AC 2010-1525: USING INTERACTIVE AUDIENCE RESPONSE SYSTEMS TO ENRICH ENGINEERING EDUCATION

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Using Audience Response Systems to Enrich Engineering Education

Abstract

Audience response systems are becoming increasingly popular in the collegiate classroom since they promote interactive learning, which can enrich and enhance the educational experience. When using such systems, each student is able to react to questions or activities prompted by the instructor by using a response device. The supporting hardware and software instantaneously records and displays the students' responses, which can be used for a variety of pedagogic applications that benefit the class.

Of particular interest to new engineering educators, this paper describes four pedagogic applications of audience response systems. These applications include using the audience response system to: become familiar with students by conducting surveys of their preferences; obtain and respond to students' perception of teaching style by collecting formative feedback on teaching; monitor and adapt to student mastery of subject matter through the formative assessment of student learning; and to teach new subject matter using interactive learning. Examples, reflections and best practices based on current literature and the author's experiences as a new engineering educator in each application are provided.

1. Introduction

Contemporary studies have demonstrated that active learning methods can increase the mastering of subject matter by students as compared to the traditional passive lecturing method[1–4]. Active learning covers a wide spectrum of activities with the common characteristic that the students individually, in groups or as a whole are involved in an activity that requires them to work with the subject matter being taught[2]. An active learning enabling technology that is being increasingly utilized is the Audience Response System (ARS). ARS are also known as electronic voting systems, interactive voting systems and by other generic and trade names.

The ARS facilitates a bi-directional learning experience by allowing each student—even in class sizes of one hundred or more—to respond to a prompt, while allowing the instructor to react to their aggregate responses. The pedagogic applications of ARS are many and include: performing formative and summative assessment on learning, soliciting formative feedback on teaching, assessing peers, building community mutual awareness, conducting experiments, initiating discussion and facilitating interactive learning of new subject matter[5,6].

Studies on the efficacy and best practices of the use of ARS in the classroom indicate that, in general, there is a net benefit associated with the use of ARS[6,7]. The documented benefits include: increased attendance, higher retention levels (within the same course), improved alertness and a higher level of student engagement. Research on the effects of ARS use on test scores is on-going, but the current research shows that test scores improve or are unaffected by the use of ARS[3,6,7]. In addition, students tend to enjoy the ARS-integrated course. Drawbacks to using the ARS include the decreased time spent to cover new content; the cost of the ARS; and the effort and time required to manage the ARS and supporting equipment[6]. Furthermore, the students may feel indignant if the ARS is used excessively or improperly.

With the body of literature on the efficacy of ARS on student outcomes continuing to grow—and perhaps best left in the capable hands of educational researchers—the focus of this paper is on pedagogic applications of the ARS in engineering education. An emphasis is placed on leveraging the inherent advantages of the ARS to overcome obstacles faced in particular by new engineering educators. Four applications of the ARS are discussed. These applications are using the ARS to: survey students to determine their preferences on course administration; soliciting students for formative feedback on teaching; assessing students' mastery of subject matter; and increasing interaction in teaching new subject matter.

This paper is arranged as follows. In Section 2 an overview of state-of-the-art ARS technology is provided. In Section 3 through Section 6, four applications of the ARS to enhance and enrich the educational experience are described. Best practices and tips for the novice ARS user are provided in Section 7. Concluding remarks are made in Section 8.

2. Audience Response Systems

There are several manufacturers of ARS, each using proprietary technology and each with unique advantages and disadvantages. The purpose of this section is to describe the components of a generic state-of-the-art ARS, identifying common but not necessarily ubiquitous features, rather than focusing on the particulars of one manufacturer's ARS. An in-depth, vis-à-vis comparison of several commercially available ARS is found in existing literature[8].

In general, the main components of an ARS are the personal response device, the receiver and the ARS software. The personal response device—sometimes known as a clicker, keypad or zapper—is a handheld instrument that is used by the student to respond to prompts posed by the instructor. The student responds by pressing one of the buttons on the device. The devices may be wired or wireless, with most modern ARS of the latter characteristic. The devices may be configured so that each transmits a unique identification code thereby allowing for each response to be mapped to the specific user. This is a useful feature if a student's response is used to determine their grade. The responses may also be submitted anonymously.

