C.A.L.T
E-Learning Enhancement Grant 2006

Literature Review

The Use of “Clicker” Technology to Enhance the Teaching / Learning Experience.

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03/07/2006
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1 Introduction
Recent technological advances and falling prices have driven an increase in the popularity of Audience Response Systems (ARSs) among tertiary educators (Draper, Cargill et al. 2001). With the increasing popularity of this technology there has been a burgeoning body of literature outlining the pedagogical costs, benefits and outcomes of using Audience Response System (ARS) in the classroom. The goal of this report is to summarise published literature on the uses of ARSs in tertiary teaching. The rationale for introducing and using ARS is discussed, and the basic pedagogical approaches used with ARSs are outlined. The potential benefits of these approaches are outlined, as are the common “pitfalls” of ARS use.

The aim of this report is to guide the authors of a subsequent report to be written on the effectiveness of an ARS in an introductory plant science course (BIOL113) held in the Botany Department of the University of Otago, New Zealand. The initial brief indicated that this report should focus, where possible, on literature regarding the use of ARS in Biology curricula. It was soon discovered, however, that there is remarkably little published literature in this area. Therefore, this report may also be a useful starting point for teachers from a range of science disciplines as well as anyone interested in learning more about ARS in general.

2 What is an “Audience Response System”? An Audience Response System (ARS) can be loosely defined as any technological innovation, or collection of innovations that allows a large group of people to register their response to a multi-choice question (MCQ). An example of ARS in action is the “Ask the Audience” section of the popular television program Who Wants to Be a Millionaire. Recorded use of ARSs in higher-education stretches back as far as 1947 (Draper 2006) although more widespread use of ARS began in the 1960s (Judson and Sawada 2002). Those early systems usually comprised hard-wired knobs or dials with a binary response option (e.g. “I understand” or “I do not understand”) that provided feedback to the presenter showing what percentage of the class had chosen a particular option (Judson and Sawada 2002).

Modern ARSs now include several major technological innovations that allow them to be both more adaptable to teaching needs, and more affordable to deploy.
The first is the use of wireless handsets, similar to television remote controls, rather than “hard-wired” systems with knobs and dials. The technical aspects of these remotes have been reviewed elsewhere (e.g. McDonald 2006) but the similarity to household remote controls has lead to these handsets being known colloquially as “Clickers”. This description is now so commonplace the term has become synonymous with modern ARSs. For clarity, this report will continue to use the term “Audience Response System” (ARS) to define a system that collects audience response data. Where appropriate, “Clickers” will be used to describe the handsets themselves. Note that ARSs are described in the literature by a number of names and there appears to be no consensus between authors (Lowery 2005). For a full list of alternative names for ARSs refer to Appendix 1.

Another key component of modern ARSs is video projection. Video projectors are now commonplace in higher education classrooms and provide a convenient, simple and importantly, instant, way to display the results of student voting. Whilst this may seem a relatively unimportant innovation, the ability to display data to the entire class is one of the cornerstones of ARS enhanced pedagogy.

The third and final key technological component of modern ARSs is the personal computer, or specifically, the software that facilitates the collection, processing, display and storage of voting data. The software component of ARSs is often overlooked when considering which brand or type of ARS to use in a teaching environment. However, as detailed below (see section 5.3 Software) ARS software is usually the component that staff have the most contact with and is at the root of a common complaint that ARSs have “a steep learning curve”.

