A DESIGN STUDY OF A STUDENT RESPONSE SYSTEM IN HIGH SCHOOL CHEMISTRY INSTRUCTION

by

JOE COZART

(Under the direction of J. Steve Oliver)

ABSTRACT

Teachers have verbal and non-verbal tools at their disposal to formatively assess students during instruction. However, it is difficult to assess all students during instructional time. Student response systems (SRS) are becoming increasingly available in the K-12 setting and offer promise in enabling teachers to quickly gather information from more students while teaching. The purpose of this design study was to examine how high school chemistry teachers could use student response systems to facilitate cognitive engagement in their students. A rubric was developed to analyze student responses, both verbal and electronic, as either high or low cognitive engagement. Analysis showed that teachers require training support on using the SRS and several weeks worth of time to adjust teaching to use the system in a way that lets students show cognitive engagement. Often, students were best able to show cognitive engagement when the teacher paused after an SRS question and asked students about why they selected particular answers. Teachers who already value student responses while teaching are able to more easily adjust their teaching to use the SRS in ways that give indications of student cognitive engagement. A semantic differential device was administered to students in both classes to collect data on their thoughts on the

SRS. Analysis of the semantic differentials showed that students felt the SRS helped in increasing engagement, participation and making the lesson material easier to understand. The findings suggest that the SRS can be used as an indicator of cognitive engagement in chemistry instruction.

INDEX WORDS: Student response system, Secondary science, Chemistry, Design study, Cognitive engagement, Professional development, Instructional technology

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CHAPTER 1

INTRODUCTION

As a teacher, it is important to find ways to evaluate the learning and accomplishment of students relative to instructional goals. Instructional goals are statements that describe criteria about which student learning and accomplishment can be evaluated. High levels of student learning and accomplishment are associated with and components of what is often labeled as comprehension. Student accomplishments and external evidence of learning are outer indicators of how well instructional goals have been achieved. From my own experiences as an educator, I know that it is difficult to truly determine what students have learned from my teaching. The students of my high school chemistry classes have been especially problematic for me to understand. From my perspective, the concepts and other subject matter knowledge components presented in the course often appear complex and foreign to the students. Worse yet, some people in my classes are less verbal and more shy so it is tough for me to know when they need help and in what specific areas they are having trouble. As I have tried to teach the difficult concepts in chemistry like stoichiometry and the mole, I use the information I get from student questions to try and guide how I explain things and how long I spend on each topic. One problem is that sometimes students do not ask questions when they do not comprehend something but will instead sit quietly through a class. The topics in chemistry tend to build on one another so if a student does not understand a concept one day then it continues to give them trouble in subsequent lessons.

Teachers need to be able to gauge the level of understanding in each of their students throughout a lesson. The problem is, most teachers have limited tools at their disposal to formatively assess students such as students questions, looking for non-verbal cues like a confused look or nod, and student performance on class assignments. This provides an incomplete picture of student progress because none of these methods completely captures each student's level of comfort with the curriculum and it also does not allow for the teacher to get input from each student simultaneously. So, at best, the teacher gets a grasp of how some students are doing in class and must proceed with the lesson under the assumption that all the other students have similar needs. What teachers need is a better way to assess how well students understand topics as they are taught so that they can better tailor instruction to meet the needs of the entire class instead of just those few who gave feedback. Student response systems (SRS) are one tool that can meet this need.

In the 1960s, it was found that, much like today, "even experienced teachers could not accurately determine a student's comprehension from non-verbal cues" (Rubin, 1970, p. 2). To address this, the student response systems were developed. The system that Rubin studied had a foot lever system in college lecture rooms that gave lecturers anonymous data on the percentage of the class choosing each answer (Rubin, 1970). Most of the studies on these devices were conceived from within a behaviorist perspective where operant conditioning was used. Researchers sought to understand whether immediate feedback, shown graphically, is a positive reinforcement for students encouraging better grades (Edens, 2008). Early results were inconclusive with some studies showing no benefit or even a negative effect from the system (Rubin, 1970).

Today, student response systems are a type of instructional technology that includes a class set of remote control devices and a receiver connected to the teacher's computer. Typically, each student has his or her own device that has buttons for answering true/false, yes/no and multiple-choice questions. Some models allow for numerical inputs and may have displays to provide information to the student on the current question as well as the percent of questions answered correctly. The receiver gets responses from the devices through infrared or radio waves and connects to the teacher's computer. The software for the SRS allows a histogram of student responses to be displayed and can also print a variety of reports on student performance. SRS are also referred to in the literature as classroom response systems, audience response systems, voting machines, wireless keypad response systems, classroom communication systems, and electronic response systems, and electronic voting system (Fies & Marshall, 2006).

Purpose

SRS are designed to meet the needs of larger college lecture classes more than the needs of middle and high school students. Thus it is not integrated as easily into the K-12 classroom (Songer, 2008). While there are lots of digital resources available to teachers, the ones that do not give direction or guidance for use in specific grade levels, types of classrooms, and curriculum are less helpful to teachers. With SRS in particular, there is "little systematic information about what social and educational infrastructure is needed to support clicker use" (Trees & Jackson, 2007, p. 22) In terms of using technology in domain specific areas within science, "a gap exists between technology for doing science and technology for learning science" (Songer, 2008, p. 472). Teachers need to know how to use SRS in their classrooms with specific subject matter content topics. Consider an example from chemistry teaching.

Many chemistry topics are taught from three complementary perspectives: microscopic, macroscopic, and symbolic. The microscopic perspective focuses on individual atoms and molecules as well as their interaction with each other. A macroscopic view pertains to larger scale effects visible and observable with the naked eye (DeJong & Taber, 2008). The symbolic angle looks at balanced formulas and equations used to represent chemical reactions. It is difficult for students to fully grasp each perspective and even more difficult to know how to make transitions between the three perspectives (DeJong & Taber, 2008). For instance, stoichiometry and the mole concept are topics that require students have a grasp of all three perspectives and also be able to negotiate transitions between them. In my experience, these are topics where many of my students have struggled. They seem to get bogged down trying to memorize a long list of steps for each possible process or problem to solve. This contrast with Elby and Hammer's (2001) findings that physics students could score higher when solving quantitative problems if rote memorization was used for each type of problem instead of focusing on larger concepts. Instead, it would be better if chemistry students were able to see the larger picture of what is happening. There are too many steps and variations in problems for most students to be successful memorizing a computational sequence. For example, in a stoichiometry problem, I have often seen students try to memorize a series of unit conversions to determine something like the mass of a product that would theoretically result from a certain mass of reactant. The smallest change in the setup of the question, like starting from moles of a reactant, seems to cause the student to view it as an entirely separate type of problem that they need to memorize a new set of steps for. Instead, it would be better if they could see the larger picture of how mass and moles relate and also how ratios of compounds are shown through a balanced equation. Because of these kinds of issues in the classroom, there is a need for research in secondary chemistry education that helps "to develop a better understanding of teaching and learning processes and outcomes with respect to particular chemistry" (DeJong & Taber, 2008, p. 648). This study seeks to inform teachers on effective uses of SRS in specific contexts to help determine how well students are meeting instructional goals.

Rationale

Current research with SRS includes a focus on individual use over groups, faulty comparison groups that are not similar because they are often less constructivist, lack description of context, rarely focus on anonymous use of SRS by students (Fies & Marshall, 2006). This qualitative study included a rich contextual account and student use was anonymous. Because usage was not tied to grades, it provided freedom to venture opinions without fear of appearing wrong in front of peers. More research is needed to help "define what it is that a CRS can add to a learning environment" (p. 106). (Fies & Marshall, 2006) and also what optimal use of SRS looks like (Edens, 2008). There is a need for research on using SRS in group environments because of the emphasis on collaborative learning environments in the national standards of science education and they are also shown "to be beneficial in terms of learning outcomes" (p. 102). (Fies & Marshall, 2006). This study sought to provide some of this needed research and show how SRS can be used to encourage high cognitive engagement. While there has been a good bit of research on SRS classroom use at the college level, particularly in physics and computer sciences, there is not much research on them in the secondary classroom environment or in chemistry (Penuel et al., 2007). There is a need for student response system research in a variety of settings and pedagogies (Fies & Marshall, 2006) In particular, there is a need for work in the secondary classrooms. Most SRS work so far is in large lecture environments while teachers in secondary environment may use them differently based on the smaller environment and also the different content taught. There is not much research so far on how SRS are used in smaller K-12 classrooms (Penuel et al., 2007). By being placed in a secondary chemistry classroom, this study provided useful information to secondary chemistry teachers on effective uses of SRS in their specific setting and challenges they may face during implementation. This specific information is not currently available in the literature.

Research Questions

1. What are the traditional tools used by participant teachers to assess student engagement?
2. In what ways can an SRS serve as an additional tool for teachers to assess student engagement?
3. From the students' perspectives does use of an SRS provide them with opportunities to demonstrate their engagement not available in classrooms without the SRS?
4. How do the teachers' tools for assessment of engagement possessed prior to the introduction of SRSs impact their willingness to adopt new systems?
5. Given SRS adoption and usage over time, do teachers shape instruction to optimize the benefits of using the SRS?

In this brief introduction to the study, we have discussed how teachers have tools to assess student engagement but that these tools are insufficient to meet their needs. Specifically, secondary chemistry topics require students use multiple perspectives and this is an area where it would be helpful for teachers to have a better viewpoint of how their students are processing the concepts being introduced to them. SRS may serve as an additional tool to better meet these teacher needs. Current research does not provide this to teachers but instead focuses in other areas like large, lecture environments and using SRS as a grading tool. This study looks at what tools teachers currently have to assess student engagement, how the SRS can be an additional tool, how teaching with an SRS changes over time, and student perceptions of the SRS as a tool to assess student engagement.

Overview

The details of this study are broken down into four additional chapters. In chapter two, some key concepts in education literature are examined individually and in relation to each other. A few pivotal areas of research that are examined include tools teachers use to assess student engagement, teaching with instructional technology, and educator professional development and its effects on teacher practice. The tools teachers use to gauge student engagement have been previously researched. The examination of this literature allows for a better understanding of the tools the teachers in this study used. It also reveals areas in which their tools are insufficient and might benefit from the SRS. The instructional technology section focuses on student response systems in particular. The devices have been directly tied to grades and also used to let students self-evaluate. When used as a tool to foster discussion, teaching strategies have varied from class discussion after collecting responses all the way to small groups discussing their answers before sending responses. This prior research served as a starting point for potential uses in this study and informed the daily adjustments in SRS usage. Once the main ideas from the literature in each area are discussed and related to one another, the ways these ideas influenced the research are discussed.

