Computers & Education 53 (2009) 819–827

Contents lists available at ScienceDirect

Computers & Education

journal homepage: www.elsevier.com/locate/compedu

Examining the benefits and challenges of using audience response systems: A review of the literature

Robin H. Kay *, Ann LeSage [1]

University of Ontario Institute of Technology, Faculty of Education, 2000 Simcoe St. North, Oshawa, Ontario, Canada L1H 7L7

ARTICLE INFO

Article history:
Received 18 January 2009
Received in revised form 3 May 2009
Accepted 4 May 2009

Keywords:
Audience response systems
Personal response system
Electronic voting system
Student response system
Review
Attitude
Learning
Assessment

ABSTRACT

Audience response systems (ARSs) permit students to answer electronically displayed multiple choice questions using a remote control device. All responses are instantly presented, in chart form, then reviewed and discussed by the instructor and the class. A brief history of ARSs is offered including a discussion of the 26 labels used to identify this technology. Next a detailed review of 67 peer-reviewed papers from 2000 to 2007 is offered presenting the benefits and challenges associated with the use of an ARS. Key benefits for using ARSs include improvements to the classroom environment (increases in attendance, attention levels, participation and engagement), learning (interaction, discussion, contingent teaching, quality of learning, learning performance), and assessment (feedback, formative, normative). The biggest challenges for teachers in using ARSs are time needed to learn and set up the ARS technology, creating effective ARS questions, adequate coverage of course material, and ability to respond to instantaneous student feedback. Student challenges include adjusting to a new method of learning, increased confusion when multiple perspectives are discussed, and negative reactions to being monitored. It is concluded that more systematic, detailed research is needed in a broader range of contexts.

1. Introduction

1.1. Overview

An Audience Response System (ARS) allows an entire class to respond to multiple choice questions displayed on a screen. After students click in their responses using remote devices, the results are instantly collected, summarized and presented to the class in visual format, usually a histogram. Responses are always anonymous to peers, but the teacher can associate ARS devices with individual students for testing purposes. With feedback from the class, an instructor is provided with an opportunity to orchestrate peer or classroom discussion about concepts being covered. ARSs have been used to improve student interaction, engagement, and attention (e.g., Draper & Brown, 2004; Hinde & Hunt, 2006), increase attendance (e.g., Bullock et al., 2002), stimulate peer and class discussion (e.g., Pelton & Pelton, 2006), provide feedback for both students and instructors in order to improve instruction (e.g., Caldwell, 2007), and improve learning performance (e.g., El-Rady, 2006).

The purpose of this review is to provide a current, comprehensive synthesis of research on ARSs from 2000 to 2007 in order to guide educators and future researchers. Previous research reviews (Caldwell, 2007; Fies & Marshall, 2006; Judson & Sawada, 2002; Simpson & Oliver, 2007) are somewhat dated and/or limited in coverage and scope. Key topics encompassed in the current review include the history of ARSs, labeling and terminology, previous literature reviews, benefits and challenges when using ARSs, and suggestions for further investigation.

1.2. History of ARSs

When ARSs were first introduced at Stanford University in 1966, they were expensive, did not function well, and were difficult to use (Abrahamson, 2006; Judson & Sawada, 2002, 2006). In 1985, a much less expensive prototype, known as *Classtalk I*, was tested and

* Corresponding author. Tel.: +1 905 721 8668x2679.
E-mail address: robin.kay@uoit.ca (R.H. Kay).
[1] Tel.: +1 905 721 8668x2886.

0360-1315/$ - see front matter
doi:10.1016/j.compedu.2009.05.001

generally well received by students and teachers at Christopher Newport University. Although ARSs became commercially available from 1992 to 1999 (Abrahamson, 2006; Beatty, 2004), the cost was still too prohibitive for widespread distribution. In 1999, a new generation of more affordable, infrared ARSs became available. Extensive use of ARSs began in 2003 (Abrahamson, 2006; Judson & Sawada, 2002, 2006) and today, numerous secondary schools, colleges and universities use this tool (Abrahamson, 2006).

1.3. Labeling and terminology

A comprehensive review of the literature reveals no less than 26 different labels for ARSs (see Kay (2008a) for a complete list). The most commonly used terms include: audience response system (n = 17 papers), personal response system (n = 7 papers), electronic voting system (n = 5 papers), and student response system (n = 4 papers). One key issue with inconsistent labeling is the difficulty it poses in locating and staying current with the latest research. For example, four relatively recent reviews on ARSs (Caldwell, 2007; Fies & Marshall, 2006; Simpson & Oliver, 2007) referenced 16–25 studies per review, yet this quantity represents only one quarter to one third of the peer-reviewed articles available on ARSs from 2000 to 2007.

