Use of an Audience Response System to Evaluate and Streamline a General Chemistry Class

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1. Introduction: A Classroom Response System (CRS) or Audience Response System (ARS), commonly called "Clickers" at the United States Military Academy (USMA), refers to a response system that allows instructors in a face-to-face classroom to collect real-time data that include such things as assessments, testing, or polls. The system used by the USMA is TurningPoint 2008 which is compatible with our current systems and software. It is clear that technologies can be a benefit when used with other instruction to support the cognitive and social processes of learning. It can also provide some unique opportunities for educators at all levels to better communicate with students. An ARS uses a wireless handheld transmitter to capture student votes and transmit data via infrared signals or wireless technology to collect and aggregate student responses immediately and then display the results in the class. When included in the design of the curriculum, an ARS can provide a new facet of interactivity that can change the way students and instructors interact.(26) Ultimately, the objective of this work is to provide a more dynamic learning and teaching environment with less time in lecture mode and more time demonstrating ability. This ARS system has been shown by others to help students become more interactive and adopt a more favorable attitude in many types of large undergraduate courses in information systems, computer science, engineering, biology, psychology, chemistry and a wide range of others with positive impact.(2,6,7,9,12,17,18,20-22,26,30) The problem or concern is that most of these studies focus on larger classes which don't have the interactivity used at the academy. This study will uses ARS to determine potential benefits for smaller, more intimate classes at our campus. Specifically, ARS will be used to more quickly assess students understanding of the lesson material which will allow the instructor to tailor the class and focus the lesson on problem areas. Another goal is to determine if ARS will allow students to get to boards more quickly to facilitate actual hands on practice with the material. Quite simply, can pre-assessment using ARS help the instructor better use the class time and be more efficient?

2. Overall plan for the study. To use ARS in a chemistry classroom to tailor the general chemistry instruction to better meet needs of the students. This system may be able to address issues such as; 1) During class, how can the instructor more quickly assess what each student understands, or misunderstands about the lesson? 2) How can that assessment be used to foster deeper understanding of the material? Or 3) Can this technology help me save time and get to the core problem to allow for better focus and understanding? I wanted to examine how a feedback system, such as CRS, could help instructors tailor the chemistry class to the students while also engaging them more in their own learning which is the key to the Thayer method. I expect that this tool could provide a better means of determining where to focus class time which could result in more time at the

boards working practical examples. Other benefits of this technology could be in making the classes more "fun" but this is subjective and keyed to each individual student. Ultimately I hope this technology can allow me to tailor each class to the needs of the students based on their responses to a pre-class assessment.

Students at the USMA are in classes that are very small when compared to other schools of similar size in the United States. However, classroom interactivity is a key component in our teaching and while this small class size helps to attain interaction with the students, it is not always the case. For example, many times a single student or several students tend to answer most open questions and many students have to be coerced into providing an answer in class. Therefore, gaining more interactivity in class is a goal to enhance learning but this interactivity should be among all students and not just a select few. In these classes, the interactivity is what drives the class and directs the instructor to areas that confuse or obfuscate the material being presented. Therein lies the problem and it is up to each instructor to tailor each class to ensure that unclear material is addressed. Of course, this is the big problem with the classes and many instructors find it difficult to determine if students understand the material. One method to address this problem is to use a pre-assessment method to determine if there are any areas not well understood by the students and then focus on these areas in class. While this is an excellent idea, making up a pre-assessment quiz for every class is time consuming and then more time is needed to administer and evaluate the responses.

According to some studies interactivity and engaging of students will facilitate more effective learning. (9,26) The most common form of interaction with students is questioning by the instructors followed by answers from the students. In this type of interaction the instructor can most often engage students, evaluate learning, and modify the class to enhance understanding. A technique used at USMA uses a type of pre-learning followed by Socratic questioning that is termed the Thayer method.(24) Unfortunately, there are some pitfalls to this approach to include lack of compliance by the students in completing assigned work coupled with limited class time, shyness, or a simple lack of knowledge or understanding. (26) This sometimes confounds the instructor and it may be difficult or impossible to judge student learning and understanding.

3. Goals of the study. To more quickly assess students understanding of the lesson material in a more systematic way which will allow the instructor to tailor the class and focus the lesson on problem areas. To clearly establish if students can put these chemistry concepts into practice which will be one step closer to deeper understanding. And to better motivate students to increase the quantity and quality of their learning. Typically instructors have used ARS to vary the traditional lecture format by posing strategically-placed questions to students. Then students submit their responses in real-time, with clickers. Certainly questioning methods can be easily implemented with clickers and there is some evidence to suggest that it will increase participation, engagement, and, the quality of student learning.

4. Potential Benefits of using ARS. The potential benefits are numerous with some of the most key enhancing learning and stimulating both discussion and peer learning. Since our classes are small in nature there in more interactivity than in larger classes but clearly there can be some benefit even for our classes. Some of the potential benefits have been outlined in many of the papers already referenced and many focus on student benefits. There are also many that discuss the potential benefits to the instructor. I have gathered a

few that demonstrate these potential impacts and they are listed below.(3-6,9,10,13-15,17,19-23,25,27-29)

i. Check understanding of the cadets prior to class (pre-assessment)
ii. Check understanding of the cadets as class precedes and alter class based on their responses
iii. Increase cadets attention to class
iv. Engage the cadets in the content
v. Encourage discussion and collaboration of cadets
vi. Encourage peer learning in cadets
vii. Allow cadets to share knowledge anonymously
viii. Add excitement to the class

