THE EFFECTIVENESS OF A CLASSROOM RESPONSE SYSTEM AS A METHOD OF FORMATIVE ASSESSMENT IN A MIDDLE SCHOOL SCIENCE CLASSROOM

by

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ABSTRACT

Formative assessments are a great tactic to determine the level of student understanding of particular concepts taught in the classroom. However, this type of assessment may take time to plan, implement, analyze, and report back to students. Students need more immediate feedback in order for the assessment to be more meaningful. This research project focused on how effective the implementation of a Classroom Response System (CRS) into a middle school science classroom was as a method of formative assessment.

The data collection took place over four complete units and alternated between non-treatment (without the CRS) and treatment (with the CRS). Data was gathered and analyzed from pre-and post-surveys, pre- and post-tests, student interviews, and teacher observations. The results showed that there was no significant gain in post-test scores, but students enjoyed using the CRS, thought that it helped clear up misconceptions, and considered it to be effective in determining if information was learned. The CRS was also effective in helping the teacher assess student knowledge gained and in helping the teacher assess teaching strategies and improve lesson delivery.

INTRODUCTION & BACKGROUND

Formative assessments are a process used by teachers and students during instruction that provides explicit feedback to adjust ongoing teaching and learning to improve students' achievement of intended instructional outcomes (McManus, 2006). I have been experimenting and learning more about formative assessments throughout my teaching career. I often receive more valuable feedback from students about what they do or do not understand from formative assessment techniques than I do from summative assessments. Often with summative assessments, which are typical end-of-unit tests, students do not read questions carefully or often lack good test-taking skills. Therefore, their scores may not reflect what they really know and understand about all concepts being tested. Formative assessments assist my teaching by allowing me to know what information is confusing or what concepts need to be re-taught.

Some examples of formative assessments, often referred to as Classroom Assessment Techniques (CATs), that I have used to quickly assess student knowledge are strategies such as: 1, 2, or 3; thumbs up, thumbs down, or thumbs to the side; the Muddiest Point; the Minute Paper; and Directed Paraphrasing. The 1, 2, or 3's and thumbs up, thumbs down, or thumbs to the side allow me to know instantly if someone does not understand the concept. However, with the Muddiest Point, the Minute Paper, and Directed Paraphrasing, I need time to read, analyze, and report my findings back to the students. Due to the number of different responses, I may not clear up every student's misconceptions. With this in mind, I have implemented an efficient technique into my classroom that quickly assesses students' thinking in real time and gives immediate feedback.

A Classroom Response System (CRS), more commonly known as a clicker system, is a set of handheld devices wirelessly connected to a receiver on a main computer. Questions written ahead of time can be projected on a white screen or on the students' handhelds. Students can answer multiple choice, true/false, and short answer questions, with a seven-line text limit available. The teacher may even just ask questions spontaneously at any time during a lesson without having to pre-write questions. Students can listen to the questions given orally by the teacher and respond.

The CRS system's most valuable feature as a formative assessment tool resides in its ability to graph data. Students can immediately see the correct answers, and teachers can explain why an answer was correct and discuss why certain choices were made. By seeing results in real time, teachers can decide if a lesson needs to be repeated or if the students demonstrated enough knowledge about the concepts to move on to new information. The CRS also allows a teacher to use the feedback to determine which students are struggling with the content and can provide an avenue for individual or group discussions about what is working in class and what is not in terms of gaining knowledge.

Focus Question

The purpose of my Action Research project was to explore the following question: What is the effectiveness of the CRS as a means to formatively assess 8th grade science students? My two sections of 46 Belgrade (MT) Middle School 8th grade students participated in this project. Specific research sub-questions included the following:

I. How can a Classroom Response System (CRS) assist students in clearing up misconceptions about concepts learned?

II. How can a Classroom Response System (CRS) assist the teacher in assessing student knowledge learned through particular science units?

III. In what ways can the Classroom Response System (CRS) be used as an effective, organized assessment tool that provides immediate feedback to the teacher and students?

IV. How can the integration of a Classroom Response System into science lessons help the teacher assess teaching strategies and help improve lesson delivery?

CONCEPTUAL FRAMEWORK

This project refers to the implementation of a Classroom Response System (CRS) into 8th grade science classrooms. Other names for CRS include Classroom Performance System, Student Performance System, Audience Response System, and Interactive Response System. Although companies and researchers differ on naming the system, they all agree on defining it. Beatty, Feldman, Leonard, Gerace, St. Cyr, Lee, and Harris, (2008) describe it best.

> In essence, a CRS is nothing more than a set of simple transmitters that students use to send in their answers to some question; a receiver and software that runs on the teacher's computer, collecting and instantly aggregating answers from the whole class; and a way to display the distribution of answer choices to the teacher and the students, typically as a histogram on a data projector or wall-mounted monitor (p. 3).

The purpose for using the CRS is also clear in the literature. Suchman, Uchiyama, Smith, and Bender (2006) explained their purpose for implementing the CRS as being a

way to formatively assess students in large college classes. Kenwright (2009) wrote that the system allows students to compare their understanding of the content with their classmates' understanding. She also wrote that the CRS provides an engaging alternative to routine lectures and increases participation.

Beatty et al. (2008) described a five-year professional development study that began in 2006 and continues past the date of this report. The purpose of their study is quite clear. "We are interested in teacher change: promoting it, supporting it, and understanding it" (p. 1). The authors listed three ingredients that were needed to study teacher change: teachers, an intervention that induces change, and a research design for observing that change.

The teachers chosen for this study were all from western Massachusetts but taught in different middle school and high school settings that varied from rural to urban. The intervention focused on classroom response system technology and technology-enhanced formative assessment. Four core principles were involved: 1) motivate and focus student learning with question-driven instruction, 2) develop students' understanding and scientific fluency with dialogical discourse, 3) optimize teaching and students' learning with formative assessment, and 4) help students cooperate in the learning process and develop metacognitive skills with metalevel communication. The study described skill areas that need to be mastered by teachers, including becoming proficient in the use and delivery of the technology as well as becoming well trained in questioning and discussion strategies (Beatty et al., 2008).

Through all my CRS sessions with my students in my classroom, my goal was for the CRS to not only help me determine how much knowledge my students demonstrated

about the science concepts, but also for it to help me develop more and better questioning and discussion strategies. According to the authors, “several teachers reported that the use of classroom response systems (CRS) and teacher enhanced formative assessments (TEFA) helped them gain more information about how their students were thinking about concepts. Furthermore, the authors reported instances where they changed their lessons as a result of the formative information that they gained about students’ thinking” (Beatty et al., 2008, p. 21).

Research has shown that a CRS is a great formative assessment tool. Tuttle (2008) described how five different technology tools can help teachers assess student learning. Tuttle’s first tool, clickers, allow teachers to “get a snapshot of students’ comprehension in real time” (Tuttle, 2008, p. 28). The teacher can immediately determine any gaps or trends in student understanding. Beatty & Gerace (2009) took the meaning of formative assessment a bit further. They wrote that CRS science instruction is improved through the coexistence of Technology Enhanced Formative Assessment (TEFA). The relationship that exists between TEFA and CRS use is apparent from their publication. The first principle of TEFA is to “motivate and focus students with question-driven instruction” (Beatty and Gerace, 2009, p. 153). The questioning process can assess student prior knowledge about the concepts at hand and use it as a platform upon which to build new knowledge. The questioning process can also challenge students to think more critically and develop better communication skills. The use of the CRS assists with the questioning process by delivering the questions, collecting the responses, displaying the results for comparison and discussion, and providing anonymity so students can be comfortable sharing their thoughts and responses in front of their peers.

Many types of questions are better used as formative assessment questions than summative assessment questions to promote deep learning. Derek Bruff (2009) described four types of these questions; all of which are multiple-choice style. For best-answer questions, the clickers are useful to allow the student to enter the choice that they feel answers the question the best. If more than one correct answer exists, the clicker allows the instructor to lead a discussion on the chosen responses. In a summative assessment, students are usually not allowed to discuss or justify their answers.

Bruff (2009) described the difficulty of placing a score on student perspective questions, including those that ask for students to give their opinions or examples of personal experience. However, with clickers, students can share this information with their peers and with their instructor. Clickers allow more timid students a chance to share information that would otherwise be kept quiet and allow these students a chance to hear others' responses that may be similar to their views.

Misconception questions, according to Bruff (2009), may elicit more appropriate answers with clickers. Students can share their current knowledge, discuss with peers the reasons for their thinking, and have another opportunity to answer when all discussion is complete. This process allows the students to "stretch their mental models" (Bruff, 2009, p. 4).

Peer assessment questions, the last on Bruff's list, allow students to assess each other's work or presentations by assigning letter grades or completing rubrics tied to the clickers. Peer assessment questioning is anonymous so peers are given good, honest feedback.

Even though his goal for this article was to share advantages that clickers have in promoting different types of questions, Bruff (2009) stated that it is during the allowed thinking and discussion times when deep learning occurs. Clickers assist students to engage in class discussions because questions can be asked in an encouraging and motivating manner.

Motivation greatly affects positive student achievement in schools. Wentzel and Wigfield (2007) addressed motivation in school in a compilation of several articles whose main themes target intervention development, strategies for minority students, social relationships, measurement, and issues involved with development. This detailed article provided a theoretical framework for my own Action Research (AR).

