1, SD = 1.6), and 55% agreed that more class discussion was generated (M=4.6, SD = 1.4).

Student comments regarding involvement were very positive with only one of the 201 comments rated as being negative. The mean rating for all comments was high (M=1.23, SD = 0.43), scale ranged from -2 to +2). Representative comments were as follows:

> It made class more fun and enjoyable.

> I wasn't falling asleep. And I was very interested.

> Much of the class seemed more interested in the Math we were doing

Fewer comments were made about participation than engagement (n=49), although the mean rating was high (M=1.04, SD = 0.35). Typical comments about participation included:

> Clickers motivated me into participating in class discussions in general!

> More hands on and intriguing way to learn. More class involvement.

> It forced people who normally don't feel cofortable participating in class discussion to participate.

Only 27 student comments were made about paying attention, but the mean rating was high (M=0.93, SD = 0.38). Sample attention-based comments were as follows:

> It made me concentrate more.

> The clickers allowed me to stay focused on the subject while in class

> I felt I read all the questions more carefully to make sure I got the right answer and paid attention more than I normally would when we just talked about something.

Finally, mean ratings about class discussion were high (M=1.11, SD = 0.33), but only nine students commented on this aspect of using ARS. Typical comments about discussion included:

> [It] takes more time with more discussion, but the discussion and more in depth learning outweighed the time used.

> Using the clickers prompted much more class discussion and it was much better than simply answering in a paper.

Assessment. Students appeared to be most enthusiastic when an ARS was used for formative assessment. Over 75% of students agreed that using ARSs was a "good way" to self test their knowledge (M=5.4, SD = 1.4). Comparing answers with other students (M=4.8, SD = 1.5) was rated lower, with only 57% agreeing that they like to see the responses of other students. Finally, just over 50% of the students agreed that they liked using an ARS for formal tests (M=4.7, SD = 1.8).

Comments about formative assessment (M=0.94, SD = 0.41), comparing responses (M=0.88 , SD = 0.34), and feedback (M=0.86, SD = 0.53) were rated relatively high. The following are typical comments made about formative assessment:

> [I] got to see how much I really understood in that class.

> It helped me see what parts of law I needed improvement in, judging by the questions I got right or wrong.

> [It] helped me by testing my knowledge and getting to know where the class and I are at.

Sample comments about comparing responses with the class were as follows:

> I liked clickers because I can see how I'm doing compared to the class.

> I also learned more about my classmates and what they were interested in.

> It is interesting to see what the rest of the class was answering.

Finally, representative comments about getting feedback included:

> I liked to be able to see the answer right away.

> I enjoyed knowing if I got a question right or wrong immediately.

Learning. Only 44% of the students agreed that they learned more when an ARS was used. The mean score for this item was 4.4 (*SD*=1.5), the lowest of all survey questions. However, open-ended comments painted a different picture. Ratings for comments about learning process (*M*=0.81, *SD* = 0.78), reviewing previous concepts (*M*=1.13, *SD* = 0.44), helping to improved memory (*M*=0.86, *SD* = 0.53), and teacher explanations (*M*=1.00, *SD* = 0.00) were relatively high. However, the mean rating for learning performance comments was negative (M=-0.26, *SD* = 1.16). Students were divided on whether learning performance improved or decreased. Comments made about the overall learning process (*n*=104) and reviewing concepts (*n*=53) were the most frequent. Typical comments made about the learning process were:

> I liked the way you had to think very fast.

> I have learned better and observe the question better.

> Learning was more fulfilling.

> A very innovative and exciting way to learn.

Representative comments about using an ARS to review concepts included

> I think it was a nice way to test our knowledge for reviews.

> It was great review of the units and topics we just covered.

> I was able to obtain answers to test-like questions easily giving me insight as to what more studying was needed.

Comments made about an ARS helping to improve memory were less frequent (n=21) but noteworthy.

> They helped me remember small but important details that were on my test.

> Clickers helped make the material that much more easy to remember.

> I find I remember things better if I get them wrong first on a test and this system always seems like a test for me so I feel I learn more this way.

Positive comments (see negative comments in challenges section) made about learning performance focused on positive reactions to test situations:

> I think clickers had a very good impact on my learning. They made my tests a lot more enjoyable and relaxing.

> Well we only used the clickers twice and both times it made me concentrate more and I got better marks. But when we did, I actually didn't care that we had to do a test and I'm pretty sure I did better than I would [have] on a sheet of paper.