Chapter three looks at the methodology of the study. Some major influences on the research design are investigated including situated cognition, social constructivism, cognitive engagement, and design studies. The situated cognition and social constructivism sections focus on how students piece together their knowledge in the classroom environment, which very much includes their interactions with the other people in that classroom. Cognitive engagement is a construct related to higher-order and critical thinking. It served to highlight the type of student engagement most valued by the researcher. A design study involves a teacher and researcher partnering together for a shared goal, the design, which they adjust as necessary throughout the study. This type of research heavily influenced the design of this study. Chapter three also highlights the participants and procedures used.

Chapter four describes the data collected from the study and the analysis of it. Rich descriptions of each classroom and teacher are given. Additionally, key excerpts from classroom experiences with and without the SRS are given. Themes that emerged from that data are described and elaborated on. Through this process, it was found that the teachers in this study already have a variety of tools that they use to assess student engagement. Thus they did not find the SRS an especially useful tool in that regard. Instead, they saw it as a way for students to conduct formative self-assessment that could be used to determine if additional tutoring outside of class was necessary. As the researcher trained teachers daily on SRS usage to promote student engagement, slight changes in practice were noted over time.

Chapter five concludes the study and offers broader implications from it. These include a deeper understanding of how the tools a teacher currently uses to assess student engagement affect how they may use the SRS as an additional tool. Also, because the researcher was present daily, small changes over time were observed that provide a detailed understanding of how teachers slowly adopt and integrate new tools into their teaching.

CHAPTER II

REVIEW OF LITERATURE

Several areas of literature helped to inform this study. They are: research on instructional uses of student response systems; assessment tools used by teachers; student cognitive engagement; and teacher resistance to change. An overview for each of these areas will be provided. Next, the depth of research will be examined and generalizations made on how similar these reports of prior research are to the study being reported here. Following that, several studies in each area will be highlighted and related to each other. Finally, the big ideas across all four major areas of research listed above will be integrated and tied to the methodology of this study.

Student Response Systems

Overview

Student response systems (SRS) allow students in a class to provide give input to a teacher through the use of remote controls that can have numeric keypads or letters for responding to multiple choice questions. The SRS consist of a class set of remote controls, a receiver to capture responses, and software to track responses. SRS are also referred to as clickers and classroom response systems. In the study being reported here, the terms SRS and clickers will be used interchangeably.

SRS have evolved over the last five decades. They were developed in part to address a common instructional issue. Past teachers, much like those today, had trouble gauging student comprehension from non-verbal cues. Asking the class if there are any questions, scanning the room for quizzical looks, and soliciting verbal responses give some indication but are overly reliant on students willingness to volunteer to speak. Even when students do share their thoughts, it is frequently too time consuming (or possibly distracting) to get input from everyone. Rubin (1970) was one of the first to report on instructional uses of an SRS. He found that when students are confused they will rarely ask a question in class. However, he was unable to show that the anonymity of SRS necessarily increased student participation. The devices first appeared at Stanford University in 1966 and were used in other college lecture classes in subsequent years (R. H. Kay & LeSage, 2009). The Stanford model used a foot lever system where students had pedals at their feet connected to light bulbs. So, the teacher could ask a multiple choice or yes/no question where, for example, the left pedal would be used for A, the middle for B, and the right one for C. Then each student would be instructed to press the pedal that represented their answer. The teacher could see responses through a central circuit board that showed the number of light bulbs turned on for the left, middle, and right pedals respectively.

In 1999, infrared systems were developed that made SRS more practical and led to more widespread use. Since that time, there has been a wealth of various types of research on the devices. Kay and LeSage (R. H. Kay & LeSage, 2009) found 67 peer-reviewed articles on SRS between 2000 and 2007. Of those, 24 focused on learning and eight had qualitative data. The analysis shows that a majority of the work done in this area is methodologically different from the studying being reported here. In terms of setting, 49 of the 67 studies focus on college students and the mean class size of these 49 classes is 308. Only one secondary and three middle school environments were studied during this time period from 2000 to 2007.

A few of the studies reviewed by Kay and LeSage will now be examined in more depth. The studies are categorized into the areas of focus and methodology. In each of the research reports that will be presented in greater depth, surveys are used to gather information on student attitudes and also perceived learning. Pre and post-test data is collected in other studies to determine how much learning has occurred. Surveys studies will be discussed first, followed by pre and post-test studies on attitudes and learning, and finally a study that combines both surveys as well as pre and post test. They are organized in the table below in the order that they will be discussed.

Author	Setting		methodology		area of focus	
	college	secondary	survey	pre and post test	attitude	learning
Trees & Jackson 2007	☑	☐	☑	☐	☑	☐
Kay & Knaack 2009	☐	☑	☑	☐	☑	☐
Penuel et. al. 2007	☐	☑	☑	☐	☐	☑
Preszler et. al 2006	☑	☐	☑	☐	☑	☑
Bunce et. al 2006	☑	☐	☐	☑	☐	☑
Kennedy & Cutts 2005	☑	☐	☐	☑	☐	☑
Edens 2006	☑	☐	☐	☑	☑	☑
Crossgrove & Curran 2008	☑	☐	☐	☑	☑	☑
Barnes 2008	☐	☑	☑	☑	☑	☑

Table 1 Setting, methodology, and area of focus for key SRS articles.

Surveys

Trees and Jackson (Trees & Jackson, 2007) studied seven large college lecture classes to see how student characteristics and course design related to student perceptions of SRS. About 1500 students took an attitudinal survey with most classes being from the natural sciences and communication. They hoped to find out if certain types of courses and students were more likely to have favorable impressions of the SRS. The student characteristics examined were student assumptions about lectures, lecture experience and class standing, and class performance. The course design factors were number of clicker questions per class and the integration of clicker use with class points.

It was found that students who do not have a positive perception of large lecture classes and students who like to be involved in class had more positive perceptions of SRS. The clickers did not encourage students to attend class, instead only the class points associated with clicker use encouraged attendance. The increased attendance came at a price in that it increased student anxiety about clicker use. An encouraging finding was that "the success of clickers is in many ways dependent on social, not technological factors" (p. 38) tied to how well the students and teacher accept clickers. This conclusion suggests that if students and teachers are excited about using clickers, technological barriers are unlikely to prevent them from using the devices.

The findings of Trees and Jackson suggest that secondary science teachers who are already attempting to engage their classes and ask questions would most effectively integrate SRS into their teaching. It is also interesting that students were able to tell if the device usage fit in with what the teacher's pedagogy. When teachers used the SRS as an aside that wasn't integrated into the normal classroom, students could tell and the benefits were decreased. This informs how I interpret student data on their perceptions of the devices. Instead of examining the student viewpoint in isolation, I know to take into account how the teacher used the device in relation to their typical teaching style. It is unclear how changing the setting to secondary classrooms may alter the relationships found so it is important to examine environments more similar to this study.

A recent study on secondary science teaching with SRS also focused on the student perspective. Kay & Knaack (2009) recruited seven teachers to use SRS for three months. They provided them with the equipment, which was the same SRS as used in the study being reported here. In terms of professional development, the researchers had participating teachers attend two half-days of training on operating the technology and teaching strategies with it. They then surveyed 213 students from those seven teacher's classes in grades 10-12 enrolled in science courses. The frequency of usage was left to the teachers and it was interesting to find that students reported SRS use one to two times per month in all seven classes. The more teachers are trained on using technology, the more likely they are to use that specific technology (Abrahamson, 2006). This is consistent with my own study where I was present and training teachers continuously and had the SRS consistently used multiple times per week.

The surveys given to the students had 11 questions each with a seven point Likert scale. They focused on four areas: overall attitudes, student involvement, assessment, and learning. An overall positive impression of clickers was reported by 62% of the students. A majority of the students, 70%, found that it increased their involvement in class. The assessment section offers particularly useful findings in relation to this study. The SRS was reported as useful in formative assessment by 75% of students but only 33% did for summative ones. In regards to learning, high scores were generally given for how the SRS helped with the learning process, remembering previous material, and with teacher explanation. Some technological barriers lowered student impressions. Typical comments of students complained about the time to learn to use them versus the time spent actually using them. The time spent learning to use them includes reviewing the proper procedure for obtaining the remote control, when to click, where to point the remote, how to interpret results, and how to return the remote control. After all the time cost of learning to use the SRS, the teachers in the study only used them once or twice a month. While this study made some mention of teacher usage, the following focuses more directly on it.

Student perceptions of SRS are important, but the teacher perspective is also valuable. Penuel, Boscardin, Masyn, & Crawford (Penuel, Boscardin, Masyn, & Crawford, 2007) surveyed 498 K-12 teachers who use SRS, 212 of whom were secondary teachers. Of those secondary teachers, 67% taught science courses. Given that when SRS are used in high school, they are often by science teachers and that there is relatively little work on SRS use in high schools, the context of the study being report here makes it useful to a wider audience than might be found in other subjects.

The survey focused on goals, instructional strategies, and perceived effects of using clickers. The researchers found SRS usage in the secondary environment was similar to reports of usage in higher education. That finding is useful for my study because it means that the wealth of previous work in the college setting may have value even in a secondary environment. Four teacher profiles were constructed of based on amount of clicker use and the types of teaching strategies used with them. The four classifications are infrequent user, teaching self-evaluator, broad but infrequent user, and broad and frequent user.

The infrequent user not only did not user the SRS often but also failed to utilize the full range of capabilities of the device. The data obtained from the clickers rarely if ever changed teacher instruction. Out of the 498 respondents, 13% were classified in the infrequent category. Teacher self-evaluators would use the SRS mainly for summative assessment and not to create class discussions. Again, the data gathered would rarely change future instruction. About 28% of teachers surveyed fell in this category. The broad but infrequent user gathered both formative and summative assessment data that drove class discussions and informed future teaching. However, the devices simply were not used often. This was the largest group of teachers with 35% being classified as broad but infrequent. The final classification is broad and frequent. Their usage is similar to the broad but infrequent classification, they just use the SRS more often. 25% of teachers were classified as broad and frequent users.

Consistent with previous findings, the teachers with broad and frequent usage had received the most training. This supports my methodology in having a researcher capable of providing training present throughout the study in hopes of encouraging more frequent and diverse SRS usage. My study seeks to have teachers use the SRS to facilitate class discussions so this research helps me see the need to have as much training for teachers as possible.

The first three articles included in this review examined focus on either attitude or learning. My study focuses on both. There is some previous research that also focuses on both. While my approach is qualitative, Preszler, Dawe, Shuster, & Shuster (2007) used survey data to do this. They studied 550 students in six college biology courses throughout a semester. Each course had the number of clicker questions randomly varied each class meeting between three levels. Low level was zero to two questions, medium was three to four questions per class, and high was five to six questions per class. This independent variable of number of clicker questions was analyzed in relation to the percent of students correctly answering exam questions. The responses were tied to student grades. Of the overall course grade, 8-19 percent came from data from the SRS. Incorrect responses received 80 percent credit and full credit was received for correct responses. The intent of awarding partial credit for incorrect responses was to reward participation. At the end of the semester, students were given a 12 question survey broken into five areas: overall impressions, student impression on specific benefits of SRS use, teaching recommendations, frequency of technical problems, and preference for group or individual study.