Thus, in many respects, modern ARSs are not markedly different from early systems. Students still respond to MCQs posed by a teacher; the responses are collated and the teacher can identify what proportion of the class chose each answer. Some of these older systems also provide a response signal to inform the student whether he or she answered correctly and it is possible for the teacher to identify which students have answered correctly (Judson and Sawada 2002). However, the technological innovations outlined here have catalysed a paradigm shift in ARS use. Whilst in early systems the technology as a catalyst for student achievement and attitude changes, with little or no class-wide feedback, modern ARSs are now used more to support to established truly interactive pedagogical strategies (Judson and Sawada 2002) (see section 4 ARS Supported Pedagogy).
3  The Rationale Behind ARS Use

ARSs are a tool. Their primary function is to facilitate interactivity in the classroom. Therefore, in order to properly outline the rationale for using an ARS, it is important to focus on this primary function and ask: Why be interactive? Draper et al. (2001) have argued that the short answer to this question is: “to improve the learning outcomes”. Draper (2006) suggests that interactivity should be a central component of all lectures. He argues that in view of the overwhelming evidence that self-paced learning (through books, podcasts, handouts, etc.) are a more effective method of content delivery than a “one-way monologue”, lectures have to be interactive to be useful.

As a tool, ARSs are unique in that they combine two important (but often mutually exclusive) aspects of interactive teaching: anonymity and instant feedback. Students can commit privately to their own answer and have it recorded by the teacher without having to expose their answer to the scrutiny (and possible ridicule) of their peers. The same effect can be achieved by getting students to record their answers on paper and submit them to the front of the class. However, this takes a significant amount of time either during or after the class to collate the results. Using an ARS, the time from posing the question to the answers being displayed is typically less than 2 minutes (Draper and Brown 2004). Primarily, this feedback allows students to identify whether they were correct or not. However, in addition, by displaying the full class response curve, an ARS can help to allay a common student concern that “everyone but me probably understood” and thus encourage interaction form these students (Wood 2004). The ability to poll and display the responses of an entire class in near-real time is the backbone of ARS supported pedagogy.

4  ARS Supported Pedagogy

While ARS-based MCQs do have inherent advantages (outlined below), the real benefit of this technology lies in its ability to support established pedagogical strategies. This section aims to identify some of the pedagogical techniques employed by lecturers using ARSs. The initial brief for this project was to focus, where possible, on examples from biology courses. However, there are very few examples of ARS use in biology or life-science classrooms in the literature. There are, however, a small number of publications focusing on interactivity in Biology
classrooms (see Allen and Tanner 2005). From that study it is clear that pedagogically, there is very little difference between interactive teaching in biological introductory courses and in other introductory courses where ARS has been used more widely, e.g. Computer Science, Physics, and Communication (Draper, Cargill et al. 2001; Glasgow Prs Report 2002). Thus, this report will use literature from all science disciplines to guide the outline of effective pedagogical approaches for ARS use in Biology classrooms. Some strategies are deliberately excluded, for example those that use ARS to facilitate human response experiments in Psychology. For a complete list of pedagogical approaches readers are directed to Draper and Brown (2004) and Dufresne et al. (1996).

It is important to note, however, that although course content makes little difference to pedagogical application of ARSs, the willingness and/or ability of staff to allot lecture time to ARS based pedagogies does. The time taken to display a question, collect votes and display the results can be minimal; however, if several questions are to be used in a fifty-minute lecture period the use of ARS can significantly reduce the time available to “cover the material” (Duncan 2005; Blodgett 2006). In many cases, use of an ARS has been coupled with a redesign of content delivery (see section 4.3 Low Content Lectures). The following ARS- supported techniques are presented in order of least to most demanding of class time, and therefore of course redesign requirements.

### 4.1 Summative Questions

Summative MCQs aim to summarise and test knowledge of content. They reinforce key aspects of fundamental knowledge that might be required to understand more conceptual abstractions. For example:

What is the type of tissue indicated by the arrow?

A) Epidermis  
B) Xylem  
C) Palisade Mesophyll  
D) Spongy Mesophyll
It is common practice to assess (assign grades to) summative ARS questions. Indeed this “mini-quiz” form of questioning is common in many classroom situations (Su 2002; Schackow and Loya 2004; Duncan 2005). Burnstein and Lederman (2001) note that if the ARS questions are worth around 15% of the total course grade attendance usually exceeds 90% and students “make genuine attempts to prepare for the [ARS] quizzes” (Burnstein and Lederman 2001). However, assigning grades to questions does tend to increase student anxiety about ARSs and therefore, if the goal is to increase student learning, this approach can be counter productive (see section 5.4 Registered vs. Unregistered). Student concerns about a portion of their grade being linked to an ARS can be compounded if the technology is perceived as unreliable or “on trial”. To prevent this, it is recommended that lecturers become confident with the use of their ARS before introducing graded MCQs.