Challenges Experienced Using ARSs

Technology. Perceptions of ARS technology was not assessed using the survey, but the mean rating for comments was negative (M=-0.48, SD = 1.05), at least for the 25 students who chose reflect on this aspect of ARS use. The majority of student complaints were related to confidence that the remote control functioned properly and registered the intended response.

> The whole process of aiming the clicker [was] bothersome.

> Well at first I didn't like the clickers—I found them rather complicated and also mine was not working correctly.

> They are too difficult to use and it was difficult to tell when the correct answer was chosen.

Overall attitudes. While most general attitudes toward ARSs were positive, comments from some students indicated that the use of the ARS was quite negative. Some of the more negative comments offered were as follows:

> I did not like using the clickers.

> Horrendous—takes up too much time.

Other comments were targeted at having to use a new method to learn.

> I prefer writing my answers on paper. I still learned during the process of clickers, but I prefer class without them.

Student involvement. Overall, students were very positive about using ARSs, with the exception of one category: stress. Mean ratings were quite low -1.00 (SD=1.05) and 23 of the 28 comments made were negative. Typical comments referred to increased pressure about understanding concepts, using an ARS in a test situation, or feeling pressure to respond.

> It made me more worried about not knowing what I need to know!!

> Using clickers on a test is very stressful. Not only are we stressed because of the test conditions, but it's difficult to work the clickers.

> I felt that clickers made me feel as if I had to rush to get my answer selected. I was nervous and felt pressure, when usually I'm confident.

Assessment. The survey indicated that 26% of secondary students "felt bad" when most of their peers responded correctly and they did not (M=4.6, , SD = 1.7). As stated earlier, student comments about assessment and ARSs were almost always positive.

Learning. Even though reviewing concepts, improving memory, and obtaining explanations from the teacher were rated as positive effects of using an ARS, a sizeable group of students (n=45) were quite vocal about the negative impact of the ARSs on learning performance. Negative comments included not having the questions available after they were answered electronically and the time pressures experienced when completing tests with an ARS.

> If anything, I didn't do as well on units test—I will be [not] able to do as well on exams as I could have because I don't have the questions in front of me to help me study. Therefore, I soon forgot all the questions from the quiz/test.

> The clickers seem to create more pressure to answer correctly which often led to answering incorrectly.

> I hated the time constraint. I was more nervous about the time, than I was working on the questions.

Strategies

Detailed data on how ARSs were used in secondary schools was not collected, however, three general strategies were reported by teachers: (a) using an ARS for formative assessment only (formative, n=398), (b) using an ARS for both summative tests and formative assessment (mixed, n=110), and (c) using an ARS for summative assessment only (summative, n =103). Means for all items on the ARS student attitude scale for each strategy selected are presented in Table 3. Note that mean values for most attitude scale items are lowest when a summative strategy was used and highest when a formative strategy was employed.

Table 3
Mean ARS Survey Item Scores as a Function of Strategy Used (n=611)

Survey Item	Summative Assessment		Mixed (Formative & Summative)		Formative Assessment	
	M	*SD*	*M*	*SD*	*M*	*SD*
Overall Attitudes						
1. I would prefer to use clickers.	4.42	(1.94)	4.72	(1.73)	5.70	(1.62)
2. When clickers were used, the class was better.	4.19	(1.46)	4.43	(1.32)	4.97	(1.50)
Student Involvement						
3. I was more engaged in the lesson when clickers were used.	4.52	(1.57)	5.05	(1.44)	5.65	(1.33)
4. I was more motivated when clickers were used.	4.44	(1.60)	4.79	(1.47)	5.57	(1.39)
5. I participated more than I normally would when clickers were used.	4.39	(1.51)	4.85	(1.56)	5.41	(1.50)
6. Using clickers generated more class discussion.	3.83	(1.35)	4.45	(1.37)	4.85	(1.49)
Assessment						
7. Using clickers was a good way to test my knowledge.	4.56	(1.59)	5.27	(1.39)	5.71	(1.28)
8. I liked seeing what other students in the class selected for answers.	4.10	(1.47)	5.23	(1.43)	4.92	(1.48)
9. I did not feel bad when most students got an answer right and I didn't.	4.32	(1.59)	3.92	(1.75)	4.89	(1.70)
10. I liked using clickers for tests.	4.09	(2.16)	4.19	(1.93)	5.11	(1.62)
Learning						
11. I learned more when clickers were used.	3.63	(1.48)	4.13	(1.37)	4.65	(1.46)

A MANOVA was run to compare formative, mixed, and summative approaches to using the ARS (Table 4). Using an ARS for formative assessment was rated significantly more positively than using an ARS for summative assessment on all 11 Likert scale items in the ARS attitude scale. Using an ARS for formative assessment also resulted in significantly higher scores on most survey items when compared to a mixed approach (formative & summative).