1.4. Previous literature reviews

Four literature reviews have been completed on ARSs (Caldwell, 2007; Fies & Marshall, 2006; Judson & Sawada, 2002; Simpson & Oliver, 2007). Judson and Sawada (2002) provided a summary of ARS use up until 1998, but their review included only eight peer-reviewed references. Because prevalent use of ARSs began after 2003, Judson and Sawada's (2002) analysis is dated. Fies and Marshall (2006) examined methods used to assess ARSs, however their review included only 16 peer-reviewed studies, only two of which two were published after 2004. Therefore, some of their conclusions are questionable. For example, they claimed that few studies reported the use of ARSs for formative assessment, yet since 2004, 16 new studies have been completed where formative assessment was employed. A more recent review by Simpson and Oliver (2007) analyzed more than 40 papers. However, only 17 of the articles cited were from peer-reviewed journals, with the majority of the results based on five key references. In addition, the impact ARSs on learning was not studied in detail.

The most current and comprehensive review was conducted by Caldwell (2007) who analyzed 25 peer-reviewed articles, many of which were published after 2000. Caldwell's analysis focussed on identifying the primary users of ARSs, articulating the rationale for using ARSs, exploring questioning strategies used with ARSs, and identifying best practices. Nevertheless, few details were offered with respect to the impact of ARSs on student learning.

In summary, it is argued that a more comprehensive review of the ARS literature is needed in order to present a more current and representative summary of benefits and challenges experienced when using this new technology.

2. Method

2.1. Studies examined

2.1.1. Overview

Several measures were taken to address some the shortcomings of previous ARS research reviews. First, a comprehensive search of peer-reviewed journals, but not conference papers or reports, was completed based on the 26 labels for ARSs (Kay, 2008a). This approach uncovered a total of 67 papers and chapters. Given that previous literature reviews included no more than 25 peer-reviewed papers, one can be reasonably assured that the current review of ARSs is comprehensive.

Of the 67 studies examined, 64 were performed between 2000 and 2007, with 49 articles published since 2004. Thirty-six studies collected data about attitudes, and 24 focussed on learning. Regarding methodology, 20 of the studies were survey-based, 12 were case studies, 13 offered theoretical analyses, eight presented qualitative data, and the remaining articles provided specific or general reviews of ARS use. See Kay (2008c) for a complete list of the articles included in this review.

2.1.2. Context of using ARSs

Before examining the benefits and challenges of using ARSs, it is informative to understand the context in which these tools have been used. The sample populations for the 67 studies reviewed in this paper were predominantly undergraduate students (n = 49 studies), with only 5 papers investigating professionals or faculty use, three examining middle school students, and one looking at secondary school classrooms. Eighteen studies were in the domain of science, eight in medicine, six in mathematics or computer science, four in engineering, four in business, and three in social science or law. The remaining studies covered a variety of subject areas including law, and philosophy. Sample size ranged from 14 to 2684 students. Seventy-six percent of the 34 studies that did report sample size examined over 80 students with an overall mean of 308. In summary, the conclusions from the current review reflect the attitudes and learning efforts of undergraduate students who were studying science- or mathematics-based subject areas in relatively large classes.

2.1.3. Data analysis

The methodology of each of the studies in this paper was analyzed based on the following elements: student population, sample size, subject area, data collection type, reliability and validity of data collection tools, and the identification of the study's area of focus (attitude and/or learning). Each study was also analyzed based on the following categories: rationale or theory for using ARSs, context of use, and benefits and challenges associated with using an ARS. Kay (2008b) provides a detailed description of the coding of variables used in this study.

It should be noted that a meta-analysis was not completed because (a) only 10 studies used formal statistics to evaluate data, (b) only four studies offered reliability estimates for data collection tools, (c) only one study presented validity information and (d) a meaningful comparison of these studies was restricted by the narrow range of subject areas covered.

3. Results and discussion

3.1. Benefits to using ARSs

3.1.1. Overall attitudes

According to Judson and Sawada (2002), prior to 1992, student attitudes toward ARSs were very positive, although much of the evidence presented was based on informal student feedback. However, more recent studies have offered considerable quantitative and qualitative evidence indicating that students are positive about the use of ARSs in higher education (Caldwell, 2007; Durbin & Durbin, 2006; Fies & Marshall, 2006; Hu et al., 2006; Simpson & Oliver, 2007). In the literature review completed for this paper, 36 out of the 38 articles that examined attitudes toward ARSs reported that students and/or teachers had positive perceptions of the technology. In addition, the majority of students reported that the technology was easy to learn and use (d'Inverno, Davis, & White, 2003; Elliott, 2003; Hinde & Hunt, 2006; Jones, Connolly, Gear, & Read, 2001; Pelton & Pelton, 2006; Pradhan, Sparano, & Ananth, 2005; Sharma, Khachan, Chan, & O'Byrne, 2005; Siau, Sheng, & Nah, 2006). It is critical, however, to focus on the specific benefits of ARSs in order to truly determine whether the technology is a viable instruction tool. These benefits will be presented within three categories (classroom environment, learning, and assessment) and are summarized in Table 1.