5. Overview of the course, Thayer method, and the ARS.

a. General Chemistry Course Overview: All incoming freshmen are required to take general chemistry at our school. The general chemistry course is a two-semester course that teaches approximately 1,100 students during the year. In a given class, about 40-50 students validate and 120 students are in advanced chemistry. The remaining students (approximately 900) are in the course. These students are then divided into smaller sections of 16 to 18 students which allows for better interactivity in the classroom. Generally, cadets in the upper third of the course are sectioned together and students in the lower third are sectioned together with the remainder placed randomly in sections. The numbers of sections will vary a bit from year-to-year but generally 45-50 sections of chemistry are taught by 16-20 different instructors.(1) Within the described framework, instructors are given a great deal of latitude in how they instruct each class however the entire course has established lectures with the same reading, problem sets, laboratories, and objectives. This ensures consistency and each section covers the same material as the other within the same time frames with the same quizzes and exams. It has been speculated by some that this provides an excellent opportunity for testing different technologies and teaching methods especially since similar students are sectioned together.(1)

b. Thayer Method and Interactivity: At USMA, the Thayer method or concept is how most classes are structured. This method makes each student responsible for assigned reading, problems, and overall preparation for the lesson. Each class is a small group of students that come to class with their questions about the lesson and also be able to respond to questions from the instructor or assist with peer learning when their classmates have questions. Instructors for the most part are to act as subject matter experts for questions, the conduct of the class, and to direct the course of the class as questions arise. Some instructors may lecture during the course of a specific class or demonstrate problems but the focus of this method is on student led learning with the instructor asking probing questions that draw out the key points in the material. (1,8) The problem arises with this method when students arrive unprepared or unwilling to ask probing questions. It becomes a challenge for the instructor, in many cases, to assess how well students know the assigned material and where the key questions may be found. Because of this problem some kind of assessment may be a good solution to assist the instructor with guiding the class to better help the students.

c. Assessment using a response system: Before we discuss how ARS is used in assessment you should understand that there are two main types of assessment and each has a role in learning. Summative assessments are given periodically to determine at a specific time what students know and do not know. This is typically in the form of quizzes or exams but can also include other methods to measure student learning. These assessments normally form the basis for grades. The other type of assessment is formative assessment and this is part of the instructional process. This assessment provides information to the student and instructor about understanding at a point in instruction. One difference in formative over summative is that we don't hold the student accountable or grade the response. Formative assessment also provides a means to practice your new skills without fear of the final grade or points. Formative assessment is a tool that easily allows for adjustments in the course to help ensure students learn the material before moving on to new material. (11,16) This is especially important in a gateway course which determines successful entry into college which is the case with general chemistry is at USMA. It is also important in courses that have information that builds up and requires that the student master earlier material before proceeding to new material. This is typical of introductory science courses such as chemistry, physics, or biology. Another important difference in formative assessment is that the student is more involved and it also can result in peer-to-peer interactions which also helps them learn, retain, and understand.

i. Before class assessment. This approach uses the ARS before class to allow students to evaluate what they know about the forthcoming lesson. It is used to get the students to think and evaluate their knowledge and it gives them a quick overview of what is to come during the lesson. There are some problems with this approach which include slowing down the start of class, potentially losing students that have no knowledge of the material, and losing students already struggling with the material. The advantage of the approach is that it allows the instructor to determine where students are at with the material and which areas are least understood. Other problems can be lack of time or using too much time which makes the lesson rushed if too much time is lost up front.

ii. During class assessment. This approach uses the ARS during class to foster understanding, highlight a concept, or stimulate questions or deeper understanding. Questions or responsive information is simply presented at some point in class to help the instructor make decisions about the conduct of class. The main problems with the approach is that is that it may interrupt the class too much, stall the class in place to address a minute point, and it does take some preparatory work to get ready with much thought by the instructor on questions.

iii. After class assessment. This approach is typically used after class to highlight critical points in the information, test understanding, or simply allow students to evaluate their learning. For the instructor, this approach provides some information on how well the material was understood by the students and it may also highlight problem areas that could potentially

be re-examined at a later time. The biggest drawback to this approach is that it is too late to make changes and some students may simply leave class with questions.

iv. Before and after class assessment. This approach uses a combination of approaches to determine before and after class knowledge. This approach has many advantages with the best demonstrating actual knowledge before and after the class. Drawbacks are similar to those discussed previously.

v. Before, during, and after class assessment. This approach is the most comprehensive and can allow the instructor to determine how students are learning during the entire class process. Clearly, this method can provide a great deal of feedback to the instructor but it may be too intrusive and take away too much class time to be worthwhile. However, in some cases, this clearly may be the way to go. Disadvantages have been discussed previously.

6. Before class (Pre-Assessment) use of an audience response system. For this study two sections of students in a general chemistry class were pre-assessed using an ARS to determine where the class focus needed to be for the day and to help the students to formulate questions for the day. For the other two sections of students classes were run as normal with questions addressed as they occurred. The ARS sections included one section in the morning and one mid-morning to help eliminate bias of time of class. The non ARS classes also included one morning and one mid-morning class. Data was collected in a notebook by the instructor on class start time, questions asked by students or discussed by instructor, time to boards, number of board problems, and ending time of class. Other additional data was also maintained such as student comments on ARS and instructor impressions on the class. Students were also assessed 8 times throughout the semester using various methods to include “muddiest point”, classroom questionnaires, in class discussion groups (voluntary), and others. The instructor also kept a log of his impressions on the classes and any comments noted as classes were conducted.