The authors mentioned that the terms "motivation and engagement" are often used in the same context. In other words, many researchers use them as synonyms to each other. However, Wentzel and Wigfield (2007) found that there is a difference between them. "Motivation is a more specific set of processes that provide energy for different behaviors; thus when individuals are more strongly motivated they can become more deeply engaged in different activities behaviorally, cognitively, and affectively" (Wentzel and Wigfield, 2007, p. 262). They also added the following to their distinction: "…effortful engaged behavior believed to reflect positive motivational orientations toward a task" (Wentzel and Wigfield, 2007, p. 263). When discussing the theme of social relationships, the researchers discovered that there indeed is a relationship between engagement of middle school students and their academic performance. The bridge that connects these concepts is smaller learning communities. Students working comfortably in small groups can establish friendships and "provide students with a sense of emotional

security and a sense of belonging" (Wentzel and Wigfield, 2007, p. 265). Overall, when students feel safe and secure, their performance academically increases. One thing that seems missing in this article is some detailed statistics that would emphasize this point.

In a study at the University of New Mexico involving 190 undergraduate students in four sections of introductory Operations Management, there was a small increase in midterm and final exam scores when using a clicker system. Two of the four sections used clickers throughout the semester to deliver quizzes. Opportunities for discussion of responses were available during the quizzes. For the two sections that used traditional paper quizzes, discussion of answers was not available until the quizzes were scored and handed back to the students. Yourstone, Kraye, and Albaum (2008) concluded that, "Our results provide statistically significant evidence that the use of clickers can have an impact on student learning as measured my test scores" (p. 85). The data in this article showed an average increase of 6.3% on the midterm examination and an increase of 3.5 % on the final examination for the classes with the clickers.

In the McREL (Mid-continent Research for Education and Learning) Report, Clark, Englert, Frazee, Shebby, and Randel (2009) stated, "In general, there is a wide agreement among assessment experts that when teachers use formative assessment as part of their everyday classroom instruction, students are more likely to attain higher levels of achievement" (p. 13). The authors discussed that formative assessments help teachers catch learning deficiencies and misconceptions and allows them to modify instruction to better fit the needs of the students. Formative assessments need to be delivered with effective, immediate feedback that helps the students clarify misunderstandings. They

also need to be planned carefully so the students become motivated to learn and are able to build confidence in their content understanding as well.

The above conceptual framework not only assisted me in understanding how useful Classroom Response Systems are in classrooms, but it gave me an insight into how it can be used successfully as a means to formatively assess students. The articles I focused on dealt with a variety of topics including practical uses of the CRS, safe environments that develop from using the CRS, motivation and engagement aspects of the CRS, and the importance of formative assessments. I focused on all of these areas throughout my research project and discovered interesting insights of the CRS's capabilities.

METHODOLOGY

My AR capstone Methodology involved four consecutive units that alternated between no implementation of the CRS and implementation of the CRS. The implementation of the CRS was the treatment for this research project and was what I was testing. The non-treatment unit was used for comparison of data and consisted of normal, everyday teaching methods. The following research design describes various data collection methods such as pre-and post-surveys, pre- and post-tests, interviews, and journals. These were not part of the treatment but were all used to gather as much data as possible in order to compare the effectiveness of the CRS to normal everyday teaching methods without the use of the CRS. The research methodology for this project received an exemption by Montana State University's Institutional Review Board, and compliance for working with human subjects was maintained.

First Non-treatment Unit

For my first non-treatment unit, I collected data throughout the unit Elements, Compounds, & Mixtures. The unit began on December 6 and lasted three weeks. First, the students took a pre-survey, using the Likert scale, that included questions regarding how students felt about paper quizzes, paper review worksheets, review sessions with the mini white boards, and class discussions about how much knowledge was learned. Then, I assessed students' prior knowledge about elements, compounds, and mixtures through a 13 question pre-test, which I announced would not be graded. I gave this to the students in the form of a written paper with questions generated in multiple-choice style, questions referring to diagrams, and questions requiring short answer responses.

The next three weeks included PowerPoint notes, labs, worksheets, paper review lessons, and mini whiteboard review sessions. (A mini whiteboard consists of a white piece of paper inside a clear view sheet that the students can write on with an expo marker). I assessed student knowledge four times through this first non-treatment unit by using the following Classroom Assessment Techniques (CAT's): muddiest point, minute paper, 1-2-3's, and thumbs up, thumbs down, or thumbs to the side. I summarized and shared the results of the Muddiest Point and Minute Paper with the students the day after they were given, but I did not share the results of the 1-2-3's or thumbs report. I used these just to get a quick mental count of how many students were comfortable with that day's information.

Throughout this unit I kept a teacher journal where I reflected on CAT results for the entire class as well as notes about individual students who were struggling. I also reflected about what was working well and what was not working well throughout the

data collection process and non-treatment unit. My reflections assisted me in choosing students to interview, but scheduling and lack of time became a factor in my decisions. Full interviews were conducted with students who finished assignments early, and questions about the review sessions and CAT's were asked sporadically through the unit to random students.

Finally, after all review was given on the concepts of this unit, I gave the students a summative unit assessment, which was the post-test. Thirteen of these questions were repeated questions from the pre-test. The final data collection method for this unit was the post-survey, which was similar to the pre-survey for this unit. The tense of the questions were changed from future tense "what will" to past tense "what did".

First Treatment Unit

The treatment unit, Atoms & The Atomic Theory, began on January 11 and continued until January 28. I began this treatment by explaining to my students what the Classroom Response System was and demonstrated how it is used. I then administered a pre-survey (Likert scale) on paper about how the students felt about wanting to learn how to use this new technology and if they thought this technology would assist them in learning the material better and clearing up any misunderstood information. This was followed by a pre-test.

The next three weeks included PowerPoint notes, labs, worksheets, and review lessons with the CRS. Instead of using the CATs described above in the non-treatment, I used the CRS. This system gave me flexibility in how I delivered the assessment. I entered in specific questions regarding the content, such as "How many protons does an

atom of Nitrogen have?" I also used the CRS to ask questions such as "I understand the information learned in today's lab." Students would respond Yes or No on the student hand-held. Another use of the CRS to deliver a formative assessment was for the students to rate, 1-3, their understanding of that day's or the previous day's information. I also utilized an entire class period at the end of the unit to assess knowledge learned by having many types of questions prepared in a variety of styles. The CRS saved me time by scoring the questions, ranking them, and showing % of students who answered each question correctly. I was able to discuss correct and incorrect answers immediately with the students.

My reflections through this treatment were similar as that described in the non-treatment, but I also reflected on what I should have done differently with the CRS and what I need to do better next time. Interviews were set up as described above, but it was too difficult to get the same students to interview as before. This first treatment unit ended with a post-test and post-survey which both contained parallel questions from the pre-test and pre-survey.

Second Non-treatment Unit

This unit immediately followed the first treatment unit and consisted of a repeat of all the data collection components of the first non-treatment unit. However, the unit covered the Periodic Table and lasted from January 31 to February 16.

Second Treatment Unit

This unit immediately followed the second non-treatment unit and consisted of a repeat of all the data collection components of the first treatment unit. However, the unit covered Bonding & Chemical Reactions. It began February 17 and ended March 11.

Throughout this AR project, I searched for the answers to my research questions. The following matrix shows these questions along with the data collection techniques that were implemented to help answer them.

Table 1
Research Matrix

Research Questions	Pre- and Post-Surveys	Pre- and Post-Tests	Individual & Focus Group Interviews	CATs	Teacher Journal
I. How can a Classroom Response System assist students in clearing up misconceptions about concepts learned?	√	√	√	√	√
II. How can a Classroom Response System assist the teacher in assessing student knowledge learned through particular science units?	√	√	√	√	√
III. In what ways can the Classroom Response System (CRS) be used as an effective, organized assessment tool that provides immediate feedback to the teacher and students?	√	√	√	√	√
V. How can the integration of a Classroom Response System into science lessons help the teacher assess teaching strategies and help improve lesson delivery?		√		√	√

Student Demographics

I teach two periods of 8th grade Physical Science and four periods of 7th grade Life Science. I chose to use my 8th graders for my AR project because they are more mature than 7th graders, have more experience knowing our school expectations, and have more practice with how a typical middle school science unit is taught. I lost a few students during the treatment time, but I used data from 25 students in period 3 and 21 in period 6. This total number of 46 students was manageable with 27 boys and 19 girls and allowed a mix of responses from students with different academic abilities and backgrounds. This mix of students included one deaf female student, one partially deaf male student, one male student with an IEP, a male student who has been home schooled for the past several years, six students who are at the top of their class academically, one student who transferred from another town just before school started, one Hispanic girl whose mother speaks only Spanish, and several students who seem too intimidated to ask questions in front of their peers. The percentage of students at our school on the Free and Reduced Lunch Program is 25%, but I do not know how many of my students are included in this statistic.

Triangulation

Triangulation is defined in *Improving Schools Through Action Research* as "a method in which multiple forms of data are collected and compared to enhance the validity and credibility of a research study" (Hendricks, 2009, p. 80). I administered a mixture of qualitative and quantitative data collection methods. By using seven different qualitative and quantitative collection techniques, this action research project ensured valid results and appropriate comparisons.

To ensure the reliability of data results, all students experienced the same data collection techniques. The post-surveys were the same as the pre-surveys but with verb tense modifications such as “will” to “did”. Parallel questions on the pre- and post-tests were provided as well. A colleague who also teaches two periods of 8th grade science at my school reviewed my pre- and post-tests. She said that all four post-tests were of equal difficulty level, but the first treatment post-test on Atoms and the Atomic Theory seemed to be slightly more difficult due to having more free response questions than the others.