3.1.2. Classroom environment benefits

3.1.2.1. Attendance. Attendance in higher education classrooms is unpredictable at best (Burnstein & Lederman, 2001; Greer & Heaney, 2004). In order to improve attendance, ARSs have been introduced at several universities. Multiple studies have found that attendance does improve when an ARS is used, provided it is linked to a portion of a student's final mark. Dramatic increases in attendance occur when 15% of a student's grade is associated with ARS participation (Burnstein & Lederman, 2001; Greer & Heaney, 2004). However, Caldwell (2007) observed that 5% of a student's grade was sufficient motivation to improve regular classroom attendance. Ideally an instructor would prefer that students attend class because they felt that using an ARS helped improve the learning process, but only two studies reported increased attendance when grades were not associated with ARS use (El-Rady, 2006; Preszler, Dawe, Shuster, & Shuster, 2007). It is worth noting that even though attendance may increase with ARS use, students do not necessarily support this practice. Greer and Heaney (2004) observed that students were displeased about being forced to attend class in order to gain academic credit for ARS participation. It is possible that using external rewards to increase classroom attendance may be effective, but could undermine the process of creating a positive learning environment.

3.1.2.2. Attention. It is self evident that students need to be focussed and paying attention when content is presented during a lecture. What may not be obvious is that during a lecture, attention may diminish after only 20 min (d'Inverno et al., 2003; Jackson, Ganger, Bridge, & Ginsburg, 2005). Given that a typical higher education class lasts from 50 min to 3 h, it is inevitable that some information will be lost. One technique for addressing student attention deficits during a class is to present ARS questions at 20 min intervals, thereby requiring students to shift their attention and actively participate in the learning process. The success of this approach has been confirmed by numerous studies which have reported that higher education students are more attentive when an ARS is used during lectures (Bergtrom, 2006; Burnstein & Lederman, 2001; Caldwell, 2007; d'Inverno et al., 2003; Draper & Brown, 2004; Elliott, 2003; Horowitz, 2006; Jackson et al., 2005; Jones et al., 2001; Latessa & Mouw, 2005; Siau et al., 2006; Slain, Abate, Hidges, Stamatakis, & Wolak, 2004).

3.1.2.3. Anonymity and participation. Students can respond to ARS questions without being judged by their peers, a tutor, or the instructor. Anonymity allows all students to be active members of the classroom community and participate in the learning process without recrimination (Banks, 2006; Durbin & Durbin, 2006). A number of researchers have reported that students appreciate this feature (Banks, 2006; Caldwell, 2007; Draper & Brown, 2004; Hu et al., 2006; Jones et al., 2001; Siau et al., 2006; Simpson & Oliver, 2007; Stuart, Brown, & Draper, 2004). In addition, substantial evidence indicates that using an ARS increases student participation when compared to classrooms where an ARS was not used (Bullock et al., 2002; Caldwell, 2007; Draper & Brown, 2004; Greer & Heaney, 2004; Jones et al., 2001; Siau et al., 2006; Stuart et al., 2004; Uhari, Renko, & Soini, 2003; Van Dijk, Van Den Berg, & Van Keulen, 2001).

3.1.2.4. Engagement. Students have reported being more interested or engaged in concepts presented and discussed using an ARS (Bergtrom, 2006; Hu et al., 2006; Preszler et al., 2007; Simpson & Oliver, 2007). However, detailed information for why students are engaged has not been collected to date. While it is assumed that students are more engaged because they are actively involved in the learning process, one alternative explanation might that they are having fun using a remote control device and observing other students' responses. More comprehensive, qualitative research is required to explore plausible explanations for increased student engagement with ARS use.

3.1.3. Learning benefits

3.1.3.1. Interaction. Numerous studies suggest that frequent and positive interaction occurs when ARSs are used (Banks, 2006; Beatty, 2004; Bergtrom, 2006; Caldwell, 2007; Elliott, 2003; Freeman, Bell, Comerton-Forder, Pickering, & Blayney, 2007; Kennedy, Cutts, & Draper, 2006; Sharma, Khachan, Chan, & O'Byrne, 2005; Siau et al., 2006; Slain et al., 2004; Stuart et al., 2004; Trees & Jackson, 2007). Specifically, researchers have reported greater articulation of student thinking (Beatty, 2004), more probing questions, an increased focus on student needs (Beatty, 2004; Siau et al., 2006), effective peer-to-peer discussions (Bergtrom, 2006; Caldwell, 2007; Kennedy et al., 2006), and active learning (Elliott, 2003; Kennedy et al., 2006; Slain et al., 2004; Stuart et al., 2004).

3.1.3.2. Discussion. A few researchers have noted that use of an ARS increases the quantity and quality of class discussions, particularly when employed with a strategy known as "peer instruction" (Beatty, 2004; Brewer, 2004; Draper & Brown, 2004; Jones et al., 2001; Nicol & Boyle, 2003). Peer instruction occurs when a teacher presents a question using an ARS, collects student responses and presents responses from the class, but does not provide the correct answer. Instead, the class is instructed to discuss possible solutions in pairs and then students are provided with the opportunity to vote a second time. After the second vote, the issues are resolved through class discussion and

Table 1
Summary of audience response system benefits.