Summative questions are often used at the beginning of a class to assess what proportion of students has completed prescribed readings. Often this approach is used in conjunction with other pedagogies (outlined below) to help free up class time for more interactive uses of ARSs. Summative questions may also help identify student misconceptions, which can be exploited and used to construct formative questions. To this end, storing responses to MCQs long-term in a database can be a useful tool (see section 5.2 Data Management).

An alternative to asking summative questions with an ARS is to use online quizzes via a system such as Blackboard™. It is not clear which medium is the more effective for delivering summative MCQs (Bunce, VandenPlas et al. 2006). However, asking summative questions in-class via an ARS is a good way to “break-up” the lecture (without straying too far from the material) and can lead to increased attention and alertness, even if it does not directly increase student learning and comprehension (Hill, Smith et al. 2004). This is one of the few “inherent” benefits of ARSs. All of the other pedagogical approaches outlined below use an ARS to enhance or support existing approaches.

4.2 Formative Questions

Students enter introductory science courses with a diverse background of factual knowledge and an equally wide variety of misconceptions (DeHaan 2005). Formative questions are those questions that aim to challenge misconceptions and reinforce (or form) new ideas. They can be thought of “questions for learning” or more
appropriately, “a scaffold for learning” (Fies 2005). The hallmarks of a formative question are familiar: students are asked to apply concepts and known facts to a new situation to deduce the correct answer. For example:

Consider the palisade mesophyll cells in the picture. Given their shape, orientation and position within the leaf, what is the most likely function of these cells?

E) Protecting other cells from strong light  
F) Providing leaf strength  
G) Preventing water loss  
H) Capturing and focusing light

Formative questions can be used to create what some lecturers have called a “teachable moment” (Sabine 2005). A teachable moment is one where only a small portion (even none) of the class chooses the correct answer. It is generally accepted that students are particularly receptive to the new explanation after the realisation that either themselves, or a large portion of their peers did not understand a concept. Some lecturers have come across this situation quite unexpectedly (e.g. Wood 2004). However, if one is prepared, there are a number of powerful pedagogical strategies associated with a teachable moment.

The first is simply to outline why each of the alternative answers is wrong. In essence: re-explain the concept. The advantage for the teacher is that the explanation can be planned for; both in terms of time and content. However, the effectiveness of this approach still depends on the ability of the teacher to explain the concept and of the students to comprehend that explanation. It is conceivable that in a large class, despite the clearest explanation a lecturer can give, there are likely to be some a few students that still do not “get it” (Mazur 1997).

The alternative, therefore, is to involve the students and facilitate a discussion. So-called discussion “sequences” have the advantage of bringing thought processes and explanations (other than the lecturers) to the classroom environment and thus cater for the students that do not understand the teacher’s explanation. Whilst class discussion has long been recognised as a powerful interactive teaching tool, Fredericken and Ames (2005) note that in classes larger than 40 students, only 2 or 3 individuals are responsible for 50% of comments. As outlined above, the anonymity
provided by ARSs can overcome much of the anxiety student may have about sharing their opinions and therefore are powerful tools for facilitating discussion.

As a general rule, discussion can take two forms: teacher-mediated discussion, wherein a teacher selects individuals to express their reasoning to the class; and student-mediated discussion, in which students are free to “chat” to their neighbour or in small groups. Teacher mediated discussion requires little departure from a traditional lecture style, whilst student mediated discussion requires a lot. However, a student-mediated approach allows for simultaneous independent cognitive activity, whilst a teacher-mediated approach leaves much of the class cognitively inert (Mazur 1997). There are a number of variations on these general themes, and it is likely that each lecturer might adopt a style that they are comfortable with. Further details on discussion sequences and their importance in interactive classrooms have been eloquently reviewed by Cutts et al. (2004).