   a. Time analysis. The time study data was of interest since the objective was to reduce class time up front to allow more time to work problems on the boards since more time at the boards has been seen as beneficial to student performance and understanding. A summary of the data collected is at shown in Table 1. The data clearly show that use of ARS in the two sections led to a reduction in the number of problems demonstrated or discussed by the instructor. Typically, in a class, students are asked if they had difficulty with the homework and difficult problems are usually demonstrated. These demonstrated problems typically take anywhere from 3 to 10 minutes to walk through since many questions are generated in the process. In the ARS class the number of demonstrated problems dropped from 3 (no ARS) to 2 (with ARS). This can be seen in all the data no matter how the time frame is presented. In addition, the ARS using sections averaged one addition board problem per class which most likely resulted from the reduced up front demonstration. The data also clearly shows that the number if board problems worked on the boards in the ARS

classes increased compared to the non ARS classes from 3 problems to 4 problems. This practical hands on practice is seen by many teachers to be the best way to learn and it should lead to better performance. The average time to get to boards dropped anywhere from 11 to 14 minutes in the ARS classes compared to the non ARS classes (See Table 1). Unfortunately, this clear change did not alter grades much when compared but there are other benefits that will be addressed. The most interesting information to be gained here is that

	Timeframe or Block	Board Problems Completed	Problems Shown	Time to get to boards
WITH ARS	**WPRI**	4	2	0:50
	WPRII	4	2	0:38
	WPRIII	4	1	0:32
	TEE	5	2	0:40
	Average	**4**	**2**	**0:40**
	Block 1	2	2	1:03
	Block 2	4	3	0:45
	Block 3	4	2	0:38
	Block 4	3	2	0:37
	Block 5	4	2	0:33
	Block 6	5	2	0:40
	Average	**4**	**2**	**0:43**
NO ARS	**WPRI**	3	3	0:56
	WPRII	3	3	0:52
	WPRIII	3	2	0:53
	TEE	3	3	0:54
	Average	**3**	**3**	**0:54**
	Block 1	2	2	0:57
	Block 2	3	3	0:54
	Block 3	3	3	0:55
	Block 4	2	3	0:49
	Block 5	3	2	0:53
	Block 6	3	3	0:54
	Average	**3**	**3**	**0:54**

Table 1. Summary of ARS Use Data. Data was collected over a semester of four sections of new incoming students in General Chemistry 101. Two sections used ARS as a pre-assessment tool and two sections did not use ARS. The Data has been shown by both time frame of major exams as well as by Block of instruction. Overall averages of board problems completed, problems demonstrated, and time to get to board work for the class are shown.

the ARS pre-assessment did get the students to boards more quickly and if you factor in that the use of the ARS system uses 5 to 10 minutes of time up front this difference is more pronounced. One argument against the use of ARS is that it will use too much time and result in less class time (14,15) however, this work shows that some time may be saved. This initial work may also suggest that

careful use combined with question selectivity may make ARS even more effective.

b. Overall grade analysis. Data on the grades were kept for all the sections and a comparison between the ARS and non ARS classes did not demonstrate a significant difference. In fact, the only student to fail the semester was in the ARS class. The overall percentages are presented in Table 2. The data in

	Percent	Predict	Delta
ARS	**82.96%**	75.64%	7.31%
	83.59%	76.26%	7.33%
Averages	**83.27%**	75.95%	7.32%
No ARS	**85.72%**	78.36%	7.37%
	85.32%	76.96%	8.36%
Averages	**85.52%**	77.66%	7.86%

Table 2. Overall grade percentages ARS compared to non ARS. This table compares the overall percentages, predicted scores, and difference between the two in four sections of students in a general chemistry class. The predicted percentage is calculated using compiled data that includes high school GPA, SAT scores, and analysis of extracurricular activities.

Table 2 shows the overall percentage earned by the students at the end of one semester compared to the predicted score using high school GPA, SAT scores, extracurricular activities, and the score on the general chemistry validation exam given upon arrival at USMA. Clearly, when comparing the ARS sections scores to the non ARS sections there is very little to no difference overall. And the predicted average scores are slightly higher in the non ARS sections compared to the average predicted scores in the ARS sections which would seem to indicate that the classes were relatively even before the comparison. The overall difference in the predicted averages to the actual percentages is also very similar which would seem to indicate that the ARS use did not enhance performance which was not the goal of this work. This data was collected to ensure that the use of ARS did not adversely affect the student's performance and this is clearly the case when this data are examined.

c. Student perceptions. During the course of this study, the students were assessed on their perceptions of the class. These assessments were completed throughout the semester using various methods and focused on many aspects of their learning and the class. Many of these assessments did not specifically

discuss the ARS system to give the students more freedom in their responses. On an initial survey which asked three questions about the class thus far there were varied answers from many students but the bulk of the students either with

	ARS	Non ARS
Most useful to you in working problems		
Tools (Mole Bridge, DA, etc)	**31**	**27**
Board Problems	**18**	**17**
Instructor	**2**	**0**
Skill or Tool to make learning easier		
Practice or Boards	**15**	**2**
Steps to Solve	**8**	**1**
Video AI	**5**	**4**
Math/Book/Concepts	**11**	**9**
Enhances learning		
Board Problems	**27**	**21**
Mole Bridge	**4**	**1**
Instructor guidance	**14**	**18**
Peers	**6**	**2**
Clickers	**7**	**0**
Other	**6**	**9**

Table 3. Summary of Data from an initial assessment. Four sections of a general chemistry class were assessed for problem solving. Two sections used ARS while the other two sections were taught in a more traditional manner. Results are the number of responses and each sheet can have multiple responses for each question. ARS sections had a total of 36 students while non ARS sections had a total of 37 students.