Benefit	Description	Evidence
Classroom environment benefits		
Attendance	Students go to class more	Burnstein and Lederman (2001), Caldwell (2007), and Greer and Heaney (2004)
Attention	Students are more focused in class	Bergtrom (2006), Burnstein and Lederman (2001), Caldwell (2007), d'Inverno et al. (2003), Draper and Brown (2004), Elliott (2003), Jackson et al. (2005), Jones et al. (2001), Latessa and Mouw (2005), Siau et al. (2006), and Slain et al. (2004)
Anonymity	All students participate anonymously	Caldwell (2007), Draper and Brown (2004), Jones et al. (2001), Siau et al. (2006), Simpson and Oliver (2007), and Stuart et al. (2004)
Participation	Students participate with peers more in class to solve problems	Bullock et al. (2002), Caldwell (2007), Draper and Brown (2004), Greer and Heaney (2004), Jones et al. (2001), Siau et al. (2006), Stuart et al. (2004), Uhari et al. (2003), and Van Dijk et al. (2001)
Engagement	Students are more engaged in class	Bergtrom (2006), Caldwell (2007), Draper and Brown (2004), Latessa and Mouw (2005), Preszler et al. (2007), Siau et al. (2006), and Simpson and Oliver (2007)
Learning benefits		
Interaction	Students interact more with peers to discuss ideas	Beatty (2004), Bergtrom (2006), Caldwell (2007), Elliott (2003), Freeman et al. (2007), Kennedy et al. (2006), Sharma, Khachan, Chan, and O'Byrne (2005), Siau et al. (2006), Slain et al. (2004), Stuart et al. (2004), Trees and Jackson (2007), and Van Dijk et al. (2001)
Discussion	Students actively discuss misconceptions to build knowledge	Beatty (2004), Brewer (2004), Draper and Brown (2004), Jones et al. (2001), and Nicol and Boyle (2003)
Contingent teaching	Instruction can be modified based on feedback from students	Brewer (2004), Caldwell (2007), Cutts (2006), Draper and Brown (2004), Elliott (2003), Greer and Heaney (2004), Hinde and Hunt (2006), Jackson et al. (2005), Kennedy and Cutts (2005), Poulis et al. (1998) and Stuart et al. (2004)
Learning performance	Learning performance increases as a results of using ARS	Bullock et al. (2002), El-Rady (2006), Fagan et al. (2002), Kaleta and Joosten (2007), Kennedy and Cutts (2005), Pradhan et al. (2005), Preszler et al. (2007), Schackow et al. (2004) and Slain et al. (2004)
Quality of learning	Qualitative difference when learning with ARS (e.g., better explanations, thinking about important concepts, resolving misconceptions)	Caldwell (2007), d'Inverno et al. (2003), Draper and Brown (2004), Elliott (2003), Greer and Heaney (2004), and Nicol and Boyle (2003)
Assessment benefits		
Feedback	Students and teacher like getting regular feedback on understanding	Abrahamson (2006), Cline (2006), Draper et al. (2002), McCabe (2006), and Pelton and Pelton (2006)
Formative	Assessment is done that improves student understanding and quality of teaching	Beatty (2004), Bergtrom (2006), Brewer (2004), Bullock et al. (2002), Caldwell (2007), Draper and Brown (2004) Dufresne and Gerace (2004), Elliott (2003), Greer and Heaney (2004), Hatch et al. (2005), Jackson et al. (2005), Siau et al. (2006), Simpson and Oliver (2007), and Stuart et al. (2004)
Compare	Students compare their ARS responses to class responses	Burton (2006), Caldwell (2007), Draper and Brown (2004), Hinde and Hunt (2006) and Simpson and Oliver (2007)

clarifications from the instructor. The research indicates that students feel they are better able to discuss and calibrate their understanding of specific concepts when peer instruction is employed (Draper & Brown, 2004).

3.1.3.3. Contingent teaching. One of the key benefits of using an ARS is that instruction can be modified based on student feedback gathered throughout a class (Brewer, 2004; Caldwell, 2007; Cutts, 2006; Draper & Brown, 2004; Elliott, 2003; Greer & Heaney, 2004; Hinde & Hunt, 2006; Jackson et al., 2005; Kennedy & Cutts, 2005; Poulis, Massen, Robens, & Gilbert, 1998; Stuart et al., 2004). If feedback from a majority of students indicates that confusion or misconceptions are evident, an experienced instructor can offer alternative explanations of the concepts in question. In essence, using an ARS changes a relatively static one-way transmission of information into a dynamic, interactive lecture guided by student input (Kennedy & Cutts, 2005).