The receiver collects the transmitted response signals sent by the personal response devices and serves as the interface to the desktop or laptop computer on which the ARS software is installed. The receiver is often connected to the computer through the USB port. The receiver may also act as a transmitter, sending a signal to the devices to indicate that the response has been received. This feature is reassuring to students if they are being graded by their responses.

The ARS software allows the instructor to compose prompts and control the range of possible responses by the students. For example, the instructor may pose a multiple choice question with possible answers A, B or C. A summary of the aggregated responses, often in the form of a histogram, is displayed through a projector after the responses are recorded. The responses may be archived for post-analysis by the instructor. Some ARS display a real-time tracking of the number of total responses received, which is useful in ensuring that students have sufficient time to respond to the prompt. Depending on the specific ARS, the software may be stand-alone or integrated into presentation software such as PowerPoint.

An example of a true or false ARS prompt with resulting histogram of the responses is shown in

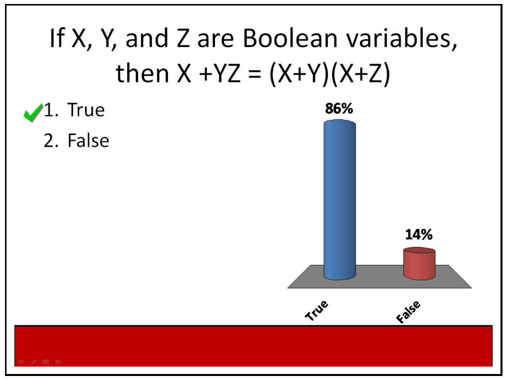

Figure 1: Example of ARS prompt and histogram of the responses to assess students' mastery of the Second Distributive Law of Boolean algebra.

Fig. 1. The prompt was created with the TurningPoint ARS by Turning Technologies. In this case, the ARS was used to assess the students' mastery of the second distributive law of Boolean algebra. The histogram, which is displayed after all the responses have been received, indicates that 86 percent of the students correctly understood this concept.

The typical cost for an ARS system ranges from approximately US$25 to US$50 per personal response device and approximately US$200 to US$500 for the receiver and software[8]. The ancillary equipment needed are a computer projector and screen.

3. Surveying Student Preferences

The anonymity and ease of polling students make the ARS useful in surveying the students' preferences toward course administration. Course administration, here referring to subject matter-independent course policies, are generally determined by the instructor without direct student input. Examples of such policies include the weighting of graded components toward the final course grade, what resources are available to students during exams and when office hours are held. For a new educator, polling students for their preferences on such topics—even if their preferred policies are not ultimately adopted—can help familiarize the new educator with the students and provides the students with a sense of empowerment.

Surveying the students on their preferences should be done at the beginning of the course. The survey should be prefaced by disclosing that the results of the polling are anonymous and that the instructor has final authority on all course policies. Typically, only a small number of questions need to be asked, perhaps three to six, and therefore the time spent on the survey is minimal.

Carefully crafting each question of the survey and the possible responses is fundamental in empowering the students but also limiting their opinions to a reasonable range. As a rule, the students should only be surveyed on course policies that the instructor is amenable to changing, otherwise the students may resent the survey as a waste of time. As an example, assume that the instructor for a course has planned for the midterm exam to count toward 30 percent of the final grade. To gauge whether or not the students agree with this policy, the following Likert scale-based question could be composed:

It is reasonable for the midterm exam to be worth 30% of the final grade.
A) Strongly agree
B) Agree
C) Neutral
D) Disagree
E) Strongly disagree

If the general trend was for the students to select A or B, then the 30 percent weighting of the midterm would be validated. However, if the students strongly disagree, then the instructor is left to ponder whether a higher or lower percentage is deemed reasonable by the students. A different way of asking this question could be:

The midterm exam should be worth what percent of the final grade?
A) 20%
B) 25%
C) 30%
D) 35%
E) 40%

With the question posed in this manner, the students can select their preference from the list of the discrete values shown. The range of the potential responses can be selected by the instructor to ensure any answer is acceptable. In this case, the instructor feels that the midterm should be worth between 20 and 40 percent of the final grade.