ARS (36 students) or the non ARS (37) students thought that board work was clearly helpful. These data are summarized in Table 3. The most striking note is how students recognize that board problems are their single most valuable asset in working problems and that the greatest asset to enhancing learning is in working board problems too. Other items of interest in how instructor guidance is key to enhancing learning along with peers. The ARS system for the two sections that used them were also noted as a means to enhance learning. It is interesting to note that ARS was not mentioned as a means to better learning for question two however, this question was geared toward problems and how they could resolve the problem. Certainly, this data agrees with other observations by

instructors that board problems enhance learning. In this initial survey, it appears that the students found ARS to be of benefit too. Table 5 is a summary of the responses in a later assessment that simply asked the students for their positive and negative comments without any additional prompting from the instructor. These data suggests that the students later in the semester felt that there was some significant contact with the instructor in both the ARS and non ARS classes. Interestingly, the ARS classes had more overall positive responses regarding contact with the instructor than the non ARS class which may be attributable to the use of the system in those classes. Also, there are several

	ARS	Non ARS
Positive Comments		
Instructor contact and application	**33**	**22**
Board Problems	**8**	**12**
Tools (RDC, book, labs)	**2**	**4**
Clickers	**4**	**1**
Other	**3**	**3**
Negative Comments		
Labs crowded or confusing	**8**	**9**
Homework (long, checked, not needed)	**4**	**1**
Board Problems	**2**	**1**
Too much information	**10**	**3**
Other	**10**	**23**

Table 4. Summary of Data from a later assessment. Four sections of a general chemistry class were assessed and asked for pros and cons of the class without any additional prompting from the instructor. Two sections used ARS while the other two sections were taught in a more traditional manner. Results are the number of responses and each sheet can have multiple responses for each question. ARS sections had a total of 36 students while non ARS sections had a total of 37 students.

students that liked the ARS system enough to provide positive comments without prompting by the instructor at all. The students also continued to comment on the board problem work as a source of understanding with only a 3 commenting in a negative manner on board problems. Other areas of comment of note are comments by the students on long class time coupled with too much material being covered. Students also thought labs were confusing and crowded. The confusion of the labs is addressed when the students complete the prelab and the crowdedness of the labs should be alleviated with the renovation to Bartlett

	ARS	Non ARS
Moles, Emperical Formula	**5**	**3**
Charges, Ions	**2**	**2**
Significant Figures	**3**	**3**
Nomenclature	**1**	**1**
Mole Bridge	**3**	**3**
Periodic Table	**3**	**3**
Mass, Compounds	**1**	**2**
Other	**4**	**4**

Table 5. Summary of data from an early semester assessment. Four sections of a general chemistry class were assessed as asked for their most unclear aspect of the material without any additional prompting from the instructor. Two sections used ARS while the other two sections were taught in a more traditional manner. Results are the number of responses and each sheet can have multiple responses for each question. ARS sections had a total of 36 students while non ARS sections had a total of 37 students.

Hall in the upcoming years. This later data strongly suggests that the students feel that the instructor has contact with them and ties the material to real world applications and the higher number of positive comments in this area could be due to the use of ARS. Early assessment data on where students were lost was very similar early in the semester with both groups stating similar points as unclear regardless of the ARS. This is seen in Table 5 and the raw numbers seem to indicate each group has similar concerns with the ARS group being more lost on some aspects of the coursework. In a later self assessment made by both groups as seen in Table 6, both groups also responded in a similar manner suggesting that both groups had similar difficulty with the material regardless of the use of the ARS. Interestingly, it appears that the non ARS groups did feel more lost in some areas of the course such as solubility, polarity, and intermolecular forces (IMFs), as well as, Henry's Law which was not listed as high in the ARS groups. Several of these concepts were reviewed using the ARS which may indicate some direct benefit of use by highlighting problematic areas of coursework. A mid-semester assessment by the students on what helped them with problem solving in general chemistry also seemed to indicate that both groups struggled in similar areas as seen in Table 7. In Table 7, both groups identified dimensional analysis, mole bridge, and stoichiometry as key concepts to solving problems. At this early stage of the year, these clearly are key ideas to understand to successfully solve problems in chemistry. Also, in Table 7, it is clear that board problems and practice problems are considered to be the two things that attributed to successful problem solving skills. Interestingly, 5 students across two sections using the ARS identified them as

		ARS	Non ARS
Clear Easy to Understand			
	Terms, Math, Molarity	10	10
	Henry's Law	1	2
	Solubility	3	3
	Other	2	3
Difficult or Unclear			
	Soubility, Polarity, IMFs	11	16
	Bonds, Book, Laboratory Work	2	3
	Henry's Law	0	4
	Other	1	1

Table 6. Summary of data from a later self assessment. Four sections of a general chemistry class were assessed and asked to identify one clear aspect of the material and one area that was difficult or unclear without any additional prompting from the instructor. Two sections used ARS while the other two sections were taught in a more traditional manner. Results are the number of responses and each sheet can have multiple responses for each question. ARS sections had a total of 36 students while non ARS sections had a total of 37 students

enhancing learning. Also, both groups identified the solving of problems at the board by the instructor as another enhancement to learning and problem solving. These data taken as a whole suggest that the students assessed themselves with similar problems in the class regardless of the ARS system in use. This seems to be true for both groups early in the semester, by mid-semester, and later in the semester as well. All things being equal was there any benefit to using the ARS system and what did the student's think at the end of the semester? Some of these questions were examined using a survey for all the sections using the ARS system. For the non ARS sections, it was their first use and they were asked about the systems since they had no previous exposure to the system in the general chemistry course. Three additional surveys were completed in the semester with similar results to these data with board problems and video AI being of great importance followed by instructor enthusiasm and help. Problem areas continued to be problem solving, nomenclature, and understanding of various concepts such as Lewis structures, bonding, and balancing equations.