3.1.3.4. Learning performance. A strong argument can be made for the use of ARSs in the classroom based on anecdotal and experimental evidence with respect to learning performance. Extensive qualitative research suggests that learning performance increases as a result of using ARSs (Brewer, 2004; Caldwell, 2007; Carnaghan & Webb, 2007; Horowitz, 2006; Hu et al., 2006; Kennedy & Cutts, 2005; Latessa & Mouw, 2005; Poulis et al., 1998; Schackow, Milton, Loya, & Friedman, 2004). In addition, many experimental studies report that classes using ARSs significantly outperform those using traditional lecture formats (Bullock et al., 2002; El-Rady, 2006; Fagan, Crouch, & Mazur, 2002; Kaleta & Joosten, 2007; Kennedy & Cutts, 2005; Pradhan et al., 2005; Preszler et al., 2007; Schackow et al., 2004; Slain et al., 2004).

3.1.3.5. Quality of learning. Numerous studies claim that higher education students report that they learn more when an ARS is used (Elliott, 2003; Greer & Heaney, 2004; Hatch, Jensen, & Moore, 2005; 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 prefer hearing explanations of ARS questions from their peers who have a similar language and therefore can explain problems and solutions more effectively than the instructor (Caldwell, 2007; Nicol &

Boyle, 2003). Other students claim that using an ARS pushes them to think more about the important concepts (Draper & Brown, 2004; Greer & Heaney, 2004). Still others believe that the use of an ARS helps them discover and resolve misconceptions (d'Inverno et al., 2003). The one drawback noted by several instructors is that not as many concepts can be addressed when using an ARS (Caldwell, 2007; Elliott, 2003). However, many of these same instructors acknowledge that reduced content coverage is more than compensated for by the depth of material that students truly understand (Elliott, 2003). In summary, using an ARS appears to emphasize the depth of student understanding, not the amount of material "covered".

3.1.4. Assessment benefits

3.1.4.1. Feedback. In a regular classroom, feedback can be acquired by multiple means, including a show of hands, asking volunteers to share answers, use of small individual whiteboards to display answers, or using coloured cards to represent multiple choice responses (Abrahamson, 2006; Cline, 2006; Draper, Cargill, & Cutts, 2002; McCabe, 2006; Pelton & Pelton, 2006). However these methods have notable disadvantages. A show of hands, for example, is limited because it is difficult to obtain a quick, accurate sense of class understanding, particularly in a large lecture. Furthermore, some students are inclined to copy the responses of others. In addition, when hands are lowered, the data is lost (Abrahamson, 2006; Pelton & Pelton, 2006). Also, relying on volunteers is somewhat restrictive because, only the confident students raise their hands (Banks, 2006; Burton, 2006; Slain et al., 2004). Note also that with a show of hands or asking volunteers to respond, anonymity is lost. Whiteboards and coloured cards are more anonymous, but amalgamating responses is a relatively slow process.

Using an ARS helps improve the feedback process by guaranteeing anonymity, quickly and efficiently collecting and summarizing student responses, and preventing students from copying the answers from their peers. Finally, with ARSs, students are required to think about a question or problem and then commit to an answer. It has been argued that this commitment to a response is particularly important when students are required to articulate and defend their answers in a peer-instruction format (Abrahamson, 2006; Beatty, 2004; Hake, 1998; Pradhan et al., 2005).

3.1.4.2. Formative assessment. Formative assessment is used to determine student understanding of concepts without grades, in order to identify misconceptions and alter the course of classroom instruction. Without a tool like an ARS, it is somewhat challenging to calibrate overall student understanding of concepts while they are presented in class. Regular use of an ARS can offer real-time feedback to both instructors and students as to how well concepts are being understood. As stated earlier, experienced teachers can quickly modify explanations or mode of instruction (contingent teaching) or students can gauge and discuss their understanding with their peers (peer-instruction). Extensive evidence suggests that using an ARS helps provide effective formative assessment (Beatty, 2004; Bergtrom, 2006; Brewer, 2004; Bullock et al., 2002; Caldwell, 2007; Draper & Brown, 2004; Dufresne & Gerace, 2004; Elliott, 2003; Greer & Heaney, 2004; Hatch et al., 2005; Jackson et al., 2005; Siau et al., 2006; Simpson & Oliver, 2007; Stuart et al., 2004).

3.1.4.3. Compare responses with other students. After ARS feedback is presented to the class students are able to compare their 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). It is unclear from the research to date, though, why students like to compare responses. It could be that the use of an ARS promotes a competitive atmosphere, a goal that may not promote a strong sense of community. Alternatively, some students may want to monitor their progress, while others may want assurance that they are not alone in their misunderstanding of key concepts. More research is needed to determine whether student appeal for comparison with peers is a positive or negative influence on developing a classroom community.

3.2. Challenges to using ARSs

Three categories of challenges were predominant in the ARS literature: technology, teacher, and student-based. Each of these challenges are discussed in detail below and summarized in Table 2.