To analyze the exam scores versus the number of clicker questions, an ANOVA was performed. It showed a significant relationship between the number of clicker questions and exam scores with alpha equal to 0.05. The survey given at the end of the semester showed that students had overall positive impressions of the SRS. Over 81 percent reported the devices increased their interest in course materials, made them more likely to attend class, and helped them retain material learned in lecture. One thing the researchers do not address thoroughly is how the integration of clicker use with grades may have served as an additional motivating factor. In terms of teaching recommendations, students preferred the medium level of questioning, three to four questions per class. Additionally, most students liked having an opportunity to discuss the question and underlying topic after submitting their responses.

Pre and Post-test Studies

Pre and post-test studies with SRS assessed students content knowledge prior to introducing clickers, then evaluating them after the study to see what learning gains could be attributed to the system. This type of research makes up a large part of research on clickers so to have a full understanding of the field, it is important to examine them. These reports can also inform my study through the focus on using the SRS to generate positive learning outcomes. Four studies in particular will be examined in more detail.

Student response systems are a tool with many uses such as quizzing, generating discussions, self-assessment, and teacher assessment. Bunce, VandenPlas, & Havanki (Bunce, VandenPlas, & Havanki, 2006) focused on the quizzing aspect in particular. They compared the SRS to WebCT online quizzes. WebCT is a learning management system that in this case had a class website with a login for each student. The students, 41 undergraduate nursing majors, were enrolled in a chemistry course combining general chemistry, organic chemistry, and biochemistry. During the last nine weeks of the course, SRS were used to quiz students directly after certain topics were taught. Other topics were quizzed using WebCT. For those, the quiz became available six hours after class and was due before the following class period.

The results on the quiz questions from both WebCT and SRS were compared to teacher created exams given at three week intervals as well as the *American Chemical Society (ACS) Exam* given at the end of the nine week period. Four chemistry instructors took all exam questions and divided them into four categories: those that were assessed with the SRS, those assessed with a WebCT quiz, content relating to both quizzing tools, and content that was not quizzed with either tool.

The findings suggest that SRS did not significantly improve achievement on teacher created exam whereas WebCT quizzes did. Comments from a course survey given at the end of the semester showed that students felt the WebCT quizzes were more helpful because they could be reviewed prior to exams. Neither quizzing tool appeared to increase scores on the ACS exam. The survey also showed that students had low engagement with the SRS. This was because the teachers displayed polling results live as students were submitting. So, most students would wait to see what a few others were submitting, and then select the same answer.

Several aspects of the methodology and findings influenced my own study. The class was given the *Group Assessment of Logical Thinking* and the results were used to group students into pairs that had similar logical thinking abilities. The pair would also share a laptop during class, though it was not made clear exactly how the laptop was used. The idea was to have students discuss answers with each other before submitting. This practice seems like a great way to use the SRS as a discussion-generating tool and became one of the suggested uses given to teachers in my own study.

The notion of class discussion prior to submission of answers was introduced in theory by Bunce, et al. (Bunce, et al., 2006) through a discussion of Mazur's Peer Instruction method and other social constructivist literature. Additionally, it was part of the preliminary design when students were separated into groups. However, in practice, student discussion was not a focus of the study. Questions were displayed on the project, the class responded with the SRS, and professors moved on with the lecture. Given this and the fact that students could see other's responses before selecting their own, it is not surprising that students did not find the tool useful. This allowed me to see the need to have responses remain hidden until the whole class had answered. Also, discussions related to SRS should inform the direction of the rest of class. If students need additional explanation on a topic, the class schedule should be adjusted to allow for that. If the class seems to understand something, there is no need to continue doing the rest of the lesson on that topic as planned. In this way, the SRS can make class time more efficient, which makes up for the time it takes to use the clickers.

SRS can help improve teaching in learning in two main ways. First, the students get an opportunity to engage with the class material in a more interactive way, which may foster deeper processing. Second, the teacher and student get instant formative assessment data. This can let students know where they do not understand and should seek help. The teacher can better focus future questioning and class discussion. The ultimate goal of this would be more positive learning outcomes for students, often measured in terms of higher exam scores. Kennedy and Cutts (2005) sought to link this type of SRS use with higher exam scores.

The researchers in this study had 241 undergraduate computer science students use clickers in 13 lectures, with two to six clicker questions per lecture. Several researchers seem to have found that up to six SRS questions per class meeting are ideal and this information was used to determine the number of questions to ask students during my own study. When each question was asked, students were encouraged to discuss with each other for up to two minutes before responding. However, no attention was paid to any discussion that may have occurred. After responses were collected, they were displayed on a histogram. The teacher would then discuss both correct and incorrect answers. About one-third of the questions had no correct answer. These would be used as a springboard for further class discussion on relevant topics.

For each student, the number of correct responses was divided by the total number of responses. These values were then compared to final exam scores. Students were divided into a two-by-two matrix with the four clusters based on high or low SRS use and high or low percentage of correct responses to SRS questions. It was found that 38 students had high usage and a high correct percentage while 35 had low participation but a high accuracy. A surprising number, 108, had high participation but low accuracy. Finally, 61 students did not participate often nor have much success when they did. These clusters were determined using a dissimilarity matrix. In terms of participation, those with low participation attempted on average less than ten of the 24 questions while high participation students attempted on average 18 of the 24 questions. The groups with high accuracy were correct on average at least half the time while the low accuracy groups were correct on average about every fourth question. The four clusters served as the independent variable and the exam scores from each semester were the dependent variables for a one-way MANOVA. Those students who were put in the high participation and accuracy cluster did significantly better on their exams than the rest of the class.

The researchers expected that anyone using the SRS often would have higher exam scores. Instead, only those in the cluster using the SRS often and accurately had significant post-test gains. Thus, they concluded that only using the SRS accurately and often has cognitive benefits. However, this oversimplifies the classroom dynamic greatly. No attention was paid to which students participated in discussions before or after responding. Also, the average SRS question had about 20-25 percent of the students answering correctly. This implies that the teacher may have been moving on when clearly the class needed additional help. Because the class did not get the additional help, it is not surprising that exam scores were not higher. Kennedy and Cutts apparently do not see this it as the teacher's role to craft instruction to student needs. Instead, the implication they offer is that the students need a baseline of content knowledge to benefit from SRS use.

The methodology used by Kennedy and Cutts (2005) gave me a better understanding of how my own study could be designed. By their focus on student achievement as a dependent variable, they seem to lose valuable details of the actual SRS experience. This fact is even noted in their discussions. They simply do not know why so many of the student responses were incorrect. Also, no attention was paid to which students were more actively engaged in class discussions. Because these important issues were neglected, it is difficult to understand why the only improved test scores were seen in those using the SRS frequently and accurately. This highlights the importance of focusing on the SRS user experience as it is happening, both the teacher and students. In particular, the students who used the SRS frequently but were often incorrect may have been exhibiting low cognitive engagement but the teacher was not aware to intervene. Or they may have had high cognitive engagement but that did not translate into higher final exam scores. Perhaps the exam itself was not valuing higher-level thinking. Because class grades were linked to SRS use in this study, I suspect students had low cognitive engagement and were trying to put in minimal effort to still get 80 percent of the SRS related grades.

Research has been done on using SRS in a behaviorist manner and through more metacognitive approaches, the former valuing outward actions while the latter values inner thought processes. In the behaviorist usage, class points are based on frequency and accuracy of responses. Often students get partial credit for answering a question and full credit for the correct answer. In this way, attendance in class is rewarded with more class points. The metacognitive approach does not directly factor SRS quizzes into grades. Instead, it is viewed as a self-assessment tool for students to monitor their own understanding of the content covered in the quiz. Edens (2008) compares the performance of classes that used the metacognitive approach with those using a behaviorist approach. Additionally, the role of the student learning style was also taken into consideration. The learning style was broken down into two areas: level of self-regulation and goal orientation.

The study took place in two introductory educational psychology courses with 120 students total. One class was setup with a behaviorist approach to SRS while the other used a metacognitive one. In the behaviorist group, the clicker quizzes counted 25 percent of the course grade whereas in the other course, they were only for self-assessment. Four types of data were collected on each student to compare to the type of classroom environment they had. A pretest at the start of the semester covered course content and also had the Motivated Strategies for Learning Questionnaire. The questionnaire supplied indicators of student motivation and learning styles. The posttest covered the same content as the pretest. Additionally, a course survey was given that investigated student attitudes on SRS use and also examined content recall by asking final exam questions again in a slightly different format.

The various test and survey data was compared to the teaching style using MANCOVA. Teaching style was classified as either operant or metacognitive. This analysis revealed there is not a main effect with teaching approach and achievement. The operant group did show higher levels of attendance and class preparation, but at the expense of increased student anxiety. Self-regulation and achievement do have a main effect. High levels of self-regulation strongly correlate with high achievement regardless of pedagogy used, though the highest was found in the metacognitive group. Students who monitor their own learning at high levels benefit the most from a teaching style that fosters this self-monitoring.

The teaching strategies used with SRS are an important factor when looking at student outcomes. The importance of integrating discussion has already been reviewed. The level of course and the type of student in the course are relevant factors with SRS use investigated by Crossgrove & Curran (2008). They looked at 194 students in an introductory biology course for non-science majors as well as an upper level genetics course with 46 students. Each class used clickers once per week with two to eight questions each time for one semester.

In the introductory course, classes began with a clicker question from content covered in the previous class session. Then other questions were scattered through the lecture, some of which came from material the students had already prepared on through homework, whereas other questions were based on new material from that day. If less than 70 percent of students got a question correct, peer discussion was used. If more than 30 percent still missed it, additional explanations were given by the lecturer.

The genetics course was taught slightly differently. They also had an introductory question to start class based on previous material. However, the remainder of the questions were generally problem-based questions. As with the other course, if less than 70 percent of the students correctly answered an SRS question, peer discussion was used. However, after that discussion time, the quiz question was not given again.

An ANOVA was conducted to compare the achievement of students on exam questions covered with type of instruction. The type of instruction was broken down into four levels, clicker questions during lecture to those topics not addressed with SRS in each of the two courses. Significantly higher exam scores were found on questions covered with the SRS, especially in the non-science majors course. While not all research has shown the SRS to increase exam scores, the researchers attribute the clear gains to the combination of discussion and clicker use. It seems that using clickers but then just continuing on with a lecture may minimize achievement gains. Now that some relevant studies with pre and post-test data have been examined, we will move to some using both surveys and pre and post-test data.