In addition to adjusting course policy, surveying students about other preferences can help allocate resources, for example:

My preferred method to receive help in this course is:
A) during office hours.
B) through e-mail.
C) through ANGEL.

Surveying students for their preferences can help the new educator adopt policies that are preferable to both student and instructor. Students feel empowered, but the final authority always rests with the instructor in accordance with what he or she deems best for the course.

4. Assessing Teaching

The next application discussed is the use of the ARS to garner formative feedback on teaching. Receiving feedback from students on teaching performance is valuable for all educators, but it is particularly beneficial for those new to the vocation. Often, student feedback on teaching is summative, conducted ex post using university, college or department evaluation forms. While this uniformity supports peer-to-peer and long-term evaluations, the fact that the surveys occur after the majority of the course has taken place inhibits their use for formative assessment. Additionally, the often pro forma evaluation can be rigid and specific questions of interest to the instructor may be difficult to pose.

The ease, flexibility and archival properties of the ARS facilitates formative assessment on teaching, which allows the instructor to adapt to feedback by the students. Using the ARS to garner feedback on teaching should be done after sufficient class periods to make the feedback meaningful, but not so frequent that it becomes distracting. Students may also become resentful if a significant amount of class time is used in evaluating the instructor of if they feel that they are subjects of an experiment. The author has found success in performing a middle-of-the-course survey, in which approximately five to eight questions are posed to the students halfway through the term. This feedback allows the new educator to identify and mitigate problems with teaching style before they become ingrained.

Common teaching concerns worth assessing include the pace or style of the lectures; the difficulty or amount of time spent on homework and lab assignments and the perceived fairness in grading. Two examples of questions intended to gather feedback on teaching are shown in the following.

The pace of the lectures is too fast.
A) Strongly agree
B) Agree
C) Neutral
D) Disagree
E) Strongly disagree

I typically spend _____ hours on each homework assignment.
A) 8 or more
B) at least 6 but less than 8
C) at least 4 but less than 6
D) at least 2 but less than 4
E) less than 2

Of course, gathering the feedback is simply the first step in improving teaching; it is how the feedback is responded to that ultimately makes one a better teacher. Asking the same questions each time a course is offered and then archiving and comparing the results is an effective way to monitor the efficacy of changes made in response to student feedback.

5. Assessing Student Mastery

To a new educator teaching a course for the first time—or teaching a course for a subsequent time at a new university—can be challenging because he or she may not know which subject matter are difficult or easy for the students to master. Indeed, this challenge exists throughout an educator's career, but it is particularly difficult without the benefit of previous experience. Strategically using the ARS to provide formative feedback on learning allows the instructor to gauge the students' mastery of the material and adapt the lesson plans accordingly.

The use of the ARS for formative assessment can be done through multiple choice questions. The questions can be quantitative or qualitative example questions or self-reflective in nature, asking students to indicate which subject matter they find difficult. For example, in assessing the students' mastery of Ohm's Law, the following three questions shown in Fig. 2 through Fig. 4

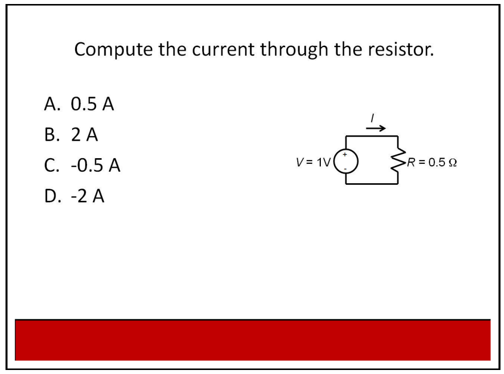

Figure 2: Example of a quantitative question to assess students' mastery of Ohm's Law.

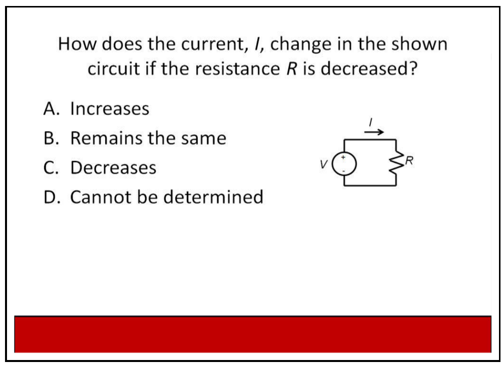

Figure 3: Example of a qualitative question to assess students' mastery of Ohm's Law.