Most published studies for which ARS-enhanced lectures have been considered successful have allowed for some form of discussion sequence. As a general rule this has included aspects of both teacher- and student-mediated discussion. It is commonly reported that designing effective questions is critical to achieving desirable outcomes with formative questions and discussion sequences (Duncan 2005). This concern is detailed below (see section 5.1 Question Design)

4.3 Low Content Lectures

A major concern among staff using ARS is a perceived inability to “cover the material” (Blodgett 2006). This is a legitimate concern: formative questions and discussion sequences do “take up” lecture time. In an attempt to address this, several approaches have been trialled that attempt to shift factual content delivery into out-of-class time to allow more time for interactive lectures. It should be noted that these techniques require major readjustment of course content and delivery.

A strategy, designed and promoted by Eric Mazur is the Peer Instruction (PI) classroom (see Mazur 1997). The PI classroom is characterised by short “mini-lectures” punctuated by extended small group discussion sessions and problem solving. PI incorporates out-of-class time learning and utilises an ARS to assess this prescribed reading material. In addition, ARSs and pre-determined formative questions are used to promote and facilitate discussion. PI has been used extensively
in a number of course types (see Mazur 1997; Fagen, Crouch et al. 2002) including a high school class in the biological sciences (Conoley 2005).

An alternative approach is Just in Time Teaching (JiTT). JiTT uses the web-based MCQs to assess students on material they are expected to have covered outside class. Often students are allowed to respond to the MCQs (using the internet) up until several hours before the lecture (Novak and Patterson 1998). The lecturer uses student responses to formulate a lecture focusing on any poorly understood conceptual material. The lecture may follow a similar format to that outlined for PI with formative question driven learning but JiTT has the advantage of allowing lecturers some time (even if only a few hours) to prepare for the class. The major disadvantage is that in addition to a reliable ARS, JiTT requires a robust system for delivery web-based MCQs. Variations of the “just-in-time” principle are also mentioned in the literature - for example, using an ARS to ask end-of-lecture questions in order to direct the following lecture session (Allen and Tanner 2005).

Dufresne and others promote a different method that almost completely removes content from the lecture period and devotes this entire time to class driven, ARS assisted discussion (see Dufresne, Gerace et al. 1996). So-called Question Driven Instruction is designed such that the time a lecturer spends presenting information is cut to less than a third of the total lecture time and, again, factual information is delivered via textbooks, multimedia and “other out-of-class resources” (Dufresne, Gerace et al. 1996). The remainder of the lecture is devoted to problem solving and formative-type questions that are largely directed by the responses of the class. Because of this, a large bank of formative ARS questions is required and in some cases the ability to create questions “on the fly”. Whilst this is possible with some systems, limitations in some ARS software make this kind of dynamic lecture difficult (see section 5.3 Software).

### 4.4 Summary

The literature describes a range of well established, ARS-supported, pedagogical techniques. Summative questions, in “mini-quiz” form can be used effectively to “break up a lecture”, increase attention and attendance. Many authors report using graded summative questions exclusively, often to track attendance and streamline marking workloads. Formative questions delivered by an ARS can be used
to help frame conceptual problems and introduce new ideas. These questions are often coupled with some form of discussion and are considered powerful tools to promote critical thinking and conceptual problem solving. A concern among lecturers is that these types of questions take up lecture time that would otherwise be used to deliver factual content. PI, JiTT and Question Driven Instruction are examples of pedagogical approaches that free up time for interactivity in the lecture by shifting factual learning outside class time. An ARS can support these pedagogies by promoting and facilitating discussion and providing an incentive to complete the prescribed readings.