Table 4
MANOVA Examining Attitude toward ARS as a Function of Teaching Strategy

Source	df	F	Scheffe's Post Hoc Analysis (p <.05)
Overall Attitude			
1. I would prefer to use clickers.	2	31.5*	Formative > Mixed & Summative
2. When clickers were used, the class was better.	2	14.6*	Formative > Mixed & Summative
Student Involvement			
3. I was more engaged in the lesson when clickers were used.	2	29.6*	Formative > Mixed > Summative
4. I was more motivated when clickers were used.	2	31.9*	Formative > Mixed & Summative
5. I participated more than I normally would when clickers were used.	2	21.3*	Formative > Mixed > Summative
6. Using clickers generated more class discussion.	2	21.4*	Formative & Mixed > Summative
Assessment			
7. Using clickers was a good way to test my knowledge.	2	30.3*	Formative > Mixed > Summative
8. I liked seeing what other students in the class selected for answers.	2	17.6*	Formative & Mixed > Summative
9. I did not feel bad when most students got an answer right and I didn't.	2	16.4*	Formative > Mixed & Summative
10. I liked using clickers for tests.	2	20.6*	Formative > Mixed & Summative
Learning			
11. I learned more when clickers were used.	2	22.6*	Formative > Mixed > Summative

* p < .001

DISCUSSION

The purpose of this study was to conduct a formative analysis of the use of ARSs in secondary school classrooms. Three areas were examined: (a) benefits, (b) challenges, and (c) teaching strategy.

Benefits

Overall attitudes. The survey data suggests that secondary students were positive about the use of ARSs, a result that is consistent with previous studies conducted in higher education. However, not all students benefited equally when using an ARS, a conclusion that is supported by some student

comments. To provide a more in depth analysis, Fies and Marshall (2006) suggested that general impressions and anecdotal comments about attitudes toward ARSs need to be supplemented by a more detailed, focused analysis.

Student involvement. The evidence provided by this study suggests that ARSs helped increase engagement, participation, and to a lesser extent, attention paid in class. These results are consistent with a number of studies looking at ARS use in higher education (Caldwell, 2007; Fies & Marshall, 2006; Judson & Sawada, 2002; Simpson & Oliver, 2007). More data is needed, though, focussing on what is engaging about ARSs, the quality of participation, and why students are more focused when an ARS is used.

Assessment. Secondary students appreciated the use of ARS for formative assessment particularly with respect to test preparation and review. Comparing answers with other students and getting general feedback played a secondary role. While the value of formative assessment is well documented in higher education (Beatty, 2004; Bergtrom, 2006; Brewer, 2004; Caldwell, 2007; Draper & Brown, 2004; Dufresne & Gerace, 2004; Greer & Heaney, 2004; Jackson et al., 2005; Siau et al., 2006; Simpson & Oliver, 2007; Stuart et al., 2004), the relative importance of different kinds of formative assessment has not been examined in detail.

Learning. A number of students commented that the quality of the learning process, specifically within the context of reviewing concepts, was an effective consequence of using an ARS. Impact on memory for material presented was noteworthy, but commented on by only a few students. While challenges will be discussed later, it is important to note that an improved learning process did not necessarily lead to increased learning performance. At least 45 students felt that learning performance was hampered, sometimes appreciably, by using an ARS, particularly when it was used as a summative assessment tool. To thoroughly investigate the impact of ARSs on learning, more detailed data collection and a wider variety of teaching strategies need to be explored.

Challenges

Overall attitudes. It is evident that some students had trouble adjusting to the novelty of using an ARS and the associated changes in teaching strategies. While this difficulty was experienced by less than 2% of the student sample, it is one that has also been observed in higher education. The suggested remedy has been to clearly explain the rationale for using an ARS and the intended benefits of this technology on learning (Crouch & Mazur, 2001; Trees & Jackson, 2007).

Student involvement. One key challenge for students in this study was the stress experienced when being required to respond to an ARS question,

particularly in a summative test situation. The comments concerning increased stress were not frequent, but they were intense. Given the student frustration level when an ARS was used for summative tests (see strategies, next section) it might be wise to use this technology for formative assessment purposes only. In addition, student anxiety might be reduced by explaining why ARSs are being used with an emphasis on learning versus having to obtain the right answer.