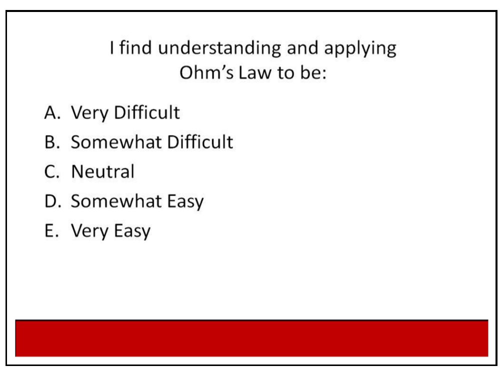

Figure 4: Example of a self-reflective question to assess students' mastery of Ohm's Law.

could be used, each assessing the mastery of the concept in a different way.

The ease of ascertaining student mastery of subject matter by use of the ARS also facilitates contingent teaching—a pedagogic style in which the content is presented to the students not based upon a fixed script, but based on their mastery of the subject matter[5]. Contingent teaching therefore allows the instructor to spend more time on material that is challenging to the students and less time on material that is easier to grasp. This use in particular is beneficial to new educators who do not benefit from previous years' worth of student discussion, graded homework, quizzes and exams to know how to pace the course.

6. Interactive Learning

The final application discussed in this paper is the use of the ARS to facilitate interactive learning exercises that would otherwise be impossible or impractical to perform without the technology. In the following, a case study of the use of the ARS to facilitate interactive learning on an advanced topic is described.

A senior-level elective course on renewable energy is taught through the Department of Electrical and Computer Engineering at Seattle University, the author's institution. In the module on wind energy, the author developed an interactive learning exercise using the ARS to teach a concept about the forecasting the power output by a wind farm. The desired outcome was for the students to understand and be able to apply a specific method for forecasting the power output of a wind farm known as the persistence method.

The power output by the wind farm is dependent on wind speed, which is inherently variable, uncertain and hence difficult to predict. The persistence forecasting method is based on the assumption that the power output of the wind farm for the next hour will be the same as the previous hour. This method generally results in a reasonably accurate forecast as it is not typical for weather patterns to change drastically over the course of a single hour.

To introduce and demonstrate the efficacy of the persistence method, an interactive exercise was developed using the ARS. The students were not exposed to any background material on the persistence or any other forecasting method prior to the exercise. The students were asked to play the role of an energy trader whose duty was to schedule the power out of the wind farm in a hypothetical next-hour forward energy market. The students were to select the amount of power to schedule from the wind farm for each hour in 10 MW increments from 10 to 100 MW. For every 1 MW magnitude difference between the scheduled and actual power produced by the wind farm, the students were deducted a point (this aspect is based on monetary charges that can occur in real-life for wind farms that do not match their schedule). Therefore, an errorless schedule would result in a score of zero; any error would result in a negative score. The actual power output by the wind farm for each hour was based on actual data.

The students were each issued a personal response device. Each of the ten buttons on the device referred to an amount of power to be scheduled for the next hour. The ARS prompt for the first hour is shown in Fig. 5—similar prompts were used for the subsequent hours. After all responses were input for a given hour, a histogram of the students' schedules and the actual power output were displayed, as shown in Fig. 6, and the deviation penalties were computed. The process continued through hour six. At the end of hour six, the deviation penalties for each student were totaled.

Table 1 summarizes the results of the exercise. The first row shows the actual power output by the wind farm, including Hour 0. The schedule using a persistence forecast is shown in the second row; note that it is simply the actual power output displaced by one hour. The median of students' schedules for each hour is shown in the third row. The results indicate that the use of the persistence forecast was superior to class median by almost a factor of two. In fact, no student

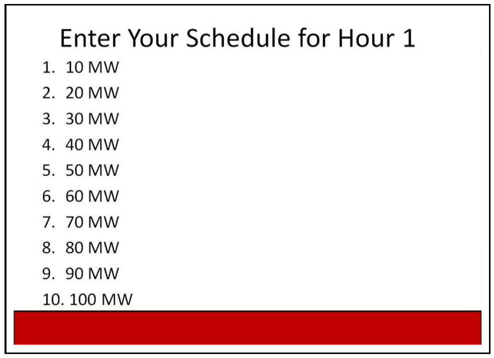

Figure 5: Prompt of the exercise for Hour 1.