Data Collection Methods

To further emphasize the importance of triangulation, the following describes how specific data collection methods answered the project’s Research Questions. These methods are pre-survey, pre-test, individual and focus group interviews, CAT’s such as the Muddiest Point and the Minute Paper, teacher journal, post-test, and post survey.

The pre-surveys, Appendix A, are important because I wanted to understand how comfortable students felt about completing the CATs and reviewing with worksheets or by verbal question-and-answer sessions such as with mini white boards. I also wanted to know if they thought they understood the material better after these types of lessons or review sessions. I wanted to know if they felt the questions they had about the material had been answered so they understood it better. Also, for treatment units with the CRS, the project sought to discover if students were interested in using the system. Once the process was explained to them, were they helped in clearing up misconceptions? Would they receive quick feedback about what they did not quite understand?

The pre-tests, Appendix B, were given to determine what the students already knew about the topic. They were teacher-generated and consisted of a variety of different

types of questions such as multiple-choice, T/F, fill-in-the-blanks, and short answers. They were used as a baseline for where to begin the unit. In data analysis, the pre-test scores were compared to the post-test scores to find a percent gain in student knowledge.

Individual and focus group interviews allowed me to gather qualitative data about how students completed other data collection methods, such as pre-surveys and CATs. I performed four focus group and ten individual interviews at the end of the first treatment unit and three focus group and three individual interviews at the end of the second treatment unit. I felt that the interviews helped close the loop with all the other data collection methods. I was able to modify the questions at any time during the interview and was flexible in the types of questions I asked and when to throw in more probing questions.

The use of CAT's gave me vital data about what was learned in that day's or the previous day's lesson/lab and gave the students immediate feedback about what they did or did not understand about the lesson/lab. For example, I used the Muddiest Point to determine what part of the lesson on determining the number of electrons, protons, and neutrons was unclear. I also administered the Minute Paper after the Flame Test Lab, for example, to know the most important things the students learned in that lab and what their questions were after doing the lab. The next day, I followed up with my students the results of the CAT and answered the questions they had. For my treatment unit, I used the CRS to administer the CAT's by asking several questions regarding that day's or the previous day's lesson. After students responded with their hand-held device, results were projected on the screen. We immediately addressed any problems students had about that lesson and clarified any misconceptions right away.

In order for me to collect qualitative data about how I perceived my students' attitudes, amount of engagement, and level of enjoyment, I kept a teacher journal. I used it to keep notes on specific comments students made about a review session, such as "This is boring", or "This is fun; when can we do this again?" The teacher journal allowed me to write notes about how the closing-the-loop sessions, discussion of results, went after delivering CAT's and after CRS sessions. I reflected about what went well about this process and what did not go so well. It also gave me a means for recording reflections about all the other data collection methods and allowed me to comment on what I should do better next time and which students appeared to benefit from each closing-the-loop session. The average number of entries written per week over the 13-week data collection period was three. The entries consisted of simple statements regarding student observations, comparisons among numbers of students answering questions correctly with the CRS, and several paragraph entries that described particular days' observations.

The teacher-generated post-tests consisted of multiple-choice questions, fill-in-the-blanks, short answers, and problem-type questions. The post-test results were compared to the pre-test scores to determine amount of knowledge gained through the unit.

The final part of my data collection cycle was the Likert scale post-surveys. It complemented all the other data collection methods because it was the final word, other than some interviews, the students had for that non-treatment or treatment unit and because it allowed them to share their thoughts about how they were influenced by the

unit details. The data collected from these post-surveys as well as from all the other data collection methods permitted multiple directions into data analysis.

DATA ANALYSIS

The first part of the data analysis includes a summary of the patterns that were found from arranging the pre- and post-survey results. Each response was assigned a number so a comparison analysis could be made. The following shows the breakdown of the points: Strongly Agree = 4, Agree = 3, Disagree = 2, Strongly Disagree = 1. The point allocation for questions that were considered negative questions (I don't care…) were reversed. Table 2 summarizes the results according to themes. The last two survey themes in this table refer to the treatment: the implication of the CRS. The others are part of the non-treatment. See Appendix A for the complete results of these surveys.

Table 2
Likert Survey Results, (N = 46)

Survey Theme	Average Likert Score Pre-Surveys	Average Likert Score Post-Surveys	Average Likert Score For theme (pre- & post-)
Student views of using review worksheets	3.20	2.98	3.09
Student views of using the mini white boards	3.10	3.15	3.13
Student views of using Classroom Assessment Techniques (CATs)	3.25	3.15	3.20
Student views of using Classroom Response System (CRS)	3.45	3.25	3.35
Student views of how CRS helped the teacher	3.05	3.20	3.12

The questions on the non-treatment surveys that pertained to the review worksheets and mini white boards had very close average Likert scores of 3.09 and 3.12 respectfully. Similarly, the average Likert score for the CATs theme was 3.20 with the highest score, 3.40, being from the second non-treatment unit pre-survey and the lowest score, 3.00, being from the first non-treatment unit post-survey.

A few comments from the surveys about the mini whiteboards include the following: “It gets us into the groove of the test.” “I knew what types of questions would be on the test.” They are fun and helpful.” One of the students who disagreed that the mini white boards were helpful responded: “It helped but it was easy to get lazy and cheat.” I agree with all the students’ comments. This method of formative assessment is useful as a good review, but the process goes too quickly for me to tally up which students answered particular questions incorrectly.

From my observations and journaling, I noted that students were focused during follow-up explanations from CAT results. Many students even asked more questions. I had to end a lot of these sessions with some questions not being answered because their questions would pertain to future units. I wanted to focus my explanations on the current unit’s information. A few responses from students for these survey questions are: “Because she can see if we need some more work on a certain subject.” “I can ask questions on what I don’t get.” Sixty-seven percent of the responses were of this nature, and only one student wrote, “My question was never answered.”

In comparison to the previously mentioned formative assessment methods, the parallel questions about the CRS on the treatment unit surveys had slightly higher scores. The average Likert score for this theme was 3.35 with the highest score, 3.50, being from

the first treatment post-survey and the lowest score, 3.20, being from the second treatment post-survey. Consequently, 98.2% of the surveyed students either agreed or strongly agreed that the CRS was helpful and enjoying. This is not surprising to me due to the interest I observed from the students when using the CRS. Eighty-four percent of the students had survey comments about the CRS similar to the following: “It helped me know what I didn’t know.” “We go over questions I needed help on.”

My observations about the CRS sessions are similar to the students’ thoughts. Even though I was able to explain right or wrong answers or specific questions from students during CAT follow-up sessions and mini white board sessions, I could immediately explain results during CRS sessions in real time and project the results while the questions were still fresh in the students’ minds. The students were engaged throughout both non-treatment and treatment formative assessment methods, but the students seemed to have more fun during the CRS sessions and looked forward to using this method more than using CATs and mini white boards.

The next theme to be discussed is the student views on how the CRS helped the teacher. This breaks down into two questions: #4: *Questions used with the CRS helped my teacher recognize if the class needed to relearn/review a concept or a lesson* and #7: *I care that my teacher spends the time discussing correct and incorrect answers during sessions with the CRS.* Similar questions were placed on the first non-treatment pre-and post-surveys, but they had to do with the CATs instead of the CRS. However, this type of question was left off the pre- and post- surveys for the second non-treatment unit. In my teacher journal, I recorded that I did not think this question would be significant, and I wanted to add other questions that I felt would give me better results. The average value

of 3.12 for the treatment unit surveys shows that the students agree with me that the CRS is not just a fun and new learning tool, but it is a great teaching tool as well.

Even though I monitored the students closely while they were taking the surveys, and I discussed the importance of them taking these surveys seriously prior to administering each, a few outliers exist in the data. One outlier in the responses was for the only Strongly Disagree response for question #1 of the first non-treatment pre-survey, *Completing the review worksheets before the test on this unit will help me be more prepared for the test*. The student wrote, "Because it helps me a lot." Clearly, she meant to circle Strongly Agree instead of Strongly Disagree. Another student circled Strongly Agree for question # 11, *I don't care if my teacher spends time going over the results of our assessments*. Her response for why was, "It is good idea to spend time for to get right answer." Five of the seven students who circled Strongly Agree for this question also had a reason why that contradicted their choice.

It appears that listing a question in the negative is confusing to some middle school students, so I tried to avoid this type of question in the remaining surveys. However, question # 7, *I often do not care what I write on quick assessments like the Muddiest Point or on the Minute Paper*, was another question on the two non-treatment pre-surveys that was stated negatively. Four students circled Agree or Strongly Agree for this question. I even explained to the students that this question was stated negatively and that they were to be careful in answering. Unfortunately, this is one of the few questions that I did not ask the students to explain their answer choice.

Another outlier in the data is from question # 7 on the treatment unit surveys: *I care that my teacher will spend the time discussing correct and incorrect answers during*

sessions with the CRS. One student circled Strongly Disagree but wrote the following explanation: “If I get it wrong you will clear it up so I won’t make that mistake again.” This does not match this student’s answer choice. However, in the post-survey for that same unit, this student’s explanation matched her circled response of Strongly Agree.