Learning. The most serious challenge associated with using an ARS was the negative impact on learning performance experienced by students who were required to use this tool for completing graded tests. Time pressure and not having a paper copy of the questions and answers to reference at a later date were two notable complaints. More thought needs to be directed toward whether summative assessment is an effective use of an ARS.

Strategy

Only one previous study reviewed the use of ARSs in a K-12 environment (Penuel et al., 2006). These researchers observed that teachers naturally divided into two groups with respect to using ARSs: (a) formative (instructional) and (b) summative (testing) use. A similar pattern was observed in the current study with secondary students. Most teachers (65%) chose to use an ARS as a formative assessment tool. Based on the survey results, students overwhelmingly preferred formative over summative use. No research to date has been done comparing these formative and summative approaches, so further research is needed to confirm this conclusion.

Recommendation to Educators

The current study was intended to be a formative analysis of the use of ARSs in secondary school classrooms, so it would be premature to offer unequivocal advice about their use in the classroom. That said, there are several recommendations that may be worth noting.

First, most secondary students in this study did not respond well when the ARS was used as a test-taking device. In fact learning performance was perceived as decreasing. In the interest of minimizing the negative impact of this tool, it might be wise to restrict the use of an ARS to formative assessment, particularly when reviewing concepts. Students appeared to appreciate this strategy the most.

Second, it is probably a good idea to clearly explain why an ARS is being used in the classroom, particularly if it will be used regularly. Caldwell (2007) and Trees and Jackson (2007) noted that if you expect to garner full student support, you need to explain why you are using ARSs and what you expect to gain from the technology.

Finally, because technology problems were experienced by some students, it would be prudent for educators to test the ARS equipment ahead of time to ensure that all remote devices respond properly. Batteries, for example, might need to be changed. When infrared remote devices are used, fluorescent lights may need to be turned off to avoid signal interference.

Caveats and Future Research

This study was a first attempt to investigate the use of ARSs in secondary school classrooms. Two main data collection sources were used—survey questions and open-ended comments. Analysis of the data was based on a comprehensive review of the literature examining the use of ARSs in higher education. There are a number of caveats, though, that need to be considered when interpreting the results.

First, the results are intended to provide a preliminary perspective on use in secondary school classrooms. More detailed examination is required in key areas such as the catalysts for student engagement, the impact of different teaching strategies, and why memory is improved when using an ARS.

Second, the results are based on short-term use of an ARS—once or twice over a one month period. The impact could be decidedly different if an ARS were used on a regular basis. For example, engagement may be reduced when students become more accustomed to using an ARS on a regular basis. On the other hand, the impact of an ARS on learning may be more significant with increased use.

Third, teaching strategies should be expanded to acquire a more complete understanding of the effectiveness of using an ARS. One promising strategy that has yet to be examined in secondary school, but which has received considerable acclaim in higher education, is peer-based instruction. This technique involves displaying a multiple-choice, higher-level question that identifies a misconception, asking students to select an answer using an ARS, giving students time to discuss and defend their answers with two to four peers, taking a revote on the original question, and having the instructor provide a brief summary of the content presented. A number of researchers have reported considerable success with this approach in higher education (Brewer, 2004; Burnstein & Lederman, 2001; Crouch & Mazur, 2001; Cutz, 2006; Draper & Brown, 2004; Hinde & Hunt, 2006; Jones et al., 2001; Ken nedy & Cutts, 2005; Miller, Santana-Vega, & Terrell, 2006; Pelton & Pelton, 2006; Nicol & Boyle, 2003).

Finally, more research is needed on learning performance. This study collected systematic data on the perceived quality of learning, but actual measures of student performance are needed to firmly establish the learning impact of ARSs.

Summary

The purpose of this study was to conduct a detailed formative analysis of the potential benefits, challenges, and use of ARSs from the perspective of secondary school students. Key benefits reported were increased engagement and motivation, effective formative review of concepts, and a higher quality learning environment. Key challenges observed included decreased learning performance when ARSs were used for summative assessment, technological glitches, negative reactions to using a new method of learning, and higher stress experienced due to perceived time constraints when responding to questions. Finally, students rated the use of ARSs higher when it was used for formative as opposed to summative assessment.

References

Abrahamson, L. (2006). A brief history of networked classrooms: Effects, cases, pedagogy, and implications. In D. A. Banks (Ed.), *Audience response systems in higher education* (pp. 1-25). Hershey, PA: Information Science Publishing.