		ARS	Non ARS
Useful to Solve Problems			
	Dimensional Analysis	16	14
	Mole Bridge, Stoichiometry	19	20
	Ionic versus Covalent Bonds	1	0
	Reflection on Board Problems	1	0
	GFPSR Format on Boards	1	1
	Periodic Table Understanding	1	1
Had Problem, What helped?			
	Significant Figures	2	1
	Video Additional Instruction	5	3
	Extra Problems w Solutions	4	2
	Understanding/Depth	3	0
	More Dimensional Analysis	4	1
	Book Unclear, Rereading	4	1
	Relate to Military	1	0
	Start Problem	2	1
	RDC	2	3
	Balancing Equations	1	1
Enhanced Learning			
	Board Problems	20	18
	Practice Problems w Solution	7	3
	Show how to solve in class	11	10
	Use of ARS System	5	0
	RDC	1	1
	Demonstrations, Review, Video AI	4	2
	Instructor AI	0	2

Table 7. Summary of data from a mid-semester assessment. Four sections of a general chemistry class were assessed and asked to identify specific information that helped them solve problems related to general chemistry. The three categories used were useful to solve, what helped with problems, and anything that enhanced learning. Two sections used ARS while the other two sections were taught in a more traditional manner. Results are the number of responses and each sheet can have multiple responses for each question. ARS sections had a total of 36 students while non ARS sections had a total of 37 students

d. End of semester survey results. Students provided end of semester survey results using an ARS system in all sections examined for this study. In all, there were 20 questions that ranged from learning to direct use of the ARS. Due to a time constraint, one section (G8) was only asked the first 8 questions while the other non ARS section (C8) was asked the entire set. A complete listing of the results of the survey is at the appendix. Some select data will be discussed in this section to show student perceptions of the ARS. In Figure 1, both the ARS and non ARS students enjoyed using the ARS for class. This result is interesting

considering that the non ARS students only had one exposure to the system which was at the end of the semester. Since the system was new to the non ARS classes, the students seemed more animated in use and the system seemed to generate much discussion among the students. The overall results from the survey shows that the majority of both groups overwhelmingly enjoyed

8.) Did you enjoy using the clicker system in class?

	ARS		Non ARS	
	Responses (percent)	(count)	Responses (percent)	(count)
Strongly Agree	65.71%	23	77.14%	27
Agree	14.29%	5	8.57%	3
Neutral	14.29%	5	11.43%	4
Disagree	2.86%	1	0.00%	0
Strongly Disagree	2.86%	1	2.86%	1
Totals	100%	35	100%	35

9.) How do you think the clickers should be used in class?

	ARS		Non ARS	
	Responses (percent)	(count)	Responses (percent)	(count)
Beginning of class	62%	21	50%	9
During class	9%	3	11.11%	2
End of class	3%	1	0%	0
All of the above	26%	9	38.89%	7
Don't use at all	0%	0	0%	0
Totals	100%	34	100%	18

Figure 1. Select End of Semester Survey Questions. Four sections of a general chemistry class were asked survey questions at the end of the semester related to their general chemistry learning experience. Two sections used ARS while the other two sections were taught in a more traditional manner. Results are the number of responses and percentage. ARS sections had a total of 36 students while non ARS sections had a total of 37 students.

the ARS at 80% of the ARS students and 86% of the non ARS students (strongly agree and agree combined). When both groups were queried on how the system should be used most thought beginning of class was a good use while the next majority thought that throughout the class would work too. This study focused on employment at the beginning however; use at both the beginning and end of the class may be of greater benefit. During class use, based on the instructor experience of this study, is problematic unless done so carefully. In Figure 2, it is clear that both the ARS group and the non ARS perceived that the ARS saved some time which was the case with the ARS group even though it didn't result in higher overall grades it did allow for greater board problem completion which is should result in more hands-on practice in the long term. Even with the additional work by the instructor and the occasional class that is longer, the students using the ARS felt that the system saved time. Figure 2 also highlights that the students in both groups felt that the ARS should be used in more classes which shows that there is a benefit to the system for student perceptions of

interaction and system effectiveness. Clearly, the ARS made an impression on both groups with the ARS group having more experience still getting similar results to the non ARS (one time use) group. In Question 12 (see Appendix) both groups think the ARS works with all types of problems to include definitions, concepts, and problems. Of these types, the multistep problems are the most difficult to set up and require the greatest thought on how to use them most effectively in class. On real interest to instructors is how the students perceive their learning experience and this is illustrated in Figure 3 which found both groups liked being anonymous and lived the interactive experience of the ARS. Many students in both groups also liked seeing other student answers which allows the students to see how they are doing compared to their classmates without being singled out by the

10.) Select the answer that best reflects how clickers used the class time		**ARS**		**Non ARS**	
		Responses (percent)	**(count)**	**Responses (percent)**	**(count)**
Saved time		55.88%	19	55.56%	10
No difference		26.47%	9	27.78%	5
Used more time		5.88%	2	0%	0
No opinion either way		11.76%	4	16.67%	3
	Totals	100%	34	100%	18

11.) How would like clickers to be used for classes in general?		**ARS**		**Non ARS**	
		Responses (percent)	**(count)**	**Responses (percent)**	**(count)**
More time in class		12.90%	4	18.75%	3
Used in more classes		45.16%	14	25%	4
Used for quizzes		3.23%	1	6.25%	1
Used for attendance		0.00%	0	0%	0
All of the above		32.26%	10	43.75%	7
Don't use at all		6.45%	2	6.25%	1
	Totals	100%	31	100%	16

Figure 2. Select End of Semester Survey Questions. Four sections of a general chemistry class were asked survey questions at the end of the semester related to their general chemistry learning experience. Two sections used ARS while the other two sections were taught in a more traditional manner. Results are the number of responses and percentage. ARS sections had a total of 36 students while non ARS sections had a total of 37 students. One section was unable to complete the entire survey due to time constraints.

instructor. Figure 3, Question 14, also addresses how students felt about their learning and it is clear that both groups felt that the ARS helped them learn. While this perception may not be quantifiable in this study since overall grades seem similar, the perception alone makes using the ARS a worthwhile endeavor. Other interesting data show in the appendix shows that students in both groups thought the ARS helped them indentify strengths and weaknesses in their learning and most students wanted to spend less than $20.00 if they had to buy

their ARS remote.