The survey data shows that the students like using the four main types of formative assessments that were used in my study. The results of the use of the review worksheets, the mini white boards, the CATs, and the CRS only differed within 0.25 of a point. A quantitative conclusion about which one was preferred most over the others cannot be made due to the closeness of the values. It seems that the students like variety, and I may have different results if I used one or the other too often.

The Likert score averages and comments from students are consistent with my observations. I noted more excitement from the students when using the CRS than the other formative assessments. This is consistent with the data due to the student views of using the CRS has the highest point value for the breakdown of themes. One thing that surprised me as I sorted through the survey data is that the students agreed that the review assignments helped them. Whenever a review assignment is assigned, whether it consists of questions at the end of textbook chapters or a handout, many students complain about them and many often do not complete these for full credit. However, the data shows that the student perception is they are beneficial. One student wrote, “It helped me review.” Another student wrote, “I go over questions that I don’t know.” One of the students who disagreed about how helpful the review worksheets were gave the following reason, “You already know the material from the worksheets and PowerPoints.” Another student

wrote, “Because it helped me a lot.” Clearly, this is an outlier, and this student probably meant to circle Strongly Agree.

Another method that I used to analyze the Likert scale survey data was to look at total point values between the themes described above. For example, the student views of using the CRS received the highest points and the student views of CATs received the lowest points. The following data table summarizes these results.

Table 3
Likert Survey Results of Total Points, (N = 46)

Survey Pattern	Average Total Points	Points away from Average
Student views of using review worksheets	547.0	-18.9
Student views of using the mini white boards	550.4	-15.5
Student views of using Classroom Assessment Techniques (CATs)	539.2	-26.7
Student views of using Classroom Response System (CRS)	614.1	48.2
Student views of how CRS helped the teacher	578.8	12.9

The theme that exhibits the highest point value was the student views on the CRS. It received 67.1 more points than student views of review worksheets, 63.7 more points than the views on mini white boards, and 74.9 more points than the views on CATs. The total points from student views of how the CRS helped the teacher is only 12.9 points above the average. This is consistent with my own observations, because I felt that the CRS was very effective in assessing students and determining what concepts I needed to explain more than others. Some students did not know how to answer this type of question on the survey. For example, question #4 on the treatment unit surveys asked,

Questions used with the CRS will help my teacher recognize if the class needs to relearn a lesson. Even though 97.9% of the surveyed students agreed or strongly agreed with this question, a few students wrote question marks as their reason why, and one student wrote, "I don't know. Did they?" as his response to this question on all four of the treatment surveys. This indicates that some students may not recognize the changes being made in instructional strategies.

The following graph shows the percentage of students responding *strongly agree* or *agree* for the particular themes described previously in this analysis.

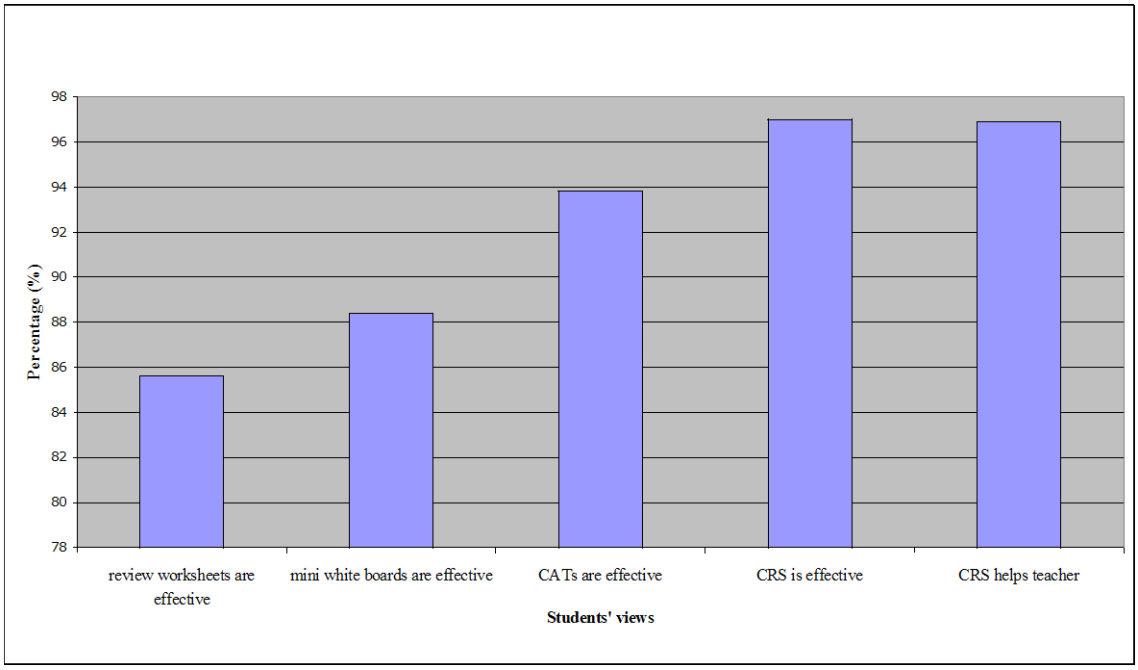


Figure 1. Student Agreement to Formative Assessment Methods, (*N* = 46).

It is clear that the largest percentage of students agree in some capacity that the CRS is more effective than the other methods of formative assessment. It is interesting that 97% of the students agree with me that the CRS helps the teacher by showing what concepts the students need help understanding. This data is also consistent with the

observations I documented with review assignments. Many students complain that they have to do review assignments, but no one complained about using the CRS during any of the times we used it in this study.

The second part of my data analysis includes a summary of the pre- and post-test scores. The following data table shows the average test scores as well as the breakdown of the average percent gain between units.

Data Table 4
Pre- and Post-Test Scores, (N=46)

Average Pre-Test Scores Non-treatment Units	Average Post-Test Score Non-treatment Units	Average % Gain Non-Treatment Units	Average Pre-Test Score Treatment Units	Average Post-Test Score Treatment Units	Average % Gain Treatment Units
48.43	86.43	37.95	49.75	83.85	34.23

A paired t-test was performed to compare post-test scores between the non-treatment (M= 86.43%, SD= 11.27) and treatment (M= 83.85%, SD= 12.09) units. The M refers to the average of the scores and the SD refers to the standard deviation. A t-test value of 0.0044 shows that there is little to no significant difference between these values. A t-test was also run to determine if there was a significant difference between the % gain between non-treatment and treatment units. The t-test value of 0.24 shows there is little to no significant difference between the % gain values. These results suggest that the CRS really does not have an effect on students' test scores. However, my 8th graders have been consistant all year with their test scores. It seems that A students will usually get A's on tests whether the review lessons were the same as past units or different, and lower level students will receive lower grades on tests. I would want to track my students for an

entire year to be able to determine if the CRS had a true effect on test scores. The following graph further emphasizes the closeness between values of average test scores and % gain. The % gain value is the percentage difference between pre-test and post-test for the same unit.

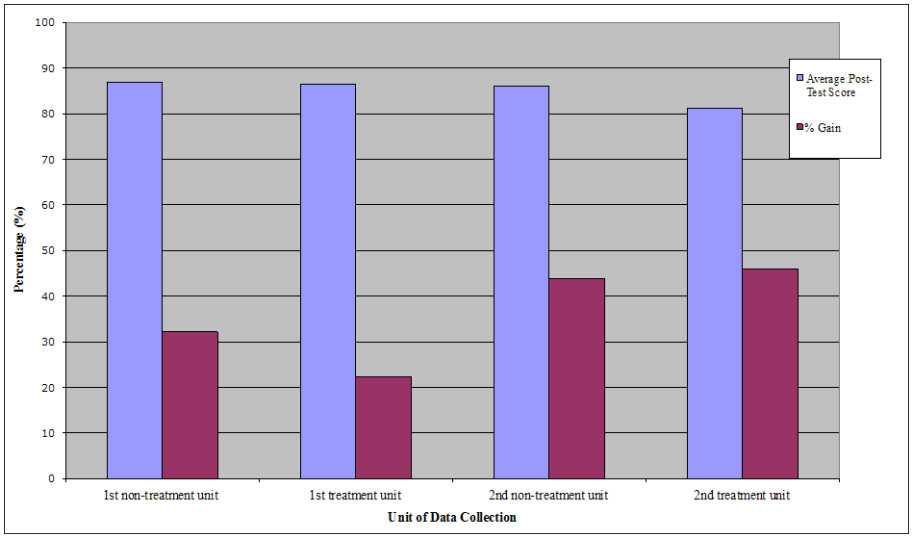


Figure 2. Post-Test Results and % Gains, (N = 46).

Even though the CRS did not have a significant affect on student test scores, it did have an affect on students' attitude towards delivery of formative assessments. The third set of data to be analyzed, the student interviews, emphasizes this point. I gave four focus group and ten individual interviews at the end of the first treatment unit as well as three focus group interviews and three individual interviews at the end of the second treatment unit.

At the end of the first treatment unit, the average rating (1 = not at all and 5 = really well) of how well the CRS helped the 18 interviewed students review for the unit's information was 4.3 out of 5. One student said, "The CRS helped narrow down what information to study." Another student said, "I remembered a lot from the CRS session."

When asked how often the CRS would help them review material, the results were, one to five times per week, after every lesson, just before quizzes and tests, and after new material is given. When asked between 1 and 5 (1 = not at all and 5 = really well) how much they enjoyed the CRS, the average was 4.75. One student's reasoning for why he answered 5 was, "You can go over a question and explain why it was right or wrong." Another student responded by saying, "It's easy to use and understand."