Allen, D., & Tanner, K. (2005). Infusing active learning into the large-enrolment Biology class: Seven strategies, from the simple to complex. *Cell Biology Education, 4,* 262-268.

Beatty, I. (2004). Transforming student learning with classroom communication systems. *EDUCAUSE Research Bulletin, 3,* 1-13. Retrieved November 3, 2007, from http://www.educause.edu/ir/library/pdf/ERB0403.pdf

Bergtrom, G. (2006). Clicker sets as learning objects. *Interdisciplinary Journal of Knowledge and Learning Objects, 2*. Retrieved November 3, 2007, from http://ijklo.org/Volume2/v2p105-110Bergtrom.pdf

Brewer, C. A. (2004). Near real-time assessment of student learning and understanding in biology courses. *BioScience, 54*(11), 1034-1039.

Burnstein, R. A., & Lederman, L. M. (2001). Using wireless keypads in lecture classes. *The Physics Teacher, 39*(1), 8-11.

Burton, K. (2006). The trial of an audience response system to facilitate problem-based learning in legal education. In D. A. Banks (Ed.), *Audience response systems in higher education* (pp. 265-276). Hershey, PA: Information Science Publishing.

Caldwell, J.E. (2007). Clickers in the large classroom: Current research and best-practice tips. *Life Sciences Education, 6*(1), 9-20.

Carnaghan, C., & Webb, A. (2007). Investigating the effects of group response systems on student satisfaction, learning, and engagement in accounting education. *Issues in Accounting Education, 22*(3), 391-409.

Crouch, C. H., & Mazur, E. (2001). Peer instruction: Ten years of experience and results. *American Journal of Physics, 69*(9), 970-977.

Cutts, Q. (2006). Practical lessons from four years of using an ARS in every lecture of a large class. In D. A. Banks (Ed.), *Audience response systems in higher education* (pp. 65-79). Hershey, PA: Information Science Publishing.

d'Inverno, R., Davis, H., & White, S. (2003). Using a personal response system for promoting student interaction. *Teaching Mathematics and Its Applications, 22*(4), 163-169.

Donovan, M. S., Brown, A. L., & Cocking, R. (Eds.) (1999). *How people learn: Brain, mind, experience, and school.* Washington, DC: National Academy Press.

Draper, S.W., & Brown, M.I. (2004). Increasing interactivity in lectures using an electronic voting system. *Journal of Computer Assisted Learning, 20*(2), 81-94.

Dufresne, R. J., & Gerace, W. J. (2004). *Assessing-to-learn: Formative assessment in physics instruction*. *The Physics Teacher, 42,* 428-433.

Fagan, A. P., Crouch, C. H., & Mazur, E. (2002). Peer instruction: Results from a range of classrooms. *The Physics Teacher, 40*(4), 206-209.

Fies, C., & Marshall, J. (2006). Classroom response systems: A review of the literature. *Journal of Science Education and Technology, 15*(1), 101-109.

Greer, L., & Heaney, P. J. (2004). Real-time analysis of student comprehension: An assessment of electronic student response technology in an introductory earth science course. *Journal of Geoscience Education, 52*(4), 345-351.

Hinde, K., & Hunt, A. (2006). Using the personal response system to enhance student learning: Some evidence from teaching economics. In D. A. Banks (Ed.), *Audience response systems in higher education* (pp. 140-154). Hershey, PA: Information Science Publishing.

Jackson, M., Ganger, A. Ac., Bridge, P. D., & Ginsburg, K. (2005). Wireless handheld computers in the undergraduate medical curriculum. *Medical Education Online, 10* (5). Retrieved November 3, 2007, from http://www.med-ed-online.org/pdf/t0000062.pdf

Jones, C., Connolly, M., Gear, A., & Read, M. (2001). Group integrative learning with group process support technology. *British Journal of Educational Technology, 32*(5), 571-581.

Judson, E., & Sawada, D. (2002). Learning from past and present: Electronic response systems in college lecture halls. *Journal of Computers in Mathematics and Science Teaching, 21*(2), 167-181.

Kay, R. H. (2008a). Audience response systems attitude scale. Retrieved November 22, 2008, from http://faculty.uoit.ca/kay/papers/arshs/AppendixA_ARS.pdf

Kay, R. H. (2008b). Coding scheme for secondary school students comments about audience response systems. Retrieved November 22, 2008, from http://faculty.uoit.ca/kay/papers/arshs/AppendixB_ARS.pdf

Kaleta, R., & Joosten, T. (2007). Student response systems: A University of Wisconsin system study of clickers. *EDUCAUSE Research Bulletin,* (10), 1-12.