Studies Combining Surveys with Pre and Post-test Data

The next group of studies continues to analyze pre and post-test data but also gathers attitudinal survey data from students. While most SRS work has been at the college level and quantitative, Barnes (2008) conducted mixed-method research in his own high school biology classroom. He was transitioning from a lecture-based classroom to a more constructivist one and used the transition to study SRS in each environment. Four classes totally 43 students participated in the study over the course of three units. Each unit lasted about 11 school days.

For each unit, half the classes would receive lecture instruction and the others would get constructivist classes using the SRS. During the constructivist units, students would work in groups of three to four with 50-60 multiple choice questions to answer using the clickers. The class went through the questions synchronously. While students are responding, the percent of correct answers was displayed. This could be used for students to further discuss their answers, though they ultimately would not know the correct answer until all students had clicked in. If less than 70 percent of students got the correct answer, the teacher would briefly lecture on the topic.

For each of the three units, students in all classes took a 30-42 question multiple choice pretest and posttest. The percent gains were compared for those in the SRS class to those in the lecture class for each unit. To analyze the data, t-test compared the percent gains in each classroom environment. Student gains were higher with the SRS, but not significant with alpha set to 0.05.

At the conclusion of the study, a survey was given to measure student perceptions. Additionally, student comments throughout the study were compiled to support the quantitative data. The survey revealed that students had overall favorable impressions of the clickers. They felt it enabled them to learn more but was also more frustrating. Comments during the units explained that the lectures were more comfortable for students even though they did not learn as much. The discussion and engagement in higher-level thinking questions required students to interact with the material more than the lecture did. Students felt that this helped them learn the material better.

SRS Summary

Through the examination and critique of these studies on SRS, several trends and best practices emerged. The teaching style used is an important factor. Instructors cannot just use the device with whatever pedagogy they want and expect students to have positive experiences. Students generally have positive impressions. However, tying to grades increases anxiety. To fully realize potential learning gains, discussion between students and the class as a whole should be encouraged. Students can discuss the content in a question with one another before responding. To help ensure quality discussions, it is important not to reveal student responses before all have answered. After everyone has answered, the correct answer can be displayed. If lots of students did not get it correct, further class discussions can help identify the misunderstanding so that students better learn the material. In most studies, 2-6 clicker questions per class were used and this seems to be a good balance of clicker use and other class activities. SRS is by no means the only tool teachers have at their disposal to assess students during class. It is important to understand how these other tools also provide useful information to teachers.

Cognitive Engagement

Cognitive engagement was first used by Corno and Mandinach (1983) to indicate that someone was actively participating in interpretations of one's self and environment. It has also been defined as students using strategies to link their own personal knowledge with scientific knowledge to understand their world (Lee & Anderson, 1993). Richardson and Newby (2006) thought of cognitive engagement as made up of cognitive abilities, motivations and experiences and defined it as the "integration and utilization of students' motivations and strategies in the course of their learning" (25). According to Walker, Greene, and Mansell (2006) "cognitive 8engagement refers to the amount and type of strategies that learners employ" (4).

Cognitive engagement is operationally defined in several ways, most of which focus on some distinction between high and low level thinking. One definition labels meaningful processing and self-regulatory activities indicative of meaningful cognitive engagement while shallow processing abilities and unreflective activities represent shallow cognitive engagement (Greene & Miller, 1996). Cognitive engagement can also be operationally defined as having two subscales, deep-processing strategy use indicative of high levels of cognitive engagement and shallow strategy use that shows lower cognitive engagement (Dupeyrat & Marine, 2005). Deep-processing strategy use is when students are involved in elaborating on material presented to them as they try to organize it in relation to their own prior knowledge. Shallow strategy use on the other hand primarily consists of rote memorization where students repeat things or read things over and over to learn them. Cognitive engagement is made of two different cognitive strategies, meaningful and shallow processing. Meaningful processing strategies connect new information to old to make a more detailed and generalizable mental model. Shallow processing strategies like memorization lead to a less detailed and generalizable mental model (Greene, Miller, Crowson, Duke, & Akey, 2004).

There is a large amount of research on cognitive engagement. However, the area is not well defined. This is not due to a lack of clarity or quality in research. Instead, the ambiguity is inherent because at best we can approximate and indirectly measure cognitive engagement. Researchers must look for outside indicators of inner processing. There is not a distinct boundary between cognitive engagement and related terms such as deep-processing strategies and critical thinking. This study takes place in classrooms where students do not learn independently but instead interact with each other. Thus, particular attention is given to cognitive engagement research that factors in the roles of context and social interaction.

The operational definitions and measures that factor context are best because of the role of situated cognition on cognitive engagement. Sociocognitive engagement is an active, social construction of shared knowledge through verbal interchange (Hogan, 1999). This is useful in the studying of secondary chemistry classroom because of the conversations between students during science activities that can help the students build their science ideas. Each student does not complete an activity in a vacuum but is instead part of a classroom environment. Situated cognition informs this notion by viewing learning as participation where individual students contribute to the science practices of the class as a whole (Roth, 1995). To be able to view actions and link them to understanding, a detailed and continuous study of the students throughout the activity is necessary (Roth, 2007). Roth (2007) elaborates on the continuous nature of learning in pointing out that "inward and outward cognitive activities are related to previous experiences that shape inward and outward action: actions and perceptions are guided by anticipations" (p. 132). As a student's setting changes, it changes their experiences and thus what they will learn about the world. Therefore, in order to study what students learn during an activity, it is vital to pay close attention to the setting the learning takes place in. This setting is also unique to each student based on the world they live in, not a generic setting applicable to the entire classroom (Roth, 2007). Now that the concept of cognitive engagement has been discussed, we can look at how it has been measured in past research studies.

Measures of Cognitive Engagement

Both quantitative and qualitative research has been done on cognitive engagement. Earlier studies in particular focused on quantitative methods. There are also survey instruments that allow students to self-report engagement. More recently, qualitative methods have emerged to evaluate student behavior against rubrics. Now, we will examine some of these early quantitative measures before moving on to qualitative ones.

Secondary task technique measures how long it takes participant to respond to tone. It is not specific to cognitive engagement and was used before the term was coined, but it can be used as a measure because longer time indicates more cognitive engagement in primary task and thus less cognitive capacity to respond to tone (Britton, Graesser, Glynn, Hamilton, & Penland, 1983). This assumes that there is a finite amount of cognitive capacity. When administering it, identifying the secondary tone is clearly explained as the secondary task of lesser importance to the subject than the reading or whatever activity is the primary purpose. This measure seems best to study secondary chemistry students' cognitive engagement because it is able to look at the student throughout the process instead of a survey or questionnaire that looks at beginning and end outputs only. However, there is an ethical concern in using something in a classroom that intentionally seeks to distract students while they try to learn. If that were overlooked and teachers did try to use this measure to identify students with different degrees of cognitive engagement, they would place the tones at key moments 10-30 seconds into when a student might be highly cognitively engaged and compare response times of different students. Those who respond quickly would be considered to have low cognitive engagement on the primary task because they were able to so quickly focus on the secondary task of noting the tone.

In addition to the secondary task technique, there are also several questionnaires and surveys that allow students to self-report on cognitive engagement. The Study Process Questionnaire measures cognitive engagement in students by evaluating student learning strategies and motivations to categorize them as using surface, deep, or achieving strategies and motivations (Biggs, 1987). The questionnaire contains 42 items with scaled responses. The items then have subscales, which are used to give a profile of participants in terms of surface, deep, or achieving strategies and also surface, deep, or achieving motivations. The Approaches to Learning Survey contains 32 items in areas of motivation and cognitive engagement including four on shallow cognitive engagement such as rote memorization and underlining as well as six items on meaningful cognitive engagement like deeper cognitive processing and meaning making (Entwistle & Ramsden, 1983). The Motivation and Strategy Use Survey "measures learning goal orientation, performance goal orientation, perceived ability, meaningful cognitive engagement, and shallow cognitive engagement" (Greene & Miller, 1996). The Motivational Strategies for Learning Questionnaire uses a Likert scale to rate how often deep-processing and shallow strategies are used (Pintrich & DeGroot, 1990).

Contextual studies of cognitive engagement.

Cognitive engagement has been studied in a variety of contexts that relate to this study. Walker, Greene, and Mansell (2006) investigated the relationships between aspects of motivation and cognitive engagement. They were able to show correlation between cognitive engagement and academic identification, motivation, and self-efficacy. Oriogun, Ravenscroft, and Cook (2005) validated a tool for assessing cognitive engagement of online groups. This is of interest because it looks into engagement of students who are actively using technology in a learning environment and also because of their discussion on analyzing transcripts to assess cognitive engagement. Geelan, Wildy, and Louden (2004) studied cognitive engagement of secondary physics students so the environment was similar to the secondary chemistry students in my own study. They focused on discrediting the notion that a teacher-centered classroom is associated with low cognitive engagement. To better understand the findings from each researcher, the studies need to be examined in greater detail.

Previous research has shown correlations between motivation, self-efficacy, and cognitive engagement (Greene & Miller, 1996; Greene, et al., 2004). Walker et al. (2006) looked into the theoretical relationships between cognitive engagement and the following: self-efficacy, intrinsic motivation, extrinsic motivation, and academic identification. Participants were 191 undergraduate students in two different courses. One was an educational psychology course with upperclassmen and the other was a career exploration course with underclassmen. The primary research question focused on whether or not academic identification correlates with cognitive engagement. Academic identification was defined as how much students value academic achievement, how much of their own self-worth is based on this achievement, and how well they feel they fit in their current academic setting.

In this study, the pertinent variables were measured with a variety of scales, instruments and surveys. Intrinsic and extrinsic motivation were evaluated with the

Academic Motivation Scale (Vallerand & Bissonnette, 1992). Self-efficacy data came from an instrument developed by Greene and Miller (1996). Osborne (1997) developed the scale used for academic identification. Cognitive engagement was measured using Greene and Miller's Motivation and Strategy Use Survey, a 54 item Likert Scale tool with 25 questions on meaningful cognitive engagement and 13 on shallow cognitive engagement.

Each variable was correlated with cognitive engagement. The researchers were expecting positive correlations with meaningful cognitive engagement for all variables except extrinsic motivation. Those with more extrinsic motivation were expected to show shallow cognitive engagement. Analysis of the data supported this initial hypothesis. This allows for a better understanding of cognitive engagement by relating the concept to other constructs that can be evaluated in students.

Online discussion groups can be used by teachers to facilitate asynchronous interactions between members of a class. The Transcript Analysis Tool (Fahy, et al., 2000) allows for transcripts to be analyzed for cognitive engagement. Oriogun, et al. (2005) empirically validated the SQUAD approach as an additional tool to assess cognitive engagement in online groups. SQUAD is an acronym that stands for suggestion, question, unclassified, answer, delivery. It is a problem based learning approach that has students work in groups. SQUAD is reported by Oriogun to provide a way to measure engagement, however, it seems to actually facilitate cognitive engagement. The benefits of the approach are that it facilitates discussion, encourages interaction between participants, integrates ideas with prior knowledge, and allows for shared knowledge, and shared solutions are created.