5 Practical Considerations

This section aims to synthesise some of the recorded experiences of staff and students who have used or do use an ARS. Outlined below are some of the commonly identified “problems” or “complaints” with the introduction and use of ARSs. Many of these issues have been identified by trial and error and are presented here as a guide of new users of ARSs. Readers are directed to Duncan (2005) and/or Robertson (2000) for further “tips and tricks”.

5.1 Question Design

Generally, because summative questions are factual they are reasonably easy to design. However, it has been noted that designing formative questions for use with an ARS is often more difficult than expected. Only recently however has the problem of designing effective ARS questions been given any formal treatment in the literature:

“Many who try teaching with a CRS discover that creating or finding “good” questions is more difficult than it first appears. The characteristics of effective CRS questions are very different from those of good exam questions, homework problems, and in-class worked examples. The vast archives of questions and problems that instructors accumulate over years of teaching or find in standard textbooks offer little assistance to the new CRS user. Few collections specifically designed for CRS-based teaching exist.”

Beatty et al. (2006)
There exist a number of formative MCQs specifically designed to exploit the misconceptions of entry-level physics students (Hestenes, Wells et al. 1992; Mazur 1997). One example, the “Force Concept Inventory” (FCI), is ideally suited to delivery via an ARS and has been successfully coupled with peer-instruction techniques for more than a decade (Mazur 1997; Hake 1998). In their paper “Designing effective questions for classroom response system teaching”, Beatty et al. (2006) develop the basic FCI to fit their desired method of teaching (Question Driven Instruction, outlined above). In doing so, they make some helpful observations that could guide staff struggling with question design.

There are very few (even isolated) examples of MCQs for ARS teaching in Biology (let alone Plant Science) courses. Certainly, nothing like the FCI exists for these courses. It would be interesting and helpful to make the ARS questions used in this project, along with a short explanation outlining the context in which they were used and the relative “success” of each question, widely available on the World Wide Web or in a peer-reviewed publication. Ultimately the goal should be to identify if (and how) basic question design differs between Biology and other courses where ARSs have been used extensively.

5.2 Data management

The ability of ARS software to store student responses in a database long-term can be a powerful tool. Specifically, analysis of this data may reveal common misconceptions which may help designing probing formative questions. Realistically, lecturers who have taught a particular subject for a number of years most likely already know which facts or concepts are the most difficult for students to grasp and hence already know what type of questions would be most effective. For new lecturers, a database of “tried and true” ARS questions could be invaluable. Also, it has been noted that even experienced lecturers are “surprised” after seeing the responses to ARS questions to discover how poorly their explanation of a particular topic has been assimilated (Wood 2004). Therefore, it is highly recommended that a database of student responses be kept to help identify student misconceptions.

5.3 Software

Most ARSs come “bundled” with software. This software is required to operate the clickers and is the interface between the hardware and the input from lecturers. Aside from not being able to cover the material, the most common complaint among
lecturers is that the bundled ARS software has “a steep learning curve” (Jackson and Trees 2003). Something that appears to have been learnt largely by trial-and-error is the most effective method of question delivery. Duncan (2005) notes that many lecturers prefer to display the questions via an Overhead Transparency Projector and dedicate the Video Projection System to the collection and display of results. It is possible to integrate PowerPoint™ slides or images into the ARS software and present questions, collect responses and display the data via a common interface (i.e. video projection) and some software (and some third-party “plugins”) allow the seamless integration of this process into a traditional PowerPoint lecture. Which system works best is probably best determined on a case-by-case basis. The general recommendation is to spend time becoming familiar with the software, its capabilities and limitations before trialling the system in a classroom.

5.4 Registered vs. Unregistered?

Generally, ARSs are positively accepted among students. However, most of the studies that have recorded student opinions have been conducted with ARSs that assign grades to questions (with one exception, see below) and this seems to be the source of concern for students (Jackson and Trees 2003). This is achieved by having a student use a single clicker, with a unique ID that is linked to their name or student ID number. This process of “registering” clickers is compulsory with some systems, but is optional on most (McDonald 2006). This allows teachers to track the responses of individual students, without compromising the peer-anonymity that is important for ARS supported pedagogy. However, this also means that staff must provide a suitable system for students to register their clicker, and must make allowances for lost or broken clickers.