3.2.1. Technological challenges

Two main technology-based difficulties were reported when using ARSs. First, when students were responsible for purchasing their own remote devices, they did not consistently bring them to class or they were lost. Because of the class dependence on ARSs, students without remote devices were unable to fully participate (Caldwell, 2007; Reay, Bao, Li, Warnakulasooriya, & Baugh, 2005). Second, a more critical technological issue occurred when remote devices did not function properly or the signal was not received by the instructor's computer. This was a particularly stressful experience when students were being evaluated (El-Rady, 2006; Hatch et al., 2005; Sharma, Khachan, Chan, & O'Byrne, 2005; Siau et al., 2006). Thus, for an ARS to be a successful learning tool, the technology has to function consistently and efficiently. Two possible solutions to the above mentioned technology problems include supplying students with remote devices in every class rather than relying on students to bring them (Reay et al., 2005) and using radio frequency devices which are more reliable than the less expensive infrared models.

3.2.2. Teacher-centred challenges

3.2.2.1. Responding to student feedback. One anticipated benefit of ARSs was to collect feedback from students throughout a lecture so that the teacher could adjust instructional strategies when necessary. Limited research has been done examining how well this approach works in practice. As Abrahamson (2006) notes, it is one thing to find out that students do not understand a concept – it is quite another to instantly adjust teaching style and offer a better explanation. Relatively inexperienced teachers may have difficulty using contingent teaching and frustration may ensue (Hu et al., 2006). It may be that peer-instruction, which involves greater student involvement when concepts are not understood, is an easier strategy to use with ARSs.

3.2.2.2. Coverage. One of the main concerns about using an ARS on a regular basis is coverage of content. Considerable research indicates that teachers, and sometimes students, believe that less content is addressed when using an ARS (Beatty, 2004; Beatty, Gerace, Leonard, & Dufresne, 2006; Burnstein & Lederman, 2001; Burton, 2006; Caldwell, 2007; Cutts, 2006; d'Inverno et al., 2003; Draper & Brown, 2004;

Table 2
Summary of audience response system challenges.

Challenge	Description	Evidence
Technology-based challenges		
Bringing remotes	Students forgot or lost remotes and could not participate in class	Caldwell (2007) and Reay et al. (2005)
ARS did not work	Remote devices did not function properly	El-Rady (2006), Hatch et al. (2005), Sharma, Khachan, Chan, and O'Byrne (2005), Siau et al. (2006)
Teacher-based challenges		
Responding to student feedback	Less experienced teachers cannot adjust to student feedback	Abrahamson (2006) and Hu et al. (2006)
Coverage	Cover less course content if ARS is used	Beatty (2004), Beatty et al. (2006), Burnstein and Lederman (2001), Caldwell (2007), d'Inverno et al. (2003), Burton (2006), Cutts (2006), Draper and Brown (2004), Fagan et al. (2002), Freeman et al. (2007), Hatch et al. (2005), Sharma, Khachan, Chan, and O'Byrne (2005), Siau et al. (2006), Slain et al. (2004), Steinhert and Snell (1999), and Stuart et al. (2004)
Developing questions	Time consuming to create ARS questions	Allen and Tanner (2005), Beatty et al. (2006), Boyle (2006), El-Rady (2006), Fagan et al. (2002), Freeman et al. (2007), Horowitz (2006), Paschal (2002) and Robertson (2000)
Student-based challenges		
New method	Students find it difficult to shift to a new way of learning	Allen and Tanner (2005), Beatty (2004), Fagan et al. (2002) and Siau et al. (2006)
Discussion	Discussion leads to confusion or wasting time	Draper and Brown (2004), Nicol and Boyle (2003), and Reay et al. (2005)
Effort	Too much effort is required by students when using ARSs	Trees and Jackson (2007)
Summative assessment	Using ARS for tests may not be popular with students	Caldwell (2007) and Kay (2008)
Attendance for grades	Students do not like ARSs used for monitoring attendance	Caldwell (2007)
Identifying students	Students want to remain anonymous	Abrahamson (2006)
Negative feedback	Students feel bad when receiving negative feedback	Carnaghan and Webb (2007)

Fagan et al., 2002; Freeman et al., 2007; Hatch et al., 2005; Horowitz, 2006; Sharma, Khachan, Chan, & O'Byrne, 2005; Siau et al., 2006; Slain et al., 2004; Steinhert & Snell, 1999; Stuart et al., 2004). Responding to higher level questions that target misconceptions can take significantly more time than merely presenting material in a lecture format. In addition, the time required to set up the ARS, hand out the remote controls at the beginning of the class, and collect remote controls at the end of the class can be significant (Hatch et al., 2005; Hu et al., 2006; Stuart et al., 2004). Moreover, some studies report that class wide discussion takes too much time and that it is easy to drift away from the main ideas being addressed (Nicol & Boyle, 2003; Reay et al., 2005).