In the study, there were three case studies of 12 weeks each. Group one had 725 messages, group two had 143 messages and group three had 171 messages. Each message was a unit of coding. The Transcript Analysis Tool (TAT) has five categories: vertical or horizontal questions, referential statements, reflections, scaffolding and engaging, and paraphrasing and citations. There were three different alignments of SQUAD and TAT. This means that the categories in SQUAD were placed alongside TAT categories that were related. Because the two approaches have slightly different categories, a single linear alignment was not possible. Instead, the three placements were all plausible arrangements that related the two tools.

Upon analyzing the data, it was found that regardless of the alignment, students showed cognitive engagement in 32-41% of the online discussions. It is unclear what level of variation would not have empirically validated SQUAD. Also, the way that cognitive engagement was determined was not described in depth. However, it appears that if a discussion post aligned with SQUAD or TAT, it was considered high cognitive engagement.

Qualitative Investigations of Cognitive Engagement

Qualitative investigations of cognitive engagement are useful for gaining a deeper understanding of student learning over long-term observations. Chin and Brown (2000) provide a useful operational definition of cognitive engagement for use in a secondary chemistry classroom by examining deep and surface learning approaches in five categories: 1) generative thinking, 2) nature of explanations, 3) asking questions, 4) metacognitive activity, and 5) approach to tasks. Each of these had four different levels, with the first two being surface learning and levels three and four indicating deep learning approaches. Generative thinking is the ability of students to create an explanation when they do not already know the solution. Nature of explanations seeks to evaluate how close to a micoscopic and non-observable cause and effect explanation is given by students. When asking questions, high cognitive engagement is shown in queries that seek a deeper understanding of a concept and less related to getting help completing a portion of an assignment. Metacognitive activity is shown in how students ponder the degree to which they comprehend the topic being investigated. The final category, approach to task, values a desire to understand topics over completion of task or work avoidance strategies. This definition best informs a study on cognitive engagement in a secondary chemistry classroom due to the broad nature of the categories and the detailed descriptions found in each of the four sublevels of the five main categories. This allows student actions to be more easily classified as high or low cognitive engagement with less ambiguity than other definitions.

Because setting is so important to cognitive engagement and many classroom settings involve students interacting with one another in some capacity, sociocognitive engagement becomes relevant to any discussion of cognitive engagement. Sociocognitive engagement can take four forms, collaborative where peers' ideas are built on each other, curious and tenacious where there is a focus on posing questions, stubborn and competive where students defend their own ideas, and expedient where task completion is valued over exploration (Hogan, 1999). Students who are interested in science and confident in their ability to learn science are more likely to be engaged in science activities than their peers without these traits. In this way, the level of sociocognitive engagement seems dependent to some degree on interest in science and self-efficacy (Hogan, 1999). However, it is not necessary that students be interested in attaining mastery or developing detailed ideas. Some students are motivated more by task completion. They want to finish their work as required and as quickly as possible. While this may strike some as a lower level motivation than those seeking mastery of the content, performance or mastery orientation can be associated with high levels of sociocognitive engagement (Hogan, 1999). Low sociocognitive engagement may take the form of passiveness, sporadic, or disruptive (Hogan, 1999).

Hogan (1999) examined high and low levels of sociocognitive engagement in the following areas: stubborn and tenacious, sociocognitively curious and tenacious, sociocognitively collaborative, sociocognitively expedient, sociocognitively passive, and non-sociocognitively disruptive or sporadic. Hogan's categories help further elaborate on Chin and Brown's categories. Stubborn and tenacious student activity can be used as further evidence of high cognitive engagement in the areas of generative thinking and nature of explanations. Sociocognitively curious and tenacious is indicative of high engagement in the area of asking questions. Sociocognitively collaborative activity shows high cognitive engagement in the areas of generative thinking, nature of explanations, and asking questions. Sociocognitively expedient is a type of approach to task that may indicate high cognitive engagement.

Hogan's final two categories show low cognitive engagement. Sociocognitively passive actions can reflect on generative thinking, nature of explanations, and asking questions. Non-sociocognitive disruptive or sporadic actions show low engagement in metacognitive activity and task approach.

Some student actions for this study will be in the context of a technology rich environment. Wu and Huang (2006) studied both teacher and student centered learning environments with four areas of cognitive engagement: solving problems, asking for help, filling out worksheets, and off-task behavior. Student actions while solving problems indicates high cognitive engagement in the areas of generative thinking, nature of explanations, and asking questions. Like Chin and Brown, Wu and Huang categorized asking for help as indicative of high cognitive engagement. Some student actions such as filling out a worksheet are an ambiguous action that cannot necessarily be categorized as high or low engagement. Finally, like Hogan, off-task behavior was used as an indicator of low cognitive engagement in the area of approach to tasks.

Formative Assessment and Feedback

Thus far, student response systems have been examined as a tool to gather data related student learning of classroom topics. As students learn, they may use higher-order thinking skills to process new information. Cognitive engagement is a useful construct to evaluate the higher-order thinking skills students can use. While the SRS is a useful tool to gather this type of information, it is by no means the only tool teachers have. The term formative assessment refers to the more general idea of teachers gathering data on student performance as they learn and providing feedback to hopefully enhance that learning.

The term formative assessment became increasingly common after a review of literature on topics relating to it conducted by Black and Wiliam (1998). This built on previous work in relevant areas such as evaluation, assessment and feedback. Black and Wiliam define formative assessment broadly to include "all those activities undertaken by teachers, and/or by their students, which provide information to be used as feedback to modify the teaching and learning activities in which they are engaged" (Black & William, page 2, 1998). This is an important area of assessment because, unlike summative assessment, it focuses more on when the learning is actually happening instead of evaluating the degree to which it occurred. When creating formative assessments, teachers must exercise care in the choice of tasks, discourse, questions, use of tests, and quality of feedback. These areas all play a role in gauging student understanding and directing further learning.

In response to Wiliam & Black's review, Sadler (1998) brings to light some additional factors to consider. The interaction between student and teacher in an academic setting is important. That is not to say it is the sole relevant interaction. The social setting and overall classroom environment also play a role in these interactions and cannot be ignored. In terms of feedback, teachers who provide quality feedback have a few characteristics. They are content experts, can empathize with students learning material, have skill in creating activities that will bring out student weaknesses and misconceptions, understand the standards and requirements of summative assessments the class is preparing for, have evaluation skills from working with students in the past perhaps including specific information for a particular student, and they are experts in creating different types of feedback for students based on the need.

Following their literature review, Wiliam & Black (2009) worked to develop a theory of formative assessment. The goals were to define formative assessment and also give a set of practices that relate to it. They defined it that "practice in a classroom is formative to the extent that evidence about student achievement is elicited, interpreted, and used by teachers, learners, or their peers, to make decisions about the next steps in instruction that are likely to be better, or better founded, than the decisions they would have taken in the absence of the evidence that was elicited" (page 9). Formative assessment is described in terms of three important areas: teacher goals, interactions between student and teacher, and the cognitive processes that result for the student that can be indirectly measured through verbal and written indicators. Now that we have discussed the theoretical background behind formative assessment, we can examine a few key studies in the area.

Formative Assessment Studies

As standardized tests become commonplace in secondary education, there is a belief among some that teaching to the test will yield the best results on that test. William, Lee, Harrison, and Black (2004) sought to discredit this through a quantitative study. 24 secondary teachers, 12 in math and 12 in science, used formative assessment strategies instead of trying to teach to the test. The researchers provided training on what this would look like including providing comment only feedback and opportunities for class discussion in lieu of lecture. The study took place over six months. A control group was assembled from data on the teachers' previous classes as well as similar classes taught by other teachers. The mean effect size in favor of the intervention was 0.32.

While the long-term approach was successful for William et. al, many studies favor shorter time periods. The Assessment for Learning (AfL) initiative was created by Black, McCormich, James, and Pedder (2006) as an instrument to assess how students have learned how to learn. AfL does this through three main areas: it has teachers ask questions that encourage responses even if the correct answer is not known, teachers provide comment only feedback that students use to adjust assignments and resubmit, and teachers are encouraged to develop peer and self-assessments.

In the study, 79 students ranging in ages from 5 to 15 were given two tasks in classroom settings. For the first, the teacher guided pupils through an activity and then conducted a discussion with the entire class. In the second, the teacher clearly defines a task but does not provide guidance to students on how to complete it. The second scenario was supposed to provide an opportunity for students to interact with one another and learn how to learn the topic required for task completion. The researchers were looking for evidence of student learning through both the completed assignments and also the conversations that took place during class.

The study failed to validate AfL as an instrument to assess students learning how to learn. Few of the children showed that they had learned new learning approaches. A drawback was that it was only conducted for a short period of time. It was believed that a longer time period would reduce participation from teachers. Also, teachers and students reported both false negatives and false positives. Finally, the learning traits from the tasks proved difficult to generalize.

Role of Feedback in Formative Assessment

Hattie and Timperley (2007) conducted a literature review on feedback. Their goals were to define feedback, show where feedback can improve teaching and learning, and the circumstances where it can have the greatest impact. They define feedback as “information provided by an agent (e.g., teacher, peer, book, parent, self, experience) regarding aspects of one's performance or understanding” (page 1). In a meta-analysis, it was found that feedback had an average effect size of 0.79. It was one of the top five contributors to achievement alongside things like direct instruction, reciprical teaching, and prior student knowledge. However, they note that not all feedback is equal. Greatest gains were seen where students were given guidance on how to improve whereas lower gains were seen for general praise, rewards, or punishment.

The goal of feedback is to help students get from where they are currently to where they would like to go academically. Hattie and Timperley create a model of feedback that separates it into four categories.. The first is feedback about the task, which generally evaluates whether responses are correct or not. While this informs students on where they are, it does little to help them get where they want to go. The second level focuses on processes used by students to complete a task. Here, teachers may critique the method used to complete a task and make suggestions for improvement. The third level encourages students to self-evaluate their learning. The fourth level focuses on the person more than the task. General praise fits this category and is less useful for students. The second and third levels are the most useful for learning.

Conclusion

In this chapter, we have seen how teachers can evaluate student learning through formative assessment. This includes the feedback that they provide. The ultimate goal of this would be to help students understand their current understanding and enable them to get to where they need to be in the specific academic area being taught. In this way, the teacher and the student both work together to achieve shared goals. Not all feedback is useful to meet these goals. Instead, only that which focuses beyond the accuracy of answers and the general attributes of students will be helpful. Feedback and formative assessments that inform students of specific procedures to improve, encourage self-assessment, and encourage classroom discussions have the greatest impact towards improving teaching and learning.