13.) Which best describes your experience with clickers?	ARS		Non ARS	
	Responses (percent)	(count)	Responses (percent)	(count)
Liked being anonymous	48%	16	47.06%	8
Liked the interactivity	33%	11	29.41%	5
Liked seeing others answers	15%	5	23.53%	4
Liked them other reasons	3%	1	0.00%	0
Neutral	0%	0	0.00%	0
Disliked using them	0%	0	0.00%	0
Waste of time	0%	0	0.00%	0
Totals	100%	33	100%	17

14.) Do you think clickers helped in your learning?	ARS		Non ARS	
	Responses (percent)	(count)	Responses (percent)	(count)
Strongly Agree	29%	10	33.33%	6
Agree	56%	19	61.11%	11
Neutral	12%	4	5.56%	1
Disagree	3%	1	0%	0
Strongly Disagree	0%	0	0%	0
Totals	100%	34	100%	18

Figure 3. Select End of Semester Survey Questions. Four sections of a general chemistry class were asked survey questions at the end of the semester related to their general chemistry learning experience. Two sections used ARS while the other two sections were taught in a more traditional manner. Results are the number of responses and percentage. ARS sections had a total of 36 students while non ARS sections had a total of 37 students. One section was unable to complete the entire survey due to time constraints.

e. ARS Student comments. Students provided comments on the ARS throughout the entire semester and at the end I spoke with both sections to see what they thought of the system in class. Both positive and negative comments were captured and are included here to highlight some of their thoughts on how it impacted learning.

   i. Positive comments included:

   - I liked the system and it made class fun, well, more fun.
   - I liked not being singled out in class
   - I like working the problems with the answer up on the board
   - I like seeing how everyone else is doing
   - It made me think of some questions
   - The ARS was easy to use pretty fast

- It made me think and sometimes I thought of a question to ask the instructor
- I felt like classes were faster even if they were not faster
- I wish more of my classes used it
- I want to use it all the time

ii. Negative comments included:

- Took time from lecture which I needed
- It didn't cover all types of problems
- Some classes were a waste of time
- I felt pressured to answer fast and move on
- Maybe only use once per week
- I wanted to see the instructor work the problems
- Waste some days and drop definitions from questions
- Should use at the beginning of class and at the end to see if we do better
- I would take the gizmo free but don't want to pay for it if we have to use it

f. Non ARS Student comments. At the end of the semester the non ARS students were shown the system and asked an end of semester survey. There was also a discussion group and this use of ARS was a one-time use for these students. The non ARS students were told that the other sections had used the system during the semester. Both positive and negative comments were captured during in class discussions and their comments are included here to highlight some of their thoughts on the ARS.

i. Positive comments included:

- I liked the system and it made class fun
- I would like to use it more
- I felt left out when I found out the other classes used it
- I loved seeing how I did on the answer
- I liked being anonymous
- I liked the definition review since instructor never highlights the definitions in regular class
- I liked the speed of class, it seemed faster

ii. Negative comments included:

- OK to use but I would not want to buy it
- Would it be used in other classes
- I feel like there is enough interaction in classes without using it

g. Instructor observations and comments. These are a few thoughts from my notes during the semester and immediately after the last class of the semester about the ARS system.

   i. The use of the ARS seemed to go well after the students learned how to use them. It took about three classes for the students to become proficient.

   ii. ARS jumped some classes to the core problem or issue with learning which was great. It allowed for a rapid identification of a universal problem in class and for the class to focus on it together as a group. It spurred more comments on those days and the students seemed to rally together to discuss the problem (peer learning).

   iii. Mixing the ARS slides in the midst of my lecture was more problematic since I tend to skip around depending upon the class questions. In the end I had to make an ARS set that was used separate from the regular slides for class. It was not a big problem but it does require some practice to get used to especially if you go back to the ARS question responses later in class.

   iv. I set the slides for ARS to 2 definitions and 1 problem per set typically so keep time down to 5 to 10 minutes up front. I tried other combinations but this number seemed to work with the minimum impact on time. I mixed them up with problem up front, definitions at the end to keep it fresh each time.

   v. I knew by the middle of the semester that the ARS classes were more streamlined compared to the other two sections not using the system. Once the students learned how to use the system and were not scared of pushing the buttons then it became very, very fast. I did start looking at the data in the middle of the semester and it was clear that the classes were more focused and the students were more animated and engaged in the class.

   vi. The students loved using the ARS and by the middle of the semester both of the ARS sections seemed more engaged and interactive compared to the other sections. The ARS students seemed more willing to talk or to even ask a question if they were confused.

   vii. ARS may be a way to identify weak students in class early on if they are assigned by number so the instructor knows who is answering. If I were to use this on a regular basis, I would use the roster system and look to see how students were responding to see which students are weak. Certainly, knowing the responses keyed to the student would be a big benefit to providing them help especially early on where foundation knowledge is critical.

viii. The ARS could potentially be used with demonstrations so students can predict what will happen in reactions at the bench. This use would heighten the interest in the demonstrations and also make the students think about what is going on in the demonstration. This engagement could potentially make demonstrations more effective down the road which would make the set up and class time use very worthwhile.

h. Instructor changes and comments. Overall the ARS system did get the students more engaged in the material and allowed them to see how others were doing without being singled out. I think the set up time and time used in class is minimal compared to the gains in interactivity in class. Selection of questions to be used is a key and focus should be on key concepts or knowledge that is a key for deeper understanding. As the classes proceeded in the semester, the ARS classes seemed to flow a bit better and I know I did a bit less talking in those classes overall (perception no real data on that). I did find that I focused on the problems highlighted in the ARS up front questions and the students did not ask nearly as much compared to the non ARS classes. I loved getting some insight into what the students were thinking by seeing their answers and this stimulated both the students and me to ask some questions in class.