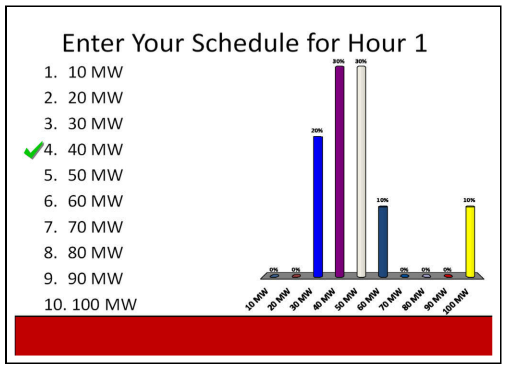

Figure 6: Example of ARS prompt and response histogram.

Table 1: Summary of Results

	Hour							
	0	1	2	3	4	5	6	Score
Actual (MW)	40	50	40	60	70	70	80	-
Persistence Forecast (MW)	-	40	50	40	60	70	70	-60
Median Student Schedule (MW)	-	20	30	30	50	60	70	-110

achieved a better score than the persistence forecast.

In a post-exercise discussion on the methods or strategies used by the students to make their schedules, approximately one third of the students reported using a method tantamount to the persistence method in the latter hours of the exercise. This is significant because the students had yet to be introduced to this technique. An artifact of this is evident in the Hours 5 and 6, as the median schedules approached the actual output. In addition to introducing this concept in a creative manner, the exercise engaged the entire classroom. Students became competitive, expressing aloud their joy or dismay after the results for each hour were shown.

7. Best Practices

The use of ARS, when done correctly, can engage students in the classroom and be used in for many pedagogic applications, such as those discussed in the previous sections. To help make

ARS beneficial to the new educator's classroom, the following best practices are provided.

- Do not feel compelled to use the ARS in every lecture; rather, use it when it has a specific purpose that enhances the class.
- Spend time preparing the questions and responses so that the activity is meaningful. Decide whether or not the question is best posed using a Likert scale, true/false, multiple choice of discrete values or some other format.
- Prior to utilizing the ARS in class for the first time in an unfamiliar room, spend time performing a practice run to ensure that the computer to be used has the appropriate software installed and that the receiver detects responses from the back of the classroom.
- Plan the personal response device distribution logistics beforehand. Consider such questions as: Will the ARS be handed out? If so, who will distribute them? How long should you allow for this process? If the students keep their personal response devices, how do you ensure that they are brought to the class when needed?
- Before each session clearly explain whether or not the students' responses are anonymous and whether or not they will count toward the their grade.
- If the ARS is used intermittently throughout the course, it is worthwhile to use one or two simple icebreaker questions such as the true or false question: "I prefer to use a PC more than a Mac." The twofold purpose of this is one, determining that the ARS is responding properly and two, allowing the students to become comfortable with the use of the personal response devices.
- When asking questions, be sure to provide ample to time for the students to respond. Insufficient time to respond is a common criticism by students. Your ARS may track the number of responses submitted which will help you manage the time.
- Take the opportunity to discuss the results of surveys and examples and to use them to initiate discussion, especially if the students are divided on a response.

8. Conclusion

Audience response systems are another tool in the tech-savvy educator's toolbox that can lead to a more interactive classroom. Though the state of the research on the quantifiable educational benefits is still evolving, there are several indicators that the use of ARS has positive effects, including increased student engagement, interaction and improved test scores. As discussed in this paper, the pedagogic applications of the ARS can be leveraged by new educators for a variety of purposes, addressing challenges such as lack of familiarity with student preferences, feedback on teaching style, assessing student mastery of material and teaching new topics. While most ARS are easy to learn to use, using them proficiently and accordance to best practices is paramount in making their use beneficial to the educator and the student. ARS technology will continue to advance and it is the duty of educators to maximize the potential that these provocative systems have to offer.

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