Students will often need to use higher-order and critical thinking skills to meet these learning goals. Cognitive engagement is a useful construct to understand where students are in the learning process. Student actions are an outward indication of inward cognitive processes. Because of this, cognitive engagement is really indirectly examined and understood. By building on prior research, a rubric will be developed in the following chapter that takes outward actions of students and uses them to classify as either high cognitive engagement or low cognitive engagement.

Student response systems can be used for both summative and formative assessment. They are most effective when used in a constructivist approach not tied to grades. By increasing student participation and getting immediate data on responses from each student, they can further class discussions. These discussions fostered by the SRS can allow students to display high cognitive engagement as they interact with their teacher and classmates. The data allows both student and teacher to better understand how well students currently understand ideas. This information can be used by the teacher to focus class discussions on areas they are most needed.

Now, we will look at the methods used to complete this study. It will include a description of the population involved. The procedures detail how the SRS is used to employ it as a formative assessment tool that encourages high cognitive engagement. Additionally, a framework for the study is created from prior literature on design studies, grounded theory, and situated cognition.

CHAPTER III

METHODS

Now that the background literature on SRS, cognitive engagement, and teacher tools have been examined, the details of this study can be discussed. To begin with, the theoretical framework used by the researcher will be examined. This will allow the reader to better understand the perspective that was used while collecting and analyzing data. Included in this perspective are experiences and biases the researcher brought to the study. Next, the participants will be described including the students, teachers, schools, and courses. The details of these participants and the types of data collected on them allows for a deeper understanding when excerpts of the classroom data are shared. Two factors influencing the data are the amount of time spent in the classroom by the researcher and the teachers' goals that were at times in conflict with the study. Each of these factors will be examined in greater detail. Finally, the methods of data analysis will be discussed. This will include how the qualitative data was compiled and coded, how the quantitative data was analyzed, and the categories of data that emerged.

Theoretical Framework

Theoretical frameworks describe how a researcher "approaches the world with a set of ideas, a framework (theory, ontology) that specifies a set of questions (epistemology) that he or she then examines in specific ways (methodology, analysis)" (Denzin & Lincoln, 2003, p. 30). The framework comes from "concepts, terms, definitions, models and theories of a particular literature base and disciplinary orientation" (Merriam, 1998, p. 46). Theory is created by "the cognitive process of discovering or manipulating abstract categories and the relationships among these categories" (LeCompte & Preissle, 1993, p. 239). While theories are by there very nature abstract, they are based on quite tangible observations. To get from an observation to a theory, Anfara & Mertz (2006) use concepts, constructs and propositions respectively. Concepts "allow us to relate events in the past to ones in the present of future" (Anfara & Mertz, 2006, p. xv). A Proposition helps distinguish relationships between a group of constructs and a theory is a group of propositions that collectively give insight to observed phenomena This study is guided and influenced by theories in social constructivism, situated cognition, cognitive engagement, critical thinking, and learning theory. Together, these ideas can help to inform and explain student behavior with student response systems in secondary chemistry classrooms.

Social Constructivism

Social constructivism "emphasizes the importance of culture and context in understanding what occurs in society and constructing knowledge based on this understanding" (Kim, 2001, p. 2). It assumes "that individuals seek understanding of the world in which they live and work" (Creswell, 2009, p. 8). Where people live and work is not in isolation but instead people develop complex understandings of their world through interacting with it, including the other people in it (Creswell, 2009). As a teacher, I have noticed that each class period is a unique learning experience. I cannot just duplicate the exact same lesson for all of my class periods and expect identical results. What the students take away from it depends not only on what I say and my lesson plans, but also on each student's personal perspective in experiencing my class and the conversations that happen between each of these individuals. Under this view, meaning making always has a social component and the researcher makes meaning from data taken from that social context (Crotty, 1998). Because of this, social constructivists often look at how people interact and the context of those interactions (Creswell, 2009).

Researchers try to understand how the context and setting influence meaning making by personally visiting the site to gather data, though their interpretation of this data is influence by their own background and assumptions (Crotty, 1998). Personally visiting the site is crucial because a researcher's own experiences influence interpretations so the researcher should be situated in the research as opposed to viewing themselves as being objective and removed from it (Creswell, 2009). I believe it is important that as an educational researcher I be present in the classroom over an extended period of time during data collection. This lets me better understand the context and to observe this process of meaning making that students go through.

Situated Cognition

Sociocognitive engagement is an active, social construction of shared knowledge through verbal interchange (Hogan, 1999). This is useful in the studying of secondary chemistry classroom because of the conversations between students during science activities that can help the students build their understanding of science concepts. Each student does not complete an activity in a vacuum but is instead part of a classroom environment. Situated cognition informs this notion by viewing learning as participation where individual students contribute to the science practices of the class as a whole (Roth, 1995). To be able to view actions and link them to understanding, a detailed and continuous study of the students throughout the activity is necessary (Roth, 2007). Roth

(2007) elaborates on the continuous nature of learning in pointing out that "inward and outward cognitive activities are related to previous experiences that shape inward and outward action: actions and perceptions are guided by anticipations" (p. 132). As a student's classroom setting changes, it changes their experiences and thus what they will learn about the world. Therefore, in order to study what students learn during an activity, it is vital to pay close attention to the setting the learning takes place in. This setting is also unique to each student based on the world they live in, not a generic setting applicable to the entire classroom (Roth, 2007).

Critical Thinking

If teaching is to affect learning, the learner must be able to update their prior knowledge of a topic based on the teaching. In order to fully understand how students learn and how teaching can influence it, it is important to examine critical thinking. Kuhn (1999) describes critical thinking in terms of meta-knowing. In other words, a person who is aware of how he or she knows something is exhibiting meta-knowledge. Kuhn argues that critical thinking is key to learning because it allows the learner to be in charge of their own thinking and enables them to update their beliefs on topics based on new experiences.

Kuhn breaks down meta-knowing into three parts: metastrategic, metacognitive, and epistemological. Each of these parts can be further thought of in terms of the degree of meta-knowing and also the first-order knowing that is the object of the second-order meta-knowing (Kuhn, 1999). While metastrategic and metacognitive each have two levels, epistemological has four distinct levels, three of which are associated with lower-level critical thinking. Prior use of critical thinking in educational practice meant a "reasonable and reflective thinking concerning what to do or believe…, the art of thinking about your thinking…, thinking appropriately moved by reasons…, and thinking that can be accessed by appeal to criteria" (Kuhn, 1999, pp. 17-18).

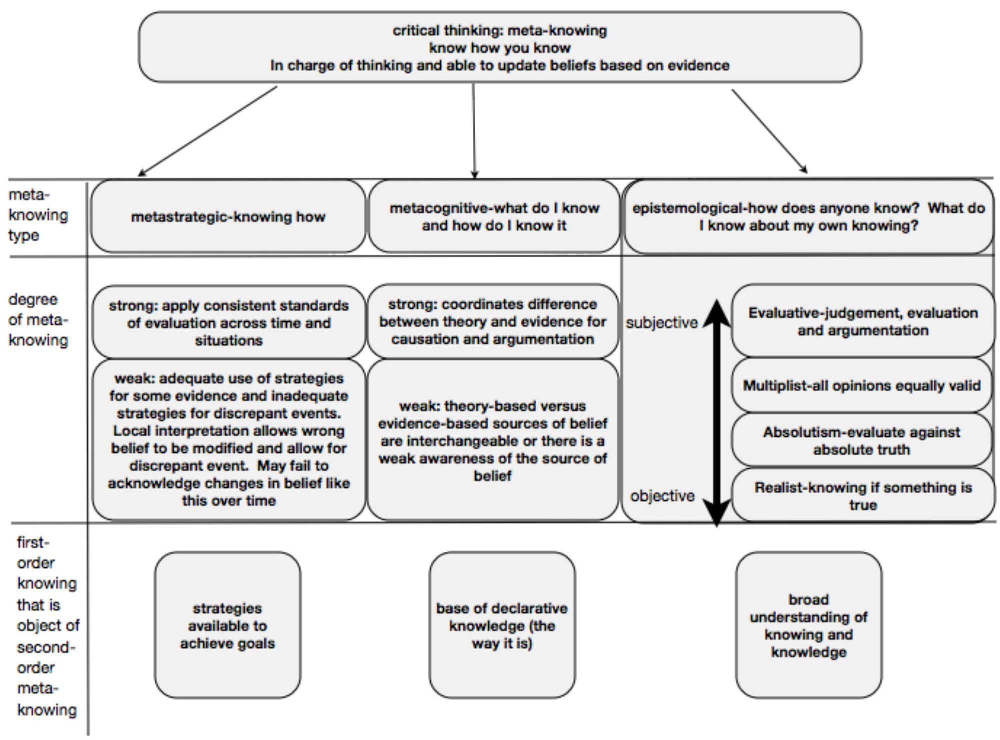

Figure 1. The Three Areas of Meta-knowing.

It is difficult for even some adults to use strong metastrategic strategies to update beliefs based on experiences (Kuhn, 1999). Instead, it is common to use some strategies that are adequate in this context for evidence that fits the belief and inadequate strategies for evidence that does not fit the belief. This combination of adequate and inadequate strategies causes new evidence to be combined with the old belief, even if the new evidence would seem to contradict the old belief. In this way, it is difficult to change the overall belief about a topic. From my own teaching experience, this helps explain why prior misconceptions can persist even when presented with a discrepant event designed to bring conceptual change.

In the same way, weak metacognitive skills for students will cause them to confuse theory-based and evidence-based beliefs. This makes logical argumentation and causation difficult. Additionally, the source of a belief is hard to ascertain with this uncertainty between theory and evidence. It is difficult to teach someone how to correctly organize theory and evidence to make accurate statements on causation and to structure logical arguments.

Kuhn describes four levels of epistemological thinking as opposed to the two degrees of metastrategic and metacognivitve thinking. The additional levels are a key component because they provide a more scaffolded way for educators to teach meta-knowing to students. While discrepant events can be explained away without changing the original belief in the metastrategic and metacognitive areas, in the epistemological area it can more easily cause students to question their current beliefs and update them from more objective to more subjective views. As students take on more subjective views, critical thinking becomes more valuable so they are better equipped to begin using stronger critical thinking in the metastrategic and metacognitive areas as well.

The realist is the most objective and has the the lowest level epistemological meta-knowing. This person is able to decipher whether or not something is true. The next stage progressing towards a subjective view is absolutism where experiences are evaluated against an absolute truth to determine if something is true or false. The third step is multiplist where all opinions are equally valued. While this is still lower level epistemological meta-knowing, it is a third step in a progression that most secondary teachers can get their students to. Presenting scenarios where even experts disagree on an issue can help students to see that absolute true and false is not sufficient to process all experiences. This can lead to the belief that since there is no right and wrong, all beliefs are valid. The final step is the evaluative one. To get here, teachers must help students see that while not all things are true or false, there are still methods to judge, evaluate, and argue for certain positions over others. Once students reach the evaluative stage, critical thinking is valued and this hopefully allows for more successful development of meta-knowing in the metastrategic and metacognitive areas.