At the end of the 2nd treatment unit, the average rating for how much the CRS helped the 12 interviewed students was 4.2 out of 5. One of the students who responded with a 5 said, "It helps me know what I do or don't get." One of the two students who gave the lowest rating of 3 said, "A lot I knew, but a lot I didn't understand." Two of the 12 students interviewed thought that an advantage of using the CRS was its privacy. One student said, "No one knew who you were." The other said, "You can't get embarrassed if you get it wrong." Eight of the 12 students interviewed, 67%, said they preferred using the CRS than quick assessments like the Muddiest Point and Minute Paper. One student's reason was, "With the CRS, still had fun but learned a lot." Another student said, "It's easier. I don't really like to write much." A third student responded, "With the CRS, there is more variety of questions instead of what is easy or did not understand." Four other students said the CRS helped them.

All but two of the interviewed students said that the CRS helped them the most with reviewing or studying for the test. "It helped see questions I didn't understand" was one response. Another was, "Understanding what you did not know. It also helped the teacher know what to go over more." The two boys who did not answer in this manner said, "chemical equations" and "atoms and stuff" was what the CRS helped them the

most with. They were referring to specific content in the units. These interview results were consistent with the survey results. For the most part, the student perception is that all methods of formative assessments helped the students, but the CRS added an exciting and engaging element.

The final summary of the data analysis involves the discussion from my teacher journal. I wrote in the journal an average of three times per week. The relevant information that will be summarized are comments about CATs, notes about CRS sessions, and observations about students while they were using the CRS.

When I summarized the information gathered from the Muddiest Points and Minute Papers, I noted how time consuming it was to sort through the papers, find and tally themes, and prepare an overhead of results to share with the students. This took an average of about 30 minutes. Then, at least 15 minutes was spent the next day going over the results with the students, discussing reasons for particular responses, and answering questions the students had.

On the other hand, the CRS saved me time. I noted that it gave me "immediate satisfaction that I can correct students' misconceptions about a concept in real time." I preferred the ability to discuss correct and incorrect answers during a review session with the CRS. The students did not have to wait another day to get their questions answered. I could immediately document how many students missed particular questions. I discussed results that day, and then could give the same questions the next day to determine if the number of correct responses increased.

My notes also indicate how beneficial the CRS is in delivering poll questions to the students. For example, on March 2, a week before the second treatment unit test, I

polled the students on how comfortable they were with the information on bonding and chemical reactions. I told them to enter a 1 if they were not comfortable at all, a 2 if they were just ok, and a 3 if they were very comfortable. This data helped me plan the next week and how much more review they needed. Of the 40 students who entered a response, 8 were not comfortable with the information and 16 were just ok. As a result, I planned a review PowerPoint for the next day before I started the next lab. I noted that the next day one student shared, "I put a 1 yesterday because of this stuff." He was referring to naming ionic and covalent compounds. I asked him if he was more comfortable that day of the review. His response was, "Yes, I am now at a 3." The CRS tallies and graphs responses immediately, so this method of polling is more efficient than thumbs up/thumbs down or 1, 2, 3's where students respond with their fingers in front of them for only me to see.

I also noted student behaviors while using the CRS. During the first treatment unit CRS session, I noted that the students were too concerned with who had which receiver by observing when answers were posted on the board, and that this inhibited their concern with knowing how many students got the answer right or wrong. For the next sessions, I would blank my projector and only show the results after everyone had entered their response. In this way, the students focused more on listening to the explanations of correct answers.

I also commented every session that the students were excited to use the CRS. I made sure that I used it no more than two times a week so the interest level remained high. I also made notes about comments students made during or after these CRS sessions. When one student saw on the board that we were using the CRS to review for

the Atoms test he responded, “Yes! We get to use the clickers! Can I help you pass them out?” Another student responded, “Cool. I like using them. They are fun.” At the end of that session, another student said, “Can we stay in here next period and do this some more?”

After all students have finished a test for me on a testing day, I always try to ask them before they leave how the test was. I do this while the questions are still in their heads. After the Atoms test, I documented the following comments. “Would have been harder if we didn’t review. The CRS helped so it was easy.” This particular student received an 86% on this test and a 64% on the 2nd treatment post-test. These were lower than the 88% and 90% she received on the two non-treatment unit post-tests. Other comments were, “Easy.” “Easy because of the CRS.” And “We need to review with the CRS every week!” I then explained to the students that the next day we would begin a new unit, and we would not use the CRS at all during it. I noted that there were many moans and complaints from the students. These observations were consistent with the survey results for enjoying the CRS more than the other forms of formative assessment.

As the data shows, the CRS may have not helped to increase students’ post-test scores, but it did add an element of engagement into my science classroom. The results from the Likert surveys and student interviews were consistent with my teacher journal comments. Students enjoyed using the CRS and were able to clear up misconceptions immediately with the CRS. They liked the capability of showing results immediately and the teacher being able to discuss the reasons for the answers right away. The data collected from the students were also consistent with my journaling in that the CRS helps

the teacher understand what the students do not know or what needs to be re-taught or explained in another way.

INTERPRETATION AND CONCLUSION

The outcomes of my action research project satisfied my curiosity of how effective a CRS is as a means to formatively assess students. The data collected over four complete units was beneficial for accessing comparison of surveys and test scores as well as accessing student perception of the effectiveness of the CRS. Even though the quantitative data did not show as conclusive results as the qualitative data, both helped me answer my research questions.

The first question that I attempted to find the answer for through my project was how the CRS would help clear up students' misconceptions about particular concepts. From a teacher's view, the CRS was useful for students to share their answers confidentially, and then immediately have feedback through discussions on correct and incorrect responses. The students also had the added benefit of asking more questions if they were still confused during these sessions. The information that was gathered from the surveys supported my thoughts about how the CRS helped the students with misconceptions. As the survey data indicates, 95% of the students agreed or strongly agreed that they were able to clear up misconceptions about the content after reviewing with the CRS.

The CRS also assisted me, as the teacher, to assess student knowledge learned through particular science units. I was able to deliver questions and access numbers of correct and incorrect responses immediately. Therefore, I was able to explain questions

and answers right away while the students still remembered their choices. Through this project, I used the CRS to ask just a few questions about one particular concept to assess student knowledge learned that day or the previous day as well as ask numerous questions as a review for that unit's information. Since all data was collected and reported in real-time, I was able to discover student understanding immediately. Students were perceptive that the CRS was helpful for the teacher as well. I was pleased that this student perception was 97.9%.

I can conclude that the CRS can be used as an effective, organized assessment tool that provides immediate feedback to the teacher and students. Survey results showed that students agreed to some level that the CRS was an effective method of formative assessment due to the 3.35 average Likert score. Interviews and my observations were reliable indicators of this conclusion as well. At the end of the data collection period, 67% of the interviewed students said they preferred the CRS over the other quick assessments, and the average rating for how the CRS helped them was 4.2 out of 5. I saved time in the set-up, implementation, and discussion of particular concepts whenever I used the CRS as a means to formatively assess my students. I immediately saw results of the students' answers, and students received immediate clarification and discussion of correct and incorrect responses. The organized manner of the CRS gathering the responses and projecting the results was more efficient for me than gathering and reading 46 different papers or trying to read 25 separate mini-whiteboards at once.

Finally, the integration of the CRS into science lessons helped me as a teacher assess my teaching strategies and helped improve lesson delivery. I was able to use the CRS to ask a few questions about that day's or the previous day's content and determine

the percentage of students who did and did not understand the material. For example, the day after I taught the students about ionic bonding, I asked the following question: *Which pair of atoms is most likely to form an ionic compound?* Since 33% of the students chose an incorrect answer, I re-taught the material with a new PowerPoint and a new practice worksheet. The next day the percentage of students who answered this question incorrectly (I used the same question but changed the choices) was only12.5%. The CRS did not have an effect on students' post-test scores throughout the treatment period, but the ability to use the CRS to determine student understanding during or after lessons was more valuable to me as the teacher.

VALUE

The key to being a successful middle school teacher is finding and implementing teaching strategies that engage the students and make them more excited to come to class to learn. Even though the CRS did not have a significant effect on the students' post-test scores through the four units that were part of my research, it did have a significant impact on engaging my students. Ninety-eight percent of the surveyed students either agreed or strongly agreed that the CRS was helpful and enjoyable despite the average post-test score for the treatment units was 2.58% less than the average post-test score for the non-treatment units. The students at our school have not had much exposure to technology except for computers in the computer lab and data collection probes in our science labs. Therefore, the implementation of the CRS was very exciting for them, and they looked forward to using it. I did not formerly plan to include an engagement

component to my research design, but it showed up in my data anyway. In this way, the CRS helped me be a more successful middle school teacher.

When I initially set up my research project, I planned to track particular students through the four units. However, I was not able to do this due to time and convenience. It was difficult finding the time during class to interview the selected students, and I did not have the same lunch period as my 8th graders. Also, a few of the students I wanted to track did not have consistent attendance and missed at least one pre- or post-survey or CRS session. If I were to repeat this project, I would be more diligent in tracking particular students.

When I use the CRS with students in the future, I will compare unit test scores over the course of a school year with all my classes. This will allow me to have more data to determine if the CRS has an effect on student unit test (post-test) scores. I only used the CRS in two units this year, and the results were not as I expected. If I was able to collect data throughout one entire school year, the data on post-test scores would be more valid.