Kennedy, G. E., & Cutts, Q. I. (2005). The association between students' use of electronic voting systems and their learning outcomes. *Journal of Computer Assisted Learning, 21*(4), 260-268.

Latessa, R., & Mouw, D. (2005). Use of audience response system to augment interactive learning. *Family Medicine, 37*(1), 12-14. Retrieved November 3, 2007, from http://www.stfm.org/fmhub/fm2005/January/Robyn12.pdf

McCabe, M. (2006). Live assessment by questioning in an interactive classroom. In D. A. Banks (Ed.), *Audience Response Systems in Higher Education* (pp. 276-288). Hershey, PA: Information Science Publishing.

Miller, R. L., Santana-Vega, E., & Terrell, M. S. (2006). Can good questions and peer discussion improve calculus instruction? *PRIMUS, 16*(3), 1-9.

Nicol, D. J., & Boyle, J. T. (2003). Peer instruction versus class-wide discussion in large classes: A comparison of two interaction methods in the wired classroom. *Studies in Higher Education, 28*(4), 457-473.

Paschal, C. B. (2002). Formative assessment in physiology teaching using a wireless classroom communication system.*Advances in Physiology Education, 26*(4), 299-308.

Pelton, L. F., & Pelton, T. (2006). Selected and constructed response systems in mathematics. In D. A. Banks (Ed.), *Audience response systems in higher education* (pp. 175-186). Hershey, PA: Information Science Publishing.

Penuel, W. R., Abrahamson, L., & Roschelle, J. (2006). Theorizing the transformed classroom: Sociocultural interpretation of the effects of audience response systems in higher education. In D. A. Banks (Ed.), *Audience response systems in higher education* (pp. 187-208). Hershey, PA: Information Science Publishing.

Pradhan, A., Sparano, D., & Ananth, C.V. (2005). The influence of an audience response system on knowledge retention: An application to resident education. *American Journal of Obstetrics and Gynecology, 193*(5*)*, 1827-30.

Preszler, R.W., Dawe, A., Shuster, C.B., & Shuster, M. (2007). Assessment of the effects of student response systems on student learning and attitudes over a broad range of biology courses. *CBE-Life Sciences Education, 6*(1), 29-41.

Reay, N. W., Bao, L., Li, P., Warnakulasooriya, R., & Baugh, G. (2005). Toward the effective use of voting machines in physics lectures. *American Journal of Physics, 73*(6), 554-558.

Schackow, T. E., Milton, C., Loya, L., & Friedman, M. (2004). Audience response system: Effect on learning in family medicine residents. *Family Medicine, 36*, 496-504.

Sharma, M. D., Khachan, J., Chan, B., & O'Byrne, J. (2005). An investigation of the effectiveness of electronic classroom communication systems in large lectures. *Australasian Journal of Educational Technology, 21*(2), 137-154.

Siau, K., Sheng, H., & Nah, F. (2006). Use of classroom response system to enhance classroom interactivity. *IEEE Transactions on Education, 49*(3), 398-403.

Simpson, V., & Oliver, M. (2007). Electronic voting systems for lectures then and now: A comparison of research and practice. *Australasian Journal of Educational Technology, 23*(*2*), 187-208.

Slain, D., Abate, M., Hidges, B. M., Stamatakis, M. K., & Wolak, S. (2004). An interactive response system to promote active learning in the doctor of pharmacy curriculum. *American Journal of Pharmaceutical Education, 68*(5), 1-9.

Stuart, S. A. J., Brown, M. I., & Draper, S.W. (2004). Using an electronic voting system in logic lectures: One practitioner's application. *Journal of Computer Assisted Learning, 20*(2), 95-102

Trees, A. R., & Jackson, M. H. (2007). The learning environment in clicker classrooms: Student processes of learning and involvement in large university course using student response systems. *Learning, Media, and Technology, 32*(1), 21-40.

Uhari, M., Renko, M., & Soini, H. (2003). Experiences of using an interactive audience response system in lectures. *BMC Medical Education, 3*(12), 1-6.

Van Dijk, L. A., Van Den Berg, G. C., & Van Keulen, H. (2001). Interactive lectures in engineering education. *European Journal of Engineering Education, 26*(1), 15-28.