The progression through the steps of epistemological meta-knowing is an important insight. It provides practical scenarios that a teacher can use to try and help students think more critically. More importantly, it provides a description of a progression students may use as they develop a deeper understanding of a topic. Instead of classifying students as either having learned or not learned a topic, this allows for a deeper description of where students are in the process of learning. It is, of course, only applicable to topics and activities that do require critical thinking. What is less clear is the degree to which being an evaluative thinker will lead to developing critical thinking in the other areas of meta-knowing.

Relationship Between Teaching and Learning

A personal goal of my own teaching is that those who are being taught will learn a certain topic. Additionally, when changes in teaching are made, subsequent changes in what is learned occur. On account of this, it sounds reasonable that teaching may cause learning. However, the very concept of teaching is dependent on the concept of learning and the fact that learning often follows teaching does not mean that teaching has a causal relationship with learning (Fenstermacher, 1986).

The problem with attempting to establish causation is that there are other key factors in the classroom affecting learning. As students learn, changes are taking place in their minds. These changes are based on classroom activities including but not limited to teaching (Nuthall, 2004). This makes sense because otherwise, a teacher could repeat the same activities all day with different classes and expect the same results, yet most teachers readily admit this is not the case. The same lesson taught in the same way to different students can produced wildly varied results. So, in order to establish any type of relationship between teaching and learning, a description of the other factors affecting the outcome is necessary. This includes the more difficult to observe student-to-student culture, relationships and interaction as well as individual student behaviors (Nuthall, 2004). This goes far beyond descriptive statistics and demographics of each class. A researcher must find out what the overall feel of the class is. Do they generally support each other, like to discuss, or work in groups? Does the class as a whole enjoying laboratory work and do they generally get along or are their divisions and definite groups of students within the overall class? Each individual level of friendship between students and the way that they work with each other is also relevant. Finally, the behavior of each student throughout each lesson must be examined. All of these factors combined make for complex data collection, which is why it is difficult for teachers to research their own classes. It also makes it more difficult to interpret the data than if a causal relationship between teaching and learning were assumed, but it does yield more accurate, and thus, more useful results.

Once these factors in the classroom are described, the more difficult part is to relate this to learning by seeking to understand how individual student experiences are influenced by teacher actions, how this is influenced by teacher-managed activities, student-to-student culture, and individual student behavior, and how each student makes sense of their overall classroom experience (Nuthall, 2004). This requires data collection far beyond observation of the teacher and then noting what the student learned from the teaching via posttest analysis. Instead, the other factors involved play a key role in what is learned.

Methodological Framework

Fies and Marshall (2006) identify three types of emerging instructional technology research in educational settings: foundation research, application research, and theory builders. This study is best informed by the theory building studies. Foundation research tries to form principles for use across settings such as motivation-usually not iterative due to reliance on control in experiment. Application research uses a particular technology in a specific setting or need for that technology. Theory builders focus on practical use as well as deeper understanding of how it is used and learning theories are emphasized over the specific technology. These typically focuses on both inward and outward aspects, seeking to inform the design of a knowledge building environment as well as informing broader relationships between teaching and learning. Often they lead to new questions about the technology and the learning theory. This type of research often appeals to practitioners wondering if they should adopt the technology more than researchers. Research questions often change over time in response to needs of environment. Design research is commonly employed as a methodology for theory builders.

Design-based research is a methodology that may prove useful to achieve this because of its focus on being embedded in real classes and on creating innovation that makes teaching more effective. "Design-based research methods is a term used to describe a particular stance taken to design- and intervention-based studies of learning in naturalistic settings" (Tabak, 2004). While there is a strong focus on creating detailed, long-term context of the learning, it is different from an ethnography particularly in the area of the design and intervention, though they both share a deep description of context (Tabak, 2004).

Design-based research can be broken down into at least four categories including developmental psychology, cognitive science, cultural psychology, and linguistic or cognitive anthropology (Bell, 2004). Developmental psychology design-based research uses a sociocognitive developmental perspective to understand growth in a classroom community and how causal relationships form between the growth and the exogenous and endogenous influences. The focus of instruction in this design is on responding to students' developmental differences more than a single way to teach the entire class (Bell, 2004).

Cognitive science design-based research focuses more on individuals and applying principles derived from laboratory research on cognition, which focuses on individual in laboratory setting and tries to apply to real-world design problems. The laboratory work leaves out any explanation of complex interactions that occur between people in a classroom. These studies often try to generalize due to the more controlled laboratory setting and assumes that it will work in lots of settings before those settings have actually been tested. In this way, they pursue "identification and application of universal laws of mind" (Bell, 2004).

Cultural psychology design-based research focuses on the microculture in the classroom where groups of students work together for an extended period. It attempts to sustain these communities long-term and attempts to be very localized and easily varied to meet the group's particular needs. However, it is difficult to apply theory developed from these to other areas since they are so dependent on that particular community (Bell, 2004).

Linguistic or cognitive anthropology design-based research is a "folk research orientation that investigates the manifested meaning of an intervention from the point of view of the participants of the research as interpreted through their activity and accounts" (Bell, 2004, p. 248). This approach to research seeks to promote the need to fit designs to local needs by carefully studying and documenting participants before, during, and after intervention. In this way, it blends with ethnography and may be thought of as design ethnography due to how it describes the participant's perspective in such depth over time. By giving this deep description of the experience of the participant, it may be easier to apply knowledge from this type of study to other similar contexts. It also sheds light on how theory mixes with practice so that it could be predicted how other theories might be implemented with similar groups of people, thus helping to bridge an area of theory-practice gap (Bell, 2004).

Brown (1992) is often credited with the first design-based research study. Brown was studying metacognition as knowledge about and control of one's own learning. The need for this type of study arose out of some problems with most training studies in that they were short-term, did not focus on type of teaching and was one-on-one, ignoring the social context of most learning in schools today (Brown, 1992). Brown felt that when studying a complex task, it is important to note degrees of comprehension and place value in alternative viewpoints over successful completion of a task. It was also shown to be difficult to study metacognition when the participant is asked to do arbitrary tasks out of the context of their life because their only purpose is to please the experimenter, which is unrealistic and not relevant to how they learn in the classroom and real life (Brown, 1992).

Classrooms are complex and by their nature have multiple variables that need to be taken into consideration when studying them (Tabak, 2004). Each student is unique and each combination of students in a class is unique so each time a lesson is taught it goes differently. Also, the type of content being taught to these students is an important factor because each student enters the class with their own set of experiences so the way they make sense of the new experiences depends on these previous experiences so the current lesson cannot be viewed in isolation. Design studies acknowledge this role of content and thus target domain-specific learning processes (Cobb, Confrey, diSessa, Lehrer, & Schauble, 2003).

Design based research methods are the method most appropriate to investigate how context affects teaching and learning (Tabak, 2004). It works on the idea that by creating and using interventions in actual classroom settings, more can be learned about the very nature of learning and the role context plays on that learning (Bell, 2004). Context is not just used to better understand the intervention in a design-based study but instead the context is used as part of the theory that is developed, making it different from evaluation research (The Design-Based Research Collective, 2003). Design experiments should be able to test embodied conjectures, conjectures of learning theory that are more laboratory based and lacking in contest, in an empirical way that lets them be accepted or rejected. In this way, the theory is made real and it is improved upon by the research in addition to the design (Sandoval, 2004). Moving to a more contextual and less controlled environment is a trade-off that allows for richer data in a more realistic situation, thus making the work more applicable to people in that particular situation (Brown, 1992).

Personal Connections, Experiences, and Bias

I have taught previously for four years in public schools in the same state in which the study took place. Over the course of that time, I have acquired increasingly refined beliefs on how a high school science classroom ought to run. Of particular relevance is my belief in the importance of relative order in a classroom. I generally expected my students to be on task during class. However, they were not necessarily seated at all times in an assigned seat nor was I the primary person speaking through the day. Another way that my classroom teaching has influenced me as a researcher is through the value I now place in discovery learning opportunities through labs. That was a part of my lesson plans at least once a week. The way that I run a classroom is not how all teachers will. Yet, I approach observations of classrooms with my own beliefs on what is the best way to teach a class that are based on what was successful for me. There are other effective strategies I did not use or that did not fit my personality. Still, my natural bent is to expect to see that which worked best for me and also to plan my study based on a classroom similar to what I had.

By its very nature, the study took place in a technology rich environment. At a minimum, each classroom had a set of student response systems, at least one computer, and a LCD projector. I have previous experiences teaching high school science in an online classroom for several years and I have also worked as a graduate assistant in an Education Technology Training Center. These times led to me being very comfortable using educational technology as a part of instruction. However, the teachers in this study did not have those same experiences. This is important to note because there are things I might feel comfortable doing with educational technology that the typical teacher is uncomfortable with due to lack of expertise or prior practice. One way this manifests itself is that I value using SRS to increase discussion between students while those first getting acclimated to the system might focus more on just getting the devices to record student responses. I believe it is important to foster discussion with SRS because that is what helps the device lead to increased student achievement (Barnes, 2008; Edens, 2008; Judson & Sawada, 2002).

Data Collection

In the fall of 2009, I sent out an email to all chemistry teachers at a county nearby. Due to time and resource constraints, I had time to spend up to three months observing teachers. In order to get a depth of understanding necessary for a design study, I limited the focus to two classrooms during that time. This allowed for an in depth view and still let me see multiple classes. For logistical reasons, it was easier to get approval in a single county and recruit the two teachers from there. After emailing the chemistry teachers in this county, four responded expressing interest. However, upon learning of the long-term nature of the study and my intended long-term presence, only two teachers agreed to participate. Thus, those were the two that I worked with.

I attended classes daily from January until early April. The first six weeks were with one teacher and the remaining seven weeks was in the other classroom. With each teacher, we met prior to class and worked to continually use the SRS in ways that would give students opportunities to show cognitive engagement. During the actual classroom time, I took field notes, videotaped relevant class time where cognitive engagement might be displayed, and compiled information from the SRS database file created by each session using the clickers.

The two teachers involved taught at different schools in the county. This county has only those two high schools in it. The teacher I was with first I will call Mr. Rein. He was in his 30th year as a public school teacher in Georgia and planned to retire at the end of the semester. The first 20 years of his experience were in another county and the last ten had been at this same school. The school had been the only high school in the community until about seven years ago. It serves approximately 1500 students per year and is in a rural setting. It is a Title I school that did not meet AYP last year due to low academic performance and also the low graduation rate of 72%.