7. Recommendations for Using the Audience Response System. The ARS system is very beneficial for our students even though are classes are small (20 or less) compared to other schools. Based on this study, there are several recommendations for their use for the future and these are only meant as a guide for use and not mandatory.

   a. Carefully select the questions for use in class. I linked them to several key objectives

   b. At the beginning of use, try several fun types of questions to get the students involved. I used some popular culture types of questions to train the students on how to respond. The benefit of this is that they will all answer the question and many will have some type of comments to make to the class. For example, I asked about which move by a famous actor “sucked” and everyone had an opinion. Also, it had no real right answer which made them defend their choices which was fun.

   c. I would not use it for every class since it does get stale if you feel forced to use it and some lessons are not well suited to ARS use. I would vary use and consider using it for demonstrations or to highlight some key concept to the students. Especially those concepts that students perceive as difficult based on their assessment throughout the semester. In chemistry, I think this system would be great to use combined with in-class laboratory demonstrations to highlight reactions. Right now, demonstrations are brought out and some questions asked before they are conducted. ARS could easily be integrated to allow students to make predictions about the reactions or experiment and then let them see what happens. This would provide a great opportunity for both discussion and peer learning.

d. I would recommend tracking student answers to try to find weaker students early. I didn't do this and later in the year felt it would be worth the additional set up and time to get it to work.

8. Conclusions. The ARS did enhance the two sections that I taught in general chemistry. I found that once the students became familiar with the technology then it was a quick and easy way to find out what students could do and more importantly what they could not do. The students in the two ARS sections tended to start quickly and also ask fewer questions after the use of the ARS. I tailored the questions to try to keep the time use down to less than 10 minutes but sometimes the discussion ARS evoked made that time a bit longer. I think it is clear that ARS can potentially save time in class if used as a pre-assessment tool and I am not sure why the extra board time did not seem to help the students to the extend I thought but that was not the goal. As far as the goal of tailoring the classes to the students was able to more easily be done since I did not have to guess what the students were thinking each morning. In the end, the ARS did get the students to boards quicker and made each ARS class more tailored since problems were highlighted. I think the greatest argument for use is that the students felt more engaged and that class seemed more fun. There is a great deal of benefit in that since everyone wants their class to be the best. Based on the end of semester perceptions of the students overall, I would recommend using the ARS for more classes and using it creatively with demonstrations or games to better engage the students. Yes, even in chemistry.

Appendix

Summary of End of Semester Survey Data

1.) Chemistry helped me to develop critical thinking skills?

	ARS		Non ARS	
	Responses (percent)	(count)	Responses (percent)	(count)
Strongly Agree	20.00%	7	17.65%	6
Agree	57.14%	20	50.00%	17
Neutral	17.14%	6	26.47%	9
Disagree	2.86%	1	5.88%	2
Strongly Disagree	2.86%	1	0.00%	0
Totals	100%	35	100%	34

2.) Which aspect of class would you like to increase?

	ARS		Non ARS	
	Responses (percent)	(count)	Responses (percent)	(count)
Demonstrations	42.86%	15	40.00%	14
Laboratories	2.86%	1	2.86%	1
Board work	17.14%	6	11.43%	4
Classroom discussion	0.00%	0	0.00%	0
Group work	2.86%	1	5.71%	2
Applications in the world	20.00%	7	17.14%	6
Nothing it OK	14.29%	5	22.86%	8
Totals	100%	35	100%	35

3.) Which aspect of class would you like to decrease?

	ARS		Non ARS	
	Responses (percent)	(count)	Responses (percent)	(count)
Demonstrations	3.03%	1	2.86%	1
Laboratories	30.30%	10	28.57%	10
Board work	12.12%	4	14.29%	5
Classroom discussion	6.06%	2	5.71%	2
Group work	12.12%	4	17.14%	6
Applications in the world	0.00%	0	5.71%	2
Nothing it is OK	36.36%	12	25.71%	9
Totals	100%	33	100%	35

4.) Was Chemistry helpful in developing your study skills?

	ARS		Non ARS	
	Responses (percent)	(count)	Responses (percent)	(count)
Strongly Agree	2.94%	1	6.06%	2
Agree	26.47%	9	27.27%	9
Neutral	52.94%	18	48.48%	16
Disagree	8.82%	3	9.09%	3
Strongly Disagree	8.82%	3	9.09%	3
Totals	100%	34	100%	33

5.) My instructor was helpful and cares about how I do in class?

	ARS		Non ARS	
	Responses (percent)	(count)	Responses (percent)	(count)
Strongly Agree	61.76%	21	67.65%	23
Agree	29.41%	10	23.53%	8
Neutral	8.82%	3	8.82%	3
Disagree	0.00%	0	0.00%	0
Strongly Disagree	0.00%	0	0.00%	0
Totals	100%	34	100%	34

6.) My instructor set a good example in class?

	ARS		Non ARS	
	Responses (percent)	(count)	Responses (percent)	(count)
Strongly Agree	48.57%	17	60%	21
Agree	42.86%	15	34%	12
Neutral	8.57%	3	6%	2
Disagree	0.00%	0	0%	0
Strongly Disagree	0.00%	0	0%	0
Totals	100%	35	100%	35

7.) I learned something about being in the Army in this class?

	ARS		Non ARS	
	Responses (percent)	(count)	Responses (percent)	(count)
Strongly Agree	26.47%	9	23.53%	8
Agree	47.06%	16	64.71%	22
Neutral	23.53%	8	11.76%	4
Disagree	2.94%	1	0.00%	0
Strongly Disagree	0.00%	0	0.00%	0
Totals	100%	34	100%	34

8.) Did you enjoy using the clicker system in class?