Also in the future, I will use the CRS to assess prior knowledge at the beginning of units, to understand how much of the content is being retained throughout the unit, to review concepts at the end of particular lessons, and to review before the unit tests. In order to keep the excitement level high, I must continue to integrate a variety of teaching strategies such as the Muddiest Point and Minute Paper quick assessments as well as traditional review worksheets. I want to keep my students engaged, but I believe that if the CRS is used too frequently, more than two times per week, the students may lose interest in it. Also, if the students are more focused on using the CRS as a competetion

when all results are projected, the goals of using the system will not be met. Therefore, careful monitoring of the projected information must be made and careful thought must be put into the right times to project the information to the whole class.

As our schools are preparing for students to be more successful in the 21st century, teachers need to bring in more innovative techniques to incorporate technology. I feel that the CRS is one such technique. I only used it the past few months as a formative assessment delivery tool, but it has more capabilities. Students can use the CRS hand held devices to take assessments such as end of unit tests. The answers are scored and recorded in the program set up on the teacher's computer. In this way, students get practice taking tests set up in ways other than paper and pencil. Students will gain experience using technology for taking tests. This exposure will prepare them for college entrance exams and other exams that are entirely delivered by technology. Also, they may feel more comfortable in jobs that require them to be proficient in using various types of technology.

My action research not only gave me insight to how effective the CRS is as a means of formative assessment, but it also gave me an understanding of how my students care about their education. My perception was that all my students involved with my project took the data collection methods seriously. Many comments that I heard or read led me to the conclusion that my students realize that I care about how well they are learning and that I want them to succeed. They not only considered the CRS to be a fun, interactive learning tool, but they also saw it as a way for me to help them learn. In my future teaching, I will remember this reflection and consider the students' thoughts and opinions as I plan lessons that meet their educational needs.

REFERENCES CITED

Beatty, I., Feldman, A., Leonard, W., Gerace, W., St. Cyr, K., Lee, H., & Harris, R. (2008). Teacher Learning of Technology-Enhanced Formative Assessment. *Scientific Reasoning Research Institute University of Massachusetts Amherst*. Retrieved March 31, 2010, from http://www.eric.ed.gov.proxybz.lib.montana.edu/ERICDocs/data/ericdocs2sql/content_storage_01/0000019b/80/3e/8c/85.pdf.

Beatty, I., & Gerace, W. (2009). Technology-Enhanced Formative Assessment: A Research-Based Pedagogy for Teaching Science with Classroom Response Technology. *Journal of Science Education Technology*, *18*, 146-162.

Bruff, D. (2009). Multiple-Choice Questions You Wouldn't Put on a Test: Promoting Deep Learning Using Clickers. *Essays on Teaching Excellence: Towards the Best in the Academy*. *21*(4). Retrieved November 23, 2010, from http://cft.vanderbilt.edu/docs/classroom-response-system-clickers-bibliography/.

Clark, T., Englert, K., Frazee, D., Shebby, S., & Randel, B. (2009). *Assessment: A McREL Report Prepared for Stupski Foundation's Learning System*. Denver, CO: Mid-continent Research for Education and Learning.

Hendricks, C. (2009). *Improving Schools Through Action Research: A Comprehensive Guide for Educators*. New Jersey: Pearson.

Kenwright, K. (2009). Clickers in the Classroom. TechTrends: Linking Research and Practice to Improve Learning. *53*(1), 74-77.

McManus, S. (2006). Attributes of Effective Formative Assessment. Retrieved November 23, 2010, from NC Department of Pulic Instruction, http://www.ncpublicschools.org/docs/accountability/educators/fastattributes04081.pdf.

Suchman, E., Uchiyama, K., Smith, R., & Bender, K. (2006). Evaluating the Impact of a Classroom Response System in a Microbiology Course. *Microbiology Education*, *7*, 3-11. Retrieved November 23, 2010, from http://cps.wiki.hoover.k12.al.us/Research.

Tuttle, H. G. (2008). Part 1: Digital Age Assessment. *Technology & Learning*, *28*(9), 22-24. Retrieved March 31, 2010, from General OneFile via Gale: http://find.galegroup.com.proxybz.lib.montana.edu/gtx/start.do?prodId=ITOF&userGroupName=mtlib_1_1123

Wentzel, K. R., & Wigfield, A. (2007). Motivational Interventions that Work: Themes and Remaining Issues. *Educational Psychologist*. *42*(4), 261-271. Retrieved April 3, 2010, from http://pdfserve.informaworld.com/23266_751311089_788105431.pdf

Yourstone, S. A., Kraye, H. S., & Albaum, G. (2008). Classroom Questioning with Immediate Electronic Response: Do Clickers Improve Learning? *Decision Sciences Journal of Innovative Education*. *4*(1), 75-88. Retrieved April 21, 2011, from http://www.et.kent.edu/fpdc-db/files/operations%20management%20Learning%20Outcomes.pdf

APPENDICES

APPENDIX A

LIKERT SURVEY RESULTS

Table A1
Pre-Survey: 1st Non-Treatment Unit Elements, Compounds, and Mixtures

Pre-Survey Question	Likert Scale Response Strongly Agree	Likert Scale Response Agree Score	Likert Scale Response Disagree Score	Likert Scale Response Strongly Disagree	Likert Scale Total Score
1. Completing review worksheets before the test on this unit will help me be more prepared for the test.	88	63	0	1	152
2. I will study corrected review worksheets to prepare for quizzes and tests.	44	75	14	1	134
3. Using the mini white boards to review at the end of lessons will help me realize what I do not understand.	28	84	10	0	127*
4. Using the mini white boards to review will help me be more prepared for the unit test.	40	84	8	0	134.5*
5. I will be able to clear up any misconceptions after we review together with the mini white boards.	36	81	6	0	123
6. The Muddiest Point assessment will help me recognize what I don't understand about a particular lesson.	56	81	4	0	141
7. The Minute Paper will help my teacher recognize if the class needs to relearn a lesson.	60	69	8	0	139.5*
8. I feel comfortable answering the Muddiest Point or the Minute Paper truthfully.	76	69	2	0	147
9. I often do not care what I write on the Muddiest Point or on the Minute Paper.	2	6	78	48	136.5*
10. I prefer to move on to the next lesson without reviewing or without the lesson being taught	1	18	66	28	118*

again.					
11. I don't care if my teacher spends time going over the results of our assessments.	7	12	54	40	113

*Students who circled two responses for the same question received an average score for that question.

Table A2
Post-Survey: 1st Non-Treatment Unit Elements, Compounds, and Mixtures

Post-Survey Question	Likert Scale Response Strongly Agree	Likert Scale Response Agree Score	Likert Scale Response Disagree Score	Likert Scale Response Strongly Disagree	Likert Scale Total Score
1. Completing review assignment before the test on this unit helped me prepare more for the test.	64	72	2	0	138
2. I studied review material to prepare for the test.	36	60	24	1	121
3. Using the mini white boards to review helped me realize what I did not understand.	76	48	12	0	136
4. Using the mini white boards to review helped me be more prepared for the unit test.	80	51	8	0	139
5. I was able to clear up any misconceptions after we reviewed together with the mini white boards.	52	57	16	0	127.5*
6. The Muddiest Point assessment at the beginning of the unit and the four question assessment last week on the white board helped my teacher recognize if the class needed to relearn a lesson.	56	66	2	1	127.5*
7. I would rather move on to the next lesson without reviewing information at the beginning of class.	0	27	38	12	77
8. I care if my teacher spends time going over the results of our assessments.	56	72	2	2	132

Table A3
Pre-Survey: 1st Treatment Unit Atoms

Pre-Survey Question	Likert Scale Response Strongly Agree	Likert Scale Response Agree Score	Likert Scale Response Disagree Score	Likert Scale Response Strongly Disagree	Likert Scale Total Score
1. Reviewing with the CRS before the test on this unit will help me be more prepared for the test.	104	57	0	0	161
2. I will be able to clear up any misconceptions about the content after we review together with the CRS.	80	66	6	0	152
3. Sessions with the CRS will help me recognize what I don't understand about a particular lesson.	92	60	4	0	156
4. Questions used with the CRS will help my teacher recognize if the class needs to relearn a lesson.	92	66	0	0	158
5. I will feel comfortable answering questions truthfully with the CRS.	108	54	0	0	162
6. I prefer to move on to the next lesson without reviewing or without discussing what was learned in the previous lesson.	20	21	36	14	91
7. I care if my teacher spends time going over the results of our assessments.	80	66	2	1	149
8. I care that my teacher will spend the time discussing correct and incorrect answers during sessions with the CRS.	92	63	0	0	155
9. Using the Classroom Response System will help me learn the content better.	84	57	6	0	147
10. I will enjoy using the Classroom Response System.	132	30	0	0	162