Usually, registering necessitates that each student purchase their own clicker. The alternatives are issuing, registering and reclaiming clickers at the beginning and end of each class (which can be impractical) or having a pool of loan clickers that can temporarily (for one semester) be registered to a student who may have to pay a bond to cover loss or damage. In any case, students often resent having to pay for clickers, especially if they have to do so at the beginning of every course (Duncan 2005). Another common concern is that students feel as though they are “forced” to show up to class in order to receive grades for answering CT questions and that clickers were simply being used to track attendance (Jackson and Trees 2003). This feeling is
compounded if the technology is unreliable or the lecturer is not competent in its use, which is sometimes the case with new CT installations or first-time users. Duncan (2005, pg 39) provides some practical tips for successful use of registered clickers. In particular he notes:

“The use of clickers shatters student’s expectations. For that reason it is critical to explain during the first class meetings why clickers are being used and what students will gain from their use”

(Duncan 2005)

The question “Are registered clickers more effective than unregistered clickers?” is an intriguing one. A recent PhD dissertation by Fies (2005) focused specifically on the pedagogy of an anonymous or “unregistered” CT classroom. Fies postulated that an unregistered ARS would provide the same learning benefits as those of a registered system. Sadly, her study did not directly compare registered vs. unregistered ARSs, and because the ARS enhanced classroom showed no significant improvement over the non-ARS classroom it is difficult to say whether unregistered ARSs provide similar learning benefits to registered ones. However, this study raises interesting questions and warrants further investigation.

5.5 Changing Current Practice

It has been noted here that the effective use of ARSs to enhance learning requires some degree of change in classroom practice. This can be difficult. Dufresne et al. (1996) list some possible barriers to widespread classroom change in higher education:

a) The tendency to teach the way we were taught.
b) Pressure on faculty to focus on matters other than instruction, namely research.
c) The lack of professional development geared towards teaching (either prior to or after appointment to a teaching position).
d) The push to cover an enormous amount of content matter.
e) Fear of losing control over the content that is covered.
f) Concern about management of students in a large lecture hall while teaching in an alternative format.
g) Memories of past failures in implementing teaching innovations without adequate support.
Unfortunately there is no “quick fix” for this. Duncan (2005) notes that student approval of CT improves as lecturers become more experienced in its use. Therefore, it is recommended to start with CT supported pedagogy that does not drastically change your current classroom dynamic e.g. simple summative questions to “break up the class”. This is a concern not limited to use of ARS but is related to all pedagogical changes in higher education and is mentioned here mainly for completeness.

5.6 Efficacy Data

As a tool for increasing interactivity in traditional lectures, the effectiveness of ARS depends on the kind of pedagogical approach it is used to support. Almost universally, the literature reports “improvements” or “increases” in student attitude, attendance and motivation in ARS enhanced classrooms (Jackson and Trees 2003; Draper and Brown 2004). However, given the substantial financial and academic resources committed to installing and using ARS in a large class, there is a strong desire to show a quantitative improvement in “learning outcomes”. There are no data on the effects of ARS on learning outcomes for Biology or Life Science introductory courses. However, despite criticism of the quality of the research (Reeves 2002), there is a good body of data available for Physics (Hake 1998), Mathematics and Psychology (Draper 2006) and Communication (Jackson and Trees 2003), which indicate strongly that ARS-enhanced classrooms result in improved learning outcomes. How learning outcomes were measured varied between studies. Most compared pre- and post-test scores on standard tests (such as the FCI) and the most reliable studies compared the results between ARS and non-ARS groups or across cohorts. Another approach that could be useful in comparing different ARS supported pedagogies is the “shift pattern” described by Guttenberg et al. (2001). Here the convergence on the correct answer after two or more attempts a question is recorded and analysed. However, as outlined in this report, and highlighted by studies such as Hake (1998) ARSs are most effective when used in conjunction with other interactive pedagogies. Therefore, it is difficult, if not impossible, to isolate the effect of CT alone (Dufresne, Gerace et al. 1996; Boyle and Nicol 2003).
5.7 Summary