	ARS		Non ARS	
	Responses (percent)	(count)	Responses (percent)	(count)
Strongly Agree	65.71%	23	77.14%	27
Agree	14.29%	5	8.57%	3
Neutral	14.29%	5	11.43%	4
Disagree	2.86%	1	0.00%	0
Strongly Disagree	2.86%	1	2.86%	1
Totals	100%	35	100%	35

9.) How do you think the clickers should be used in class?

	ARS		Non ARS	
	Responses (percent)	(count)	Responses (percent)	(count)
Beginning of class	62%	21	50%	9
During class	9%	3	11.11%	2
End of class	3%	1	0%	0
All of the above	26%	9	38.89%	7
Don't use at all	0%	0	0%	0
Totals	100%	34	100%	18

10.) Select the answer that best reflects how clickers used the class time

	ARS		Non ARS	
	Responses (percent)	(count)	Responses (percent)	(count)
Saved time	55.88%	19	55.56%	10
No difference	26.47%	9	27.78%	5
Used more time	5.88%	2	0%	0
No opinion either way	11.76%	4	16.67%	3
Totals	100%	34	100%	18

11.) How would like clickers to be used for classes in general?

	ARS		Non ARS	
	Responses (percent)	(count)	Responses (percent)	(count)
More time in class	12.90%	4	18.75%	3
Used in more classes	45.16%	14	25%	4
Used for quizzes	3.23%	1	6.25%	1
Used for attendance	0.00%	0	0%	0
All of the above	32.26%	10	43.75%	7
Don't use at all	6.45%	2	6.25%	1
Totals	100%	31	100%	16

12.) Which type of information is best used with the clicker system?

	ARS		Non ARS	
	Responses (percent)	(count)	Responses (percent)	(count)
Definitions	0%	0	0.00%	0
Concepts	9%	3	11.11%	2
Problems	0%	0	0.00%	0
All of the above	47%	16	38.89%	7
1 and 2	38%	13	44.44%	8
1 and 3	3%	1	0.00%	0
2 and 3	3%	1	5.56%	1
Don't use at all	0%	0	0.00%	0
Totals	100%	34	100%	18

13.) Which best describes your experience with clickers?

	ARS		Non ARS	
	Responses (percent)	(count)	Responses (percent)	(count)
Liked being anonymous	48%	16	47.06%	8
Liked the interactivity	33%	11	29.41%	5
Liked seeing others answers	15%	5	23.53%	4
Liked them other reasons	3%	1	0.00%	0
Neutral	0%	0	0.00%	0
Disliked using them	0%	0	0.00%	0
Waste of time	0%	0	0.00%	0
Totals	100%	33	100%	17

14.) Do you think clickers helped in your learning?

	ARS		Non ARS	
	Responses (percent)	(count)	Responses (percent)	(count)
Strongly Agree	29%	10	33.33%	6
Agree	56%	19	61.11%	11
Neutral	12%	4	5.56%	1
Disagree	3%	1	0%	0
Strongly Disagree	0%	0	0%	0
Totals	100%	34	100%	18

15.) Do you think clickers helped you to find your weaknesses in the lesson?

	ARS		Non ARS	
	Responses (percent)	(count)	Responses (percent)	(count)
Strongly Agree	28%	9	17.65%	3
Agree	53%	17	64.71%	11
Neutral	16%	5	11.76%	2
Disagree	3%	1	5.88%	1
Strongly Disagree	0%	0	0%	0
Totals	100%	32	100%	17

16.) Do you think clickers helped you to find your strengths in the lesson?

	ARS		Non ARS	
	Responses (percent)	(count)	Responses (percent)	(count)
Strongly Agree	28.13%	9	37.50%	6
Agree	40.63%	13	43.75%	7
Neutral	21.88%	7	6.25%	1
Disagree	6.25%	2	6.25%	1
Strongly Disagree	3.13%	1	6.25%	1
Totals	100%	32	100%	16

17.) Do you think clickers helped you to formulate questions about the lesson?

	ARS		Non ARS	
	Responses (percent)	(count)	Responses (percent)	(count)
Strongly Agree	26.47%	9	33.33%	6
Agree	32.35%	11	33.33%	6
Neutral	23.53%	8	16.67%	3
Disagree	17.65%	6	16.67%	3
Strongly Disagree	0.00%	0	0%	0
Totals	100%	34	100%	18

18.) Would you be willing to pay for a clicker if it is used in more classes?

	ARS		Non ARS	
	Responses (percent)	(count)	Responses (percent)	(count)
Strongly Agree	9%	3	17.65%	3
Agree	15%	5	29.41%	5
Neutral	18%	6	11.76%	2
Disagree	36%	12	17.65%	3
Strongly Disagree	21%	7	23.53%	4
Totals	100%	33	100%	17

19.) How much would you be willing to pay if you had to purchase a clicker?

	ARS		Non ARS	
	Responses (percent)	(count)	Responses (percent)	(count)
$5.00 - $10.00	15.15%	5	16.67%	3
$11.00 - $20.00	24.24%	8	33.33%	6
$21.00 - $35.00	9.09%	3	16.67%	3
$36.00 - $50.00	0.00%	0	0%	0
> $51.00	6.06%	2	11.11%	2
Not willing to pay at all	45.45%	15	22.22%	4
Totals	100%	33	100%	18

20.) I would rather use the clicker system in class for surveys and assessments?

	ARS		Non ARS	
	Responses (percent)	(count)	Responses (percent)	(count)
Strongly Agree	27.27%	9	61.11%	11
Agree	45.45%	15	33.33%	6
Neutral	18.18%	6	5.56%	1
Disagree	6.06%	2	0.00%	0
Strongly Disagree	3.03%	1	0.00%	0
Totals	100%	33	100%	18

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