Table A4
Post-Survey: 1st Treatment Unit Atoms

Post-Survey Question	Likert Scale Response Strongly Agree	Likert Scale Response Agree Score	Likert Scale Response Disagree Score	Likert Scale Response Strongly Disagree	Likert Scale Total Score
1. Reviewing with the CRS before the test on this unit helped me be more prepared for the test.	116	45	2	0	163
2. I was able to clear up any misconceptions about the content after we reviewed together with the CRS.	88	57	6	0	153.5
3. Sessions with the CRS helped me recognize what I didn't understand about a particular lesson or concept.	108	48	2	1	159
4. Questions used with the CRS helped my teacher recognize if the class needed to relearn a lesson or concept.	92	54	2	1	149
5. I felt comfortable answering questions truthfully with the CRS.	128	39	0	0	167
6. I would have preferred to move on to the next lesson without reviewing or without discussing what was learned in the previous lesson.	8	12	44	16	81.5
7. I cared that my teacher spent the time discussing correct and incorrect answers during sessions with the CRS.	100	57	2	0	159
8. Using the Classroom Response System helped me learn the content better.	84	63	6	0	153
9. I enjoyed using the Classroom Response System.	120	42	2	0	164

Table A5
Pre-Survey: 2nd Non-treatment Unit The Periodic Table

Pre-Survey Question	Likert Scale Response Strongly Agree	Likert Scale Response Agree Score	Likert Scale Response Disagree Score	Likert Scale Response Strongly Disagree	Likert Scale Total Score
1. Completing review worksheets before the test on this unit will help me be more prepared for the test.	48	93	0	1	144.5*
2. I will study corrected review worksheets to prepare for quizzes and tests.	56	75	10	0	143.5*
3. Using the mini white boards to review will help me be more prepared for the unit test.	68	69	8	0	147.5*
4. I will be able to clear up any misconceptions after we review together with the mini white boards	68	60	14	0	144.5*
5. The Muddiest Point & Minute Paper quick assessments will help me recognize what I don't understand about a particular lesson.	60	75	4	1	145*
6. I feel comfortable answering quick assessments like the Muddiest Point or the Minute Paper truthfully.	84	63	2	0	154*
7. I often do not care what I write on quick assessments like the Muddiest Point or on the Minute Paper.	8	9	42	18	79.5*
8. Review worksheets/assignments will help me throughout this unit better than the Classroom Response System.	16	27	34	15	92*
9. Quick paper assessments like the Muddiest Point and Minute Paper will help the teacher	16	39	28	9	99.5*

understand what I do not understand about particular information better than the CRS.					
10. Using the mini-whiteboards to review at the end of this unit will help me more than the CRS.	4	21	46	10	91*

Table A6
Post-Survey: 2nd Non-treatment Unit The Periodic Table

Post-Survey Question	Likert Scale Response Strongly Agree	Likert Scale Response Agree Score	Likert Scale Response Disagree Score	Likert Scale Response Strongly Disagree	Likert Scale Total Score
1. Completing the review assignment before the test on this unit helped me be more prepared for the test.	56	87	2	0	145
2. I studied the corrected review assignment to prepare for the test.	24	57	32	3	116
3. Using the mini white boards to review helped me be more prepared for the unit test.	72	69	6	0	147
4. I was able to clear up any misconceptions after we reviewed together with the mini white boards	52	75	10	0	137
5. The Muddiest Point & Minute Paper quick assessments helped me recognize what I didn't understand about a particular lesson or topic.	36	90	8	1	135
6. I felt comfortable answering quick assessments like the Muddiest Point or the Minute Paper truthfully.	88	66	0	0	154
7. The review assignment helped me prepare for this test better than the Classroom Response System (CRS) helped me prepare for the last test.	24	39	32	8	108
8. Quick paper assessments like the Muddiest Point and Minute Paper helped the teacher understand what I did not understand about particular information better than the CRS did last unit.	28	45	24	9	108.5*

9. Using the mini-whiteboards to review at the end of this unit will helped me be more prepared for the test better than the CRS helped me prepare for the last test.	20	30	44	6	100

Table A7
Pre-Survey: 2nd Treatment Unit Bonding and Chemical Reactions

Pre-Survey Question	Likert Scale Response Strongly Agree	Likert Scale Response Agree Score	Likert Scale Response Disagree Score	Likert Scale Response Strongly Disagree	Likert Scale Total Score
1. Reviewing with the CRS before the test on this unit will help me be more prepared for the test.	92	63	0	0	155
2. I will be able to clear up any misconceptions about the content after we review together with the CRS.	72	69	2	0	148*
3. Sessions with the CRS will help me recognize what I don't understand about a particular lesson.	76	66	4	0	148.5*
4. Questions used with the CRS will help my teacher recognize if the class needs to relearn a lesson.	44	72	6	0	124.5*
5. I will feel comfortable answering questions truthfully with the CRS.	120	42	0	0	162
6. I prefer to move on to the next lesson without reviewing or without discussing what was learned in the previous lesson.	4	21	34	18	77
7. I care that my teacher will spend the time discussing correct and incorrect answers during sessions with the CRS.	80	60	2	1	143
8. Using the Classroom Response System will help me learn the content better.	76	66	4	0	146
9. I will enjoy using the Classroom Response System throughout this unit.	96	54	0	0	152.5*

Table A8
Post-Survey: 2nd Treatment Unit Bonding and Chemical Reactions

Post-Survey Question	Likert Scale Response Strongly Agree	Likert Scale Response Agree Score	Likert Scale Response Disagree Score	Likert Scale Response Strongly Disagree	Likert Scale Total Score
1. Reviewing with the CRS before the test on this unit helped me be more prepared for the test.	92	59	0	0	151
2. I was able to clear up any misconceptions about the content after we reviewed together with the CRS.	68	71	2	0	144.5*
3. Sessions with the CRS helped me recognize what I did not understand about a particular lesson.	81	68	2	0	151
4. Questions used with the CRS helped my teacher recognize if the class needed to relearn/review a concept or a lesson.	74	67	0	0	141
5. I felt comfortable answering questions truthfully with the CRS.	121	38	0	0	156
6. I prefer to move on to the next lesson without reviewing or without discussing what was learned in the previous lesson.	8	22	38	14	84
7. I care that my teacher spends the time discussing correct and incorrect answers during sessions with the CRS.	89	59	2	0	150
8. Using the Classroom Response System helped me learn the content better.	76	62	2	0	140
9. I enjoyed using the CRS throughout this unit.	110	46	0	0	156

APPENDIX B

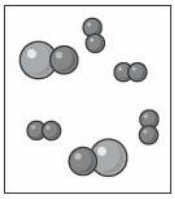
PRE-TESTS

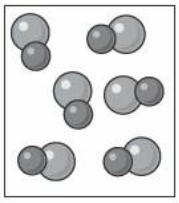
Pre-Test: 1st Non-treatment Unit: Elements, Compounds, & Mixtures

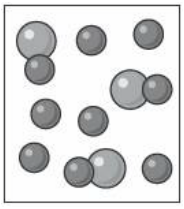
1. Which of the following is not an element?
    a. Brass
    b. Neon
    c. Hydrogen
    d. Iron

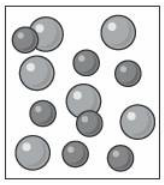
2. What is the smallest particle of the element gold (Au) that can still be classified as gold?
    a. atom
    b. molecule
    c. neutron
    d. proton

3. Which of the following illustrations represents a pure substance?

a. 

c. 

b. 

d. 

4. Which formulas represent compounds?
    a. O_2, H_2O_2
    b. CO_2, H_2O
    c. H_2, CO_2
    d. H_2, O_2

5. If different kinds of atoms are represented by different colored dots, which picture represents a sample of a compound?

a.

b.

c.

d.

6. If different kinds of atoms are represented by different colored dots, which picture below represents a mixture?

a.

b.

c.

d.

7. Which of the following is a compound?
    a. oxygen
    b. water
    c. nitrogen
    d. air

8. Which symbol represents carbon?
    a. CA
    b. N
    c. K
    d. C

9. A mixture of powdered iron and sulfur reacts chemically when heated. What will be formed?
    a. a single element
    b. two other elements
    c. a solution
    d. a compound

10. Carbon dioxide is
    a. an element.
    b. a compound.
    c. a solution.
    d. a mixture.

11. An unknown element that is malleable, shiny, and conducts electricity would most likely be classified as
    a. a nonmetal.
    b. a salt.
    c. a metal.
    d. a metalloid.

12. Explain in detail why matter is classified as pure substances (elements and compounds) and mixtures (solutions, colloids, and suspensions).

13. Diagram the difference between homogenous mixtures and heterogeneous mixtures. Be specific.

1st Treatment Unit Pre-Test: Atoms

1. The smallest part to which an element can be divided yet still be that element is
    a. A molecule
    b. An electron
    c. A proton
    d. An atom

2. The center of an atom
    a. Is the electron cloud
    b. Is the nucleus
    c. Contains protons and electrons
    d. Contains protons only

3. The atomic number
    a. Is the same for all elements
    b. Is the sum of protons and neutrons in an atom
    c. Is the sum of protons and electrons in an atom
    d. Is the number of protons in an atom

4. _____ have a positive charge.
    a. Protons
    b. Neutrons
    c. Electrons
    d. None of the above

5. The most reactive elements are located in _____ of the Periodic Table.
    a. Group 1
    b. Group 11
    c. Group 8
    d. Group 18

6. The chemical symbol for iron is
    a. I
    b. In
    c. F
    d. Fe

7. The number of electrons equals the number of protons in electrically neutral atoms.
    a. True
    b. False

8. An atom can never become charged.
    a. True b. False
9. How many protons does an atom of Carbon have? _____

10. How many electrons does an atom of Carbon have? _____

11. What is the mass number of Carbon? _____

12. How many neutrons does an atom of Lithium have? _____

13. The element with atomic number 18 has _____ protons in each atom.

14. A neutral atom of the element with atomic number 2 has _____ neutrons.

15. Which subatomic particles are found in the nucleus of an atom?

Pre-Test: 2nd Non-Treatment Unit The Periodic Table

1. An element that is a very reactive gas is most likely a member of the
    a. Noble gases
    b. Alkali metals
    c. Halogens
    d. Actinides

2. Which statement is **true**?
    a. Alkali metals are generally found in their uncombined form.
    b. Alkali metals are Group 1 elements.
    c. Alkali metals should be stored under water.
    d. Alkali metals are unreactive.