Some researchers have reported that concepts covered in a traditional lecture may not be understood as well as concepts learned in an ARS-based classroom (Beatty et al., 2006; Caldwell, 2007). One way to cover subject matter not addressed in class is to require students to do more outside reading and class preparation (Bergtrom, 2006; Bullock et al., 2002; Burnstein & Lederman, 2001; Caldwell, 2007; Slain et al., 2004). Research to date is limited with respect to evaluating how well this strategy works.

3.2.2.3. Developing questions. Writing good ARS questions can be a demanding task for instructors. Researchers agree that the most effective questions have the following characteristics: they address a specific learning goal, make students aware of opinions other than their own, uncover misconceptions and confusions, explore ideas in a new context, and elicit a wide range of responses (Caldwell, 2007; Crouch & Mazur, 2001; Miller, Santana-Vega, & Terrell, 2006; Tanner & Allen, 2005). Unfortunately there are very few collections of ARS questions available in most fields, so instructors have to develop original questions, a process that is very time consuming (Allen & Tanner, 2005; Beatty et al., 2006; Boyle, 2006; El-Rady, 2006; Fagan et al., 2002; Freeman et al., 2007; Horowitz, 2006; Paschal, 2002; Robertson, 2000).

3.2.3. Student-centered challenges

3.2.3.1. New method of learning. Some students may respond negatively to the use of an ARS simply because the rules for learning have changed. A switch of teaching methods from lecturing to ARS questioning can lead to stress, frustration, and resistance in the beginning (Beatty, 2004; Boyle, 2006; Fagan et al., 2002). In addition, some students are distracted by the use of an ARS (Siau et al., 2006). Still others question their ability to direct their own learning with this tool (Allen & Tanner, 2005). Finally, as discussed previously, some students indicate that less content is covered when using the ARS approach (Allen & Tanner, 2005). While resistance to using ARSs is relatively uncommon (Fagan et al., 2002), it is important note these concerns.

Trees and Jackson (2007) reported that using an ARS requires more cognitive energy and cooperation from students. This type of extended effort may not be readily accepted by all students, particularly those who are accustomed to and more comfortable with relatively passive lectures. More research is needed, though, to determine whether students adapt to and accept the additional cognitive effort that may be required when using an ARS. The popularity of ARSs and the positive impact on learning suggests that the extra effort required may not be a significant barrier (Caldwell, 2007; Fies & Marshall, 2006; Judson & Sawada, 2002, 2006; Simpson & Oliver, 2007).

3.2.3.2. Increased confusion in discussions. Not all discussions run smoothly when an ARS is used. Some students dominate group discussions (Nicol & Boyle, 2003) and the debate of different perspectives and solutions can increase student confusion (Nicol & Boyle, 2003; Reay et al., 2005). Furthermore, some students feel that ARS-based discussion distracts them from the concepts being presented in a lesson (Draper &

Brown, 2004) or view class discussion as intimidating and a source of anxiety (Nicol & Boyle, 2003). Even though these problems have not been widely reported, more information is needed about creating effective discussion that is focussed, non-threatening, and efficient.

3.2.3.3. Being monitored. There is some evidence to suggest that students react negatively to being monitored by ARSs. Key problem areas include summative assessment, attendance, eliminating anonymity, and reaction to negative feedback. Each of these challenges will be discussed in turn.

Summative assessment, or the evaluation of student performance based on formal grades, has been used extensively with ARSs in higher education (Fies & Marshall, 2006), although little research has been conducted on the impact of this practice. Some evidence suggests that students do not enjoy using ARSs for grades (Caldwell, 2007). In a recent paper (Kay, LeSage, & Knaack, in press), secondary school students did not like using ARSs for tests. However, when ARSs were used for formative assessment, students were significantly more motivated and cognitively engaged. More research, though, is needed to examine the impact of summative assessment and ARSs on learning.

As stated earlier, ARSs have been used in some higher education classes to monitor attendance. While not widely reported, some students resented being scrutinized and disapproved of grades being attached to ARS participation (Caldwell, 2007). Another unfortunate reaction to monitoring is that students brought multiple remote devices to class to record attendance for missing classmates, a practice reported 20–58% of the time (Caldwell, 2007). It could be argued that an effective learning environment should provide inherent learning incentives so that students want to attend. Attaching a grade to attendance using an ARS may cultivate resistance and undermine the goal of developing an effective learning environment.

While students clearly appreciate the anonymity associated with using ARSs (Caldwell, 2007; Draper & Brown, 2004; Jones et al., 2001; Siau et al., 2006; Simpson & Oliver, 2007; Stuart et al., 2004), the reasons why students feel more comfortable when they cannot be identified are unclear at this point. One study reported that some students are less confident about using an ARS when their names are associated with a specific remote device. Abrahamson (2006) identified one possible reason for this reticence – students do not like being watched over by "big brother". In small classes, perhaps at the middle and secondary school level, it may be necessary to monitor progress so that teachers can provide individual attention to students. However, in large classes, individual attention is not a realistic goal and, other than attendance and participation, there may be little reason to remove anonymity.