Time and effort is required to successfully deploy an ARS in a classroom. For staff, care must be taken to design effective questions that fulfil their pedagogical goals. Familiarity with the ARS software is essential if the lecturer is to deliver questions effectively yet alleviate concerns of students confronted with this new technology. Also, consideration must be given to creating a database of student responses to assist staff in identifying student misconceptions. All of the pedagogical approaches outlined in this report require a change to the “traditional” lecturing style. To keep the new classroom both manageable and effective, consideration should be given to how quickly to implement such a change. There a number of pedagogical and practical considerations associated with registering clickers. Registered clickers require slightly more time and effort by staff and may lead to increased anxiety among students. The relative benefits of registered vs. unregistered CT systems are unknown. Finally, a lack of data specific to the biological sciences makes it is difficult to predict if an ARS will be effective in BIOL113. However, the literature suggests that if care is taken to become familiar with the technology, and if lecturers are willing and able to make changes to their pedagogical approach, then ARSs can help improve learning outcomes for students.

6 Conclusions and Recommendations

Technological advances over the last decade have made ARSs affordable enough for widespread use in higher education institutions. However, Reeves (2002) recommends that the temptation to introduce “technology for technologies sake” should be avoided. Modern ARSs have few inherent benefits but they are a powerful tool to support well conceived interactive pedagogical techniques. To this end, staff must have a clear pedagogical goal in mind when introducing ARSs. The “novelty factor” of ARSs will ease the introduction of this technology but lecturers must be conscious of student concerns and be confident in their own abilities to use the system before drastically modifying their pedagogical approach.

This report has provided a background to the literature on the use of ARSs in higher education. As a recent graduate with no teaching experience, the author finds it difficult to make sweeping recommendations about the use of ARSs in higher education. Indeed, much of the advice in the literature might well appear to be common sense, especially to lecturers who are in tune with staff and student opinion.
However, an underlying message (from the literature at least) seems to be: Be prepared. ARSs can (and will) change the way traditional lectures are run. The challenge is to direct this change towards favourable outcomes for students.

7 Bibliography

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8 Further Reading

Recently, a substantial volume on the use of ARSs has been published. The work was not available when preparing this report but may contain significant insights from experienced users of ARS. The book is entitled *Audience Response Systems in*
9 Appendix 1

In addition to “Audience Response System” or “Clickers”, systems that collect and collate audience responses are referred to by a number of names. This table outlines some for the more common names (or names used in literature cited in this report) and acronyms used to describe this technology. It could prove useful when searching for updated literature.

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<tr>
<th>Name</th>
<th>Acronym</th>
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<td>Electronic Response System</td>
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<tr>
<td>Interactive Learning System</td>
<td>ILS</td>
<td>(Lowery 2005)</td>
</tr>
</tbody>
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10 Appendix 2
Possible Contact People for ARS Info / Guidance

Steve Draper (Psychology)  
Quentin Cutts (Computer Science)  
also E. Witt (Statistics)  
All at Glasgow University

There is mention of ARS use in biology classrooms in their report (2002), but no specifics given. Steve Draper has published extensively on ARS use and maintains a website with volumes of information. Highly recommended contact for ARS use in the UK. The others appear to support the use of ARS in their courses but Draper appears to be the primary driving force. He maintains a list of interested parties (in the UK) on his website: http://www.psy.gla.ac.uk/~steve/ilig/people.html. This list is more complete than I could hope to compile from the literature. Sadly there is nothing similar for the USA or elsewhere.