3. Which statement about the periodic table is **false**?
    a. There are more metals than nonmetals
    b. The metalloids are located in Groups 13 through 16.
    c. The elements at the far left of the table are nonmetals.
    d. Elements are arranged by increasing atomic number.

4. One property of most nonmetals is that they are
    a. Shiny
    b. Poor conductors of electric current
    c. Flattened when hit with a hammer
    d. Solids at room temperature

5. Which is a **true** statement about elements?
    a. Every element occurs naturally.
    b. All elements are found in their uncombined form in nature
    c. Each element has a unique atomic number
    d. All of the elements exist in approximately equal quantities

6. Fill out the following data table:

Element Name	Group Number	Number of protons	Number of electrons	Number of valence electrons
Sodium				
Neon				
Chlorine				
Aluminum				

7. Explain what valence electrons are and what is significant about them.

8. Describe two trends as you move from left to right on the Periodic Table.

9. Explain what is most significant about the noble gases.

10. Explain why hydrogen is so reactive.

Pre-Test: 2nd Treatment Unit Bonding & Chemical Reactions

1. The smallest part of a covalently bonded compound (such as H_20) is
    a. An atom
    b. A molecule
    c. A nucleus
    d. A proton

2. Which of the following best describes why ionic bonds occur?
    a. Atoms have to share electrons.
    b. Atoms have to make electrons disappear.
    c. One or more protons transfer from one atom to another.
    d. One or more valence electrons transfer from one atom to another**.**

3. The joining of atoms to form new substances is a definition for
    a. Chemical reactions
    b. Chemical bonding
    c. Physical changes
    d. Physical properties

4. Electrons free to move throughout a material are associated with a(n)
    a. Covalent bond
    b. Ionic bond
    c. Metallic bond
    d. None of the above

5. Which of the following describes what happens when an atom becomes an ion with a 2- charge?
    a. The atom gains 2 protons.
    b. The atom loses 2 protons.
    c. The atom gains 2 electrons.
    d. The atom loses 2 electrons.

6. The properties of malleability and ductility are associated with which type of bonds?
    a. Ionic
    b. Covalent
    c. Metallic
    d. None of the above

7. What type of element tends to lose electrons when it forms bonds?
    a. Metal
    b. Metalloid
    c. Nonmetal
    d. Noble gas

8. Which pair of atoms can form an ionic bond?

a. Sodium and neon
b. Fluorine and chlorine
c. Potassium and fluorine
d. Sodium and potassium

9. What is the correct formula for magnesium fluoride?
   a. Mg_2F
   b. MgF_2
   c. MgF
   d. Mg_2F_2

10. Which of the following is a covalent compound?
   a. KI
   b. $CaCl_2$
   c. NO
   d. Fe_2O_3

11. Substances that speed up chemical reactions are
   a. Inhibitors
   b. Bubbles
   c. Catalysts
   d. Products

12. Which of the following equations is balanced correctly?
   a. $3\ Fe + 3O_2 \text{ ----------> } 2Fe_2O_3$
   b. $LiO_2 \text{ ----------> } 4Li + O_2$
   c. $P + O_2 \text{ ----------> } 2P_2O_5$
   d. $Br_2 + 2NaI \text{ ----------> } I_2 + 2NaBr$

13. What type of reaction is the following equation? $N_2 + 3H_2 \text{ ---------> } 2NH_3$
   a. Decomposition
   b. Single-replacement
   c. Double-replacement
   d. Synthesis

14. Which of the following is not a clue to a chemical reaction?
   a. Change of state
   b. Gas bubbles formed
   c. Precipitate formed
   d. Decrease in temperature

15. How many atoms of nitrogen are in the following formula? $Fe(NO_3)_2$
   a. 1
   b. 2
   c. 3
   d. 4

16. What type of reaction is the following equation? NH_4OH ----------> NH_3 + H_2O
    a. Synthesis
    b. Decomposition
    c. Single-replacement
    d. Double-replacement

17. Students measured 2.0 g of baking soda and 5.0 g of vinegar. They mixed them together in a beaker and watched as bubbles formed. The mass of the resulting liquid is 6.7 g. Based on the law of conservation of mass, what should the mass of the products be?
    a. 5.0 g
    b. 6.7 g
    c. 7.0 g
    d. 10.0 g

APPENDIX C

PRE- AND POST-TESTS SCORES

Table C1
Compilation of Pre- and Post-Test Scores and % Gains per Unit

Student	Pre-Test 1	Post-Test 1	% Gain	Pre-Test 2	Post-Test 2	% Gain	Pre-Test 3	Post-Test 3	% Gain	Pre-Test 4	Post-Test 4	% Gain
1	53	88	35	70	86	16	59	88	29	47	87	40
2	Na	90	19	63	90	27	62	79	17	47	82	35
3	76	95	19	63	94	31	41	97	56	47	90	43
4	47	88	41	53	86	33	35	90	55	29	64	35
5	35	53	18	53	44	-9	32	98	66	18	76	58
6	24	65	41	47	73	26	50	69	19	41	74	33
7	65	90	25	60	94	34	41	80	39	24	84	60
8	71	88	17	57	86	29	56	88	32	35	90	55
9	Na	76	Na	40	70	30	29	74	45	24	74	50
10	65	87	22	83	92	9	35	85	50	Na	70	Na
11	35	93	58	33	76	43	41	91	50	35	74	39
12	88	96	8	80	92	12	38	91	53	35	86	51
13	47	82	35	90	96	6	74	94	20	35	89	54
14	76	100	24	83	98	15	68	99	31	41	98	57
15	47	97	50	77	94	17	53	98	45	29	96	67
16	47	95	48	53	98	45	50	100	50	41	88	47
17	65	88	23	47	88	41	32	88	56	47	83	36
18	18	56	38	40	64	24	29	46	17	35	52	17
19	41	Na	Na	47	58	11	22	68	46	41	57	16
20	53	79	26	53	90	37	50	88	38	41	82	41
21	76	90	14	37	94	57	59	95	36	6	78	72
22	Na	78	Na	77	70	-7	32	68	36	41	67	26
23	12	80	68	40	72	32	47	88	41	53	78	25
24	71	91	20	80	82	2	47	90	43	35	82	47
25	Na	91	Na	83	90	7	32	84	52	47	82	35
26	59	96	37	63	98	35	47	95	48	47	94	47
27	59	93	34	77	92	15	38	96	58	24	95	71
28	35	79	44	47	84	37	28	87	59	35	84	49
29	35	77	42	67	78	11	50	72	22	24	76	52
30	53	95	42	77	92	15	43	92	49	24	86	62
31	29	81	52	73	85	12	32	83	51	35	66	31
32	47	96	49	80	100	20	41	88	47	18	82	64
33	47	88	41	53	72	19	26	64	38	47	57	10
34	47	85	38	70	98	28	66	90	24	35	94	59
35	59	74	15	67	78	11	29	70	41	29	65	36
36	71	97	26	73	98	25	59	100	41	59	94	35
37	65	93	28	47	86	39	37	76	39	29	80	51
38	76	88	12	73	94	21	41	86	45	35	89	54
39	71	96	25	83	94	11	44	94	50	41	86	45
40	Na	86	Na	67	88	21	24	94	70	18	82	64

41	59	75	16	60	78	18	Na	63	Na	47	71	24
42	53	87	34	77	96	19	32	80	48	29	72	43
43	Na	98	Na	90	98	8	35	98	63	41	90	49
44	71	98	27	87	100	13	56	100	44	59	100	41
45	65	97	32	63	94	31	41	96	55	24	98	74
46	59	98	39	40	96	56	32	91	59	24	94	70
Average	54.3	86.96	32.05	63.98	86.43	22.46	42.56	85.89	43.84	35.51	81.26	46.00

APPENDIX D

INTERVIEW QUESTIONS

1st Treatment Unit Interview Questions

1. Did you study on your own for the quiz?
2. Did you remember a lot of the information from the PowerPoint notes?
3. Did the CRS session help you review the information? Rate between 1 and 5 how much it helped. 1 = not at all; 5 = very much
4. How often would the CRS session help you review material?
5. Rate between 1 and 5 how much you enjoy the CRS. 1= not at all; 5 = very much

2nd Treatment Unit Interview Questions

1. What are some advantages of using the CRS?
2. What are some disadvantages of using the CRS?
3. What were some advantages of quick assessments like the Muddiest Points and Minute Paper?
4. What were some disadvantages of quick assessments like the Muddiest Points and Minute Paper?
5. Did you prefer doing quick assessments like the Muddiest Point and Minute Paper more than the CRS? Explain why or why not.
6. Rate between 1 and 5 how much the CRS helped you during the two units that we used them. 1 = not at all; 5 = very much
7. What did the CRS help you the most with?
8. What did the Muddiest Points and Minute Papers help you the most with?