One final monitoring concern about using ARSs is that students who respond incorrectly may feel uncomfortable, particularly when a majority of the class is correct. Carnaghan and Webb (2007) were the only researchers to report this phenomenon. It is possible that the specific teaching strategy used with an ARS may influence how students react to getting answers right or wrong. For example, if cooperation and articulation of ideas is emphasized instead of getting a correct answer, students may feel less insecure about incorrect answers. The goal of peer instruction, for example, is to uncover and discuss misconceptions, so reasoning is more valued than choosing the right answer.

4. Future research

4.1. Methodology for investigating ARSs

A number of authors have argued that there are several key problems with current research on ARSs including: a lack of systematic research, a bias toward using anecdotal, qualitative data, excessive focus on attitudes as opposed to learning and cognitive processes, and samples derived from limited educational settings. Each of these limitations will be discussed.

4.1.1. Lack of systematic research

Several authors (Caldwell, 2007; Fies & Marshall, 2006; Freeman et al., 2007) have noted that research on ARSs has been largely unsystematic. However, it is not clear what these authors mean by "systematic". In the current review, a number of studies have been conducted in a thoughtful, planned manner where the learning impact of ARSs was calibrated (Bullock et al., 2002; Fagan et al., 2002; Kennedy & Cutts, 2005; Paschal, 2002; Pradhan et al., 2005; Rao & DiCarlo, 2000; Schackow et al., 2004). However, data collection instruments are noticeably lacking in reliability and validity analysis. Only four studies reported estimates of validity and reliability (Penuel, Boscardin, Masyn, & Crawford, 2007; Schackow et al., 2004; Siau et al., 2006; Trees & Jackson, 2007). Therefore it is necessary to improve data collection procedures and perhaps focus future studies on specific measurable goals.

4.1.2. Bias toward qualitative research

Several authors have maintained that the majority of ARS data collected to date is anecdotal or qualitative (Fies & Marshall, 2006; Kaleta & Joosten, 2007; Schackow et al., 2004). An analysis of data collection techniques used in the current review partially supports this claim. Almost half the data collected was qualitative, however, 29% used surveys, and 11% assessed learning performance. However, both qualitative and quantitative data is needed to fully understand the use and impact of ARSs, so triangulation of methods might be a desirable direction for future research efforts.

4.1.3. Attitude vs. learning

Some researchers have noted that the majority of ARS investigations consist of broad assessments of attitude and/or anecdotal observations (Carnaghan & Webb, 2007; Kennedy & Cutts, 2005; Siau et al., 2006; Simpson & Oliver, 2007). Indeed, 54% of the 67 studies in the current review examined attitudes toward ARSs. On the other hand, over one third examined learning and learning performance. However, no studies could be found examining the actual cognitive processes involved when students are involved in ARS-stimulated discussion (Kennedy et al., 2006; Penuel, Abrahamson, & Roschelle, 2006). Clearly this is an untapped area for further ARS investigation.

4.1.4. Limited educational settings

The wide-spread implementation of ARSs has only been observed in the past five to seven years, with the majority of use occurring at the tertiary level. It is speculated that the cost of ARSs is only now becoming affordable in the K-12 domain. In the current review, of the 61

studies where data was collected, 59 looked at higher education or professionals with the primary focus on mathematics and science. A reasonable argument could be made that there is a need for a broader range of settings to be examined including K-12 classrooms and non mathematics/science-based courses (Fies & Marshall, 2006) in order to fully understand the educational impact of ARSs.

4.1.5. Future research opportunities

A review of 67 peer-reviewed articles and chapters has revealed key benefits and challenges with respect to using ARSs. However, with any new area of research, there are often many questions left unanswered. These questions provide at least four directions for future researchers.

First, more detailed research is needed to determine why specific benefits and challenges influence the use of ARSs. For example, what is engaging about an ARS and is increased interaction superficial or meaningful in terms of learning? Does resistance to using ARSs translate into a long term negative impact on learning?

Second, more research is needed on analysing the impact of specific types of questions on creating student-centred, knowledge-rich learning that builds classroom community. There is considerable research to suggest that questions that focus on misconceptions are effective, but what about application questions or case study problems? To what extent does formative feedback influence student acquisition of concepts?

Third, the context of ARS use needs to be expanded to include social science subject areas and K-12 classrooms. It is unclear whether ARSs are best suited for more technical subjects or whether a different set of strategies needs to be used for smaller classes and younger students. Broadening the research scope of investigation should provide important data on the use and effectiveness of ARSs in different learning environments.

Finally, more research is needed on individual differences in the use of ARSs. Focussing on gender, grade level, age, and learning style would be a viable starting point. There is considerable data on individual differences in the use of other technologies, so it is important to determine if these differences extend to the use of ARSs. From a practical and ethical perspective, it is essential that we identify potential students that would be negatively affected by the use of ARSs so that we can accommodate these individuals.

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