Contact: s.draper@psy.gla.ac.uk  
Website (Recommended): http://www.psy.gla.ac.uk/~steve/ilig/

Michael McCabe  
(Also listed in the above website)  
Department of Mathematics, University of Portsmouth, UK  
He takes a much broader view and includes web-based assessment also. However might be a suitable alternative contact to the University of Glasgow people.  
Reference: (McCabe and Lucas 2003)  
Contact: michael.mccabe@port.ac.uk

William B. Wood  
Department of Molecular, Cellular and Developmental Biology, University of Colorado, Boulder, CO 80309  
Editor in Chief of CBE - Life Sciences Education and has published accounts of personal use of ARSs e.g. (Wood 2004). Recommended contact in the USA  
Contact: wood@colorado.edu

University of Massachusetts, Amherst  
Their website mentions that their PRS system has been used in Biology 100, Biology 101 and Biology 105, but I can find no specific contact person. However, they promote ARS use quite extensively and were the first group I found in my initial web search for institutions. A good contact in the USA?  
See: www.umass.edu/prs

Deborah Allen  
Department of Biological Sciences, University of Delaware, Newark, DE 19716  
More “active learning” rather than ARS specifically. Not sure if she has personal experience with ARS. Publishes a lot with Kimberly Tanner in CBE - Life Sciences Education e.g.: (Tanner and Allen 2005) and (Tanner and Allen 2006). Reference of Note: (Allen and Tanner 2005)  
Contact: deallen@udel.edu
Carol Brewer
Division of Biological Sciences at the University of Montana, Missoula, MT
Discusses the use of a web-based assessment tool (but not clickers). She may still be an important contact.
Reference of Note: (Brewer 2004)
Contact: carol.brewer@umontana.edu

Neil Sabine (Biology)
Indiana University East; 2325 Chester Blvd Richmond, IN
Obviously he has some first hand experience with ARS use in Biology classrooms. Already contacted and seemed keen to share information.
Contact: nsabine@indiana.edu

BaoHui Zhang
Michigan State University
Microbiology and Molecular Genetics Department
Reference: (Zhang, Richmond et al. 2005)
Contact: bhzhang@msu.edu
Interesting Websites:

Educause:
http://www.educause.edu/
In particular they have a Podcast that they do from time to time that covers various aspects of technology in higher education. Examples (including the one about Clickers) are in the “Daniel” folder of the student drive.
(\hebe\students$\daniel\clicker_podcasts)

A Blog entry:
http://shrimpandgrits.rickandpatty.com/2006/03/10/who-wants-to-be-a-student/
Very very interesting. Even if I don’t agree with his conclusions! Cites Bunce et al. (2006) and claims that Clickers are worse than web-delivered Multi-choice Questions and therefore he won’t be adopting clickers “…at least not without better results than seen here”. Bunce et al do suggest that Web-delivered questions might be better than clicker-delivered questions, but also the explain why this is true in their study:

“Teachers may not be aware of how such a small change in their teaching can have a large impact on student learning. SRS, without the opportunity for reflection, could fall short of its full potential as a learning tool. WebCT quizzes, on the other hand, afford students the opportunity to reflect when they compare their answer to the correct answer shortly after taking the quiz. The time constraint is not an issue with WebCT reflection because students use it outside of lecture.”

The concern of this blogger seems to be centred on the cost of the clickers and the perceived lack of benefits for his students. However it is clear from the literature that Clickers coupled with changes in pedagogy are effective – and this is noted by Bunce et al. – I feel the view taken by this blogger is quite narrow and he is clearly not well informed. Reading both the blog and the paper is recomended

Another Blog entry:
http://beckybrawer.blogspot.com/
Claims to focus generally on “The Role of the Internet in Education” but has a post about ARS. Hasn’t been updated since May (this is a long time for a blog!).
Bibliography:

(2002). Results of the evaluation of the use of PRS in Glasgow University. Glasgow, Scotland, Glasgow University.