Mr. Rein teaches on a 90 minute block schedule. He first has a planning period, followed by chemistry and then two blocks of physics. The chemistry class is the one that participated in the study. The school does not have multiple levels of courses such as honors chemistry or college preparatory chemistry. The course is not specifically a graduation requirement for students but it does count as one of the three sciences required. It is popular with those planning to go to college because many four-year institutions require applicants have chemistry in high school. Algebra II is a co-requisite. Because of the math requirement and the college interest of all enrolled, the class generally had students who exhibited interest in succeeding in the course. All students had grades of 60 or higher with 70 being the passing cutoff. So all students were either passing the course or had grades nearly in the passing range.

In terms of education, he got an undergraduate degree in biology and masters in science education. He began teaching biology but later moved on to physics, astronomy, and chemistry. While Mr. Rein has a personal passion for biology, he is not passionate about teaching high school biology. In fact, he said that teaching killed some of the excitement for him so he now prefers to teach chemistry.

Mr. Rein enjoys trying new things in his teaching. Throughout the school year, he was piloting a lab-aids textbook called A Natural Approach to Chemistry. He agreed to do this because of the free probe ware that comes with it and also because he is hoping to network with the vendors. Upon retiring, he plans to stay in the field of education so that makes him interested in networking with education vendors.

This teacher described himself as someone comfortable with technology. His local IT person entrusted him with an administrative login so that he could manage software installation for the department computers. Additionally, he had signed up for a Promethian interactive whiteboard that was set to arrive shortly after my data collection in his classroom ended. The school got ten interactive whiteboards and was assigning them to those teachers who were most enthusiastic about them. Mr. Rein had no prior experience with SRS but had seen some student teachers use them in neighboring classroom, which got him interested in my study.

In terms of classroom management, Mr. Rein is very organized and the classroom runs in an orderly manner. He does not use strict rules such as assigned seats and requiring students to raise hands to receive permission to speak. However, he is able to subtly create an environment where the students generally do stay on task and follow his requests. Students come in and sit in the same spots daily. It is rare for someone to interrupt another speaker or for the whole class to get too loud. At no point did I see Mr. Rein raise his voice.

Mr. Rein always has the agenda for students on the left side of the board. On a typical day, he quickly takes roll, explains the first activity and gets students working. Labs occur multiple times per week. The class changes activities at least every thirty minutes so that during the 90-minute block period, students have a variety of opportunities to learn material. Teacher-led discussions are common. Every few minutes he will pause to ask a question. At times the class will shout out the answer while at other times he will randomly select a student name from a stack of index cards to call out a person. During quantitative lessons, it is common for groups of students to come to the board to write their work down followed by a class discussion on both the methods and the final answers reached.

The second teacher in the study will be called Mr. Harrick. His school opened in 2003 as the second high school in the same county as the first school in this study.. It serves 1692 students and is a Title I school. It did not meet AYP last year due to low test scores and also the low graduation rate of 78%.

Mr. Harrick has been at this school for several years. He has an undergraduate degree in molecular biology and a master's degree in science education. During the semester of the study, he ended up teaching three physical science courses. The original schedule when he agreed to the study included a chemistry class but that was changed between fall and spring semesters. He never received a reason for the decision. In other semesters, he has also taught a scientific research class. That is a real passion of his and he is often trying to recruit students for it. It did not have high enough enrollment this semester but Mr. Harrick is hopeful the school will be able to offer it in the fall.

The physical science course is a basic graduation requirement at the school. Several students in the class had previously failed the course, some had even failed with Mr. Harrick previously. The science portion of the Georgia High School Graduation Test focuses heavily on content from physical science and also biology. These two courses also have standardized state created End-of-Course Tests. Mr. Harrick's top instructional goal is to prepare students for each of these exams. It is more common for college-preparatory students to enroll in chemistry and physics instead of physical science. Therefore, those in physical science are not as certain that they would like to attend college after graduating from high school. While most students participate during class time, four students in the course show little to no interest in passing the course. They do little work each day and sleep often. Mr. Harrick does not encourage them to participate and is pleased when they sleep because he finds them less distracting to the others in the class who are more interested in working.

In terms of teaching style, Mr. Harrick prefers to teach the minimum content required by state standards in courses. This is not necessarily defined by what the standards call for but instead on the depth he sees in standardized tests. For example, when discussing density in physical science, the class goes through the basic equation of mass over volume. However, no practice problems are worked where the equation is rearranged to solve for mass or volume. This is because, in his experience, the state End-of-Course Test typically just has students solve for density given mass and volume.

Classroom management is important to this teacher. He demands order, but not necessarily silence. Students are almost always seated and each desk is numbered corresponding to names on a seating chart. An unusual characteristic is that Mr. Harrick does not like to directly answer student questions. It is important to him that students be in a regimen where they find their own answers. When students ask him a question, he will refer them to places in their texts and notes where the subject is covered.

Mr. Harrick is comfortable with technology. He has his own personal laptop and LCD projector hooked up at all times. The school provides a desktop computer but he prefers his own laptop because of additional software he has. A limitation of his personal computer is that it cannot get online so when internet access is needed, he connects the projector to the school computer. The school computer, conversely, cannot have software installed on it so the CPS program associated with the specific SRS model used could only be run on the laptop.

Each day, the class begins daily with students getting out their notebooks and adding additional items. The teacher projects a word processing document with a numbered list of items that should be in the notebook. The items are numbered chronologically. If a new item is presented that day, he types it in, names it, and either hands it out or instructs them on creating it. These notebooks are not collected but he will ask for them to turn in items by assignment number. So, for example, he might tell the class to turn in assignment 55 instead of asking for section 3 homework. Quizzes are given weekly every Friday on whatever was covered in class unless a test is given that day. These decisions are based on his belief that his students will do better with structure and are likely to forget things over the weekend.

Influences on Data Collection

The instructional style and classroom needs of the teachers affected the design in each class. While I as the researcher had a primary goal of finding ways to use the SRS to facilitate high cognitive engagement, the teachers continued to have their same instructional goals they had prior to the study. My goals were combined with theirs or at times seen as a supplement. Because of this, the sole focus on a given day was never my goals but instead how we could partner together to both achieve our goals.

With Mr. Rein, he already had several methods he used to formatively assess students. His interest was more in encouraging students to figure out how to find the right answers than it was on seeing how cognitively engaged they were. While he was supportive of my aims, lesson plans and actual practice in the classroom ultimately reflected his goals.

Mr. Harrick is less organized than Mr. Rein. This meant that Mr. Harrick did not already have plans to use the SRS in a particular way each day so he was more flexible on how we would theoretically be willing to use the SRS . However, his lack of organization meant that it was difficult to plan and implement the types of uses I had in mind. Also, his top priority was student success on state standardized tests. The types of questions he wanted to ask students with the clickers were focused more on this test preparation than the ones I suggested. Regardless of question type, when the results were obtained, they rarely influenced his future teaching plans. This highlights his focus on rote learning for standardized test questions. If students did not get the right answer, and there was almost always definitive answers with his questions, he felt it best to focus on what the right answer should have been. Mr. Harrick did not value spending time determining why a student selected their answer.

Time Spent in the Classroom

I spent about six weeks in each classroom. This included all class meetings even if the SRS were not used that day and the visits were for the duration of the class period. This length of time I was present had several affects on the data collection. The students, teacher, and myself all became familiar with each other and the SRS.

It is not uncommon for a high school class to have the occasional visitor such as an observing administrator, student teacher, or researcher. My long-term presence allowed students to see me as a regular part of that particular class. This was beneficial because they were able to be comfortable and act as they normally would instead of possibly feeling the need to act differently while being researched. Both teachers confirmed throughout the study that their students were acting as would be expected even if a researcher were not present.

As the researcher, I also had an opportunity to become comfortable in each classroom. During my observations, I was able to see classroom norms both with and without use of the SRS. The way that students behaved and interacted with each other was easily observed. Additionally, the teaching style of each instructor quickly became apparent. In Mr. Rein's classroom, he used a variety of assessment tools including some with random selection. Meanwhile Mr. Harrick did not place as much value on student input. Thus, the integration of the SRS was a more natural transition for Mr. Rein than it was for Mr. Harrick. Having insight in these areas allows for a deeper understanding of how the class interactions with the SRS related to their typical behaviors.

Both of the teachers in this study stated that they quickly became comfortable with me in their classrooms. There are both positive and negative aspects to this familiarity. It was beneficial when the teachers seemed to freely share their teaching philosophies, instructional plans, and ways they wanted to see the SRS used. A trust developed that resulted in my being able to occasionally write SRS questions to be used in class time. However, this increased familiarity also meant that over time teachers were less worried about using the device in the way I advocated.

During the course of the study, I became a normal part of the classroom. Students were not surprised to see me because I was always there for that class. It was common for students to ask me a variety of questions ranging from procedural classroom related inquiries to personal ones about my family life. This indicates that students felt comfortable with me being present in the classroom. If they were not comfortable with me being present, I suspect they would have not verbally interacted with me much. The first day that I was present in each classroom, the teacher introduced me to the class as a researcher who would be studying their use of SRS. In each case, I was then given an opportunity to say a few things about myself. I told the classes that I had previously taught chemistry and physical science in local area high schools for several years. Next, I discussed the doctoral degree I am working on at the nearby university and how their participation in my study related to my degree requirements. Because the students knew from my initial introduction to them that I have a background as a high school science teacher, this led to their asking content specific questions to me when the teacher was helping someone else or I was just closer. Additionally, they know that I am paying attention and even taping portions of class, so sometimes they would get clarification from me on procedural aspects of the class such as when an assignment was due. Surprisingly, some even showed interest in me as a person when they would ask basic personal questions about my family and future career plans.

Over time, the students and teachers not only became comfortable with my presence, but also with the SRS. From my own experiences in the high school classroom, the first few times a class interacts with a new piece of instructional technology, the focus is often on the device itself more than the content being taught. As the students began using it several times per week for several weeks, the novelty of the device itself wore off and it became seen as an instructional tool that is a regular part of the classroom. In the same way, both classes already had LCD projectors that were used almost daily, so when the teacher projected something from the computer, it was not something that impressed the students or in any way distracted them.

Analysis

Grounded theory and constant comparative analysis both influenced data collection and analysis. Charmaz (2003) views grounded theory as having either a constructivist or objectivist approach. Constructivist focus on the phenomena beings studied with data and analysis being a shared experience of the participant and researcher as well as their relationships together. In this sense, the method is a tool for knowing. Because of this, the researcher immerses him or herself in the study. Data analysis is a construction of both the events and context and also the researcher's reflection on those events and context. Because the researcher is immersed in the study, analysis is constantly occurring. In contrast, an objective grounded theorist tries to remain distant from the participant to get an objective view of the experience.

The immersive constructivist view is more appropriate for this study based on the inherently active role of the researcher in a design study, as will be discussed in the methodological framework section. As a former chemistry teacher, it would be unrealistic to try to ignore my own beliefs about effective teaching in this subject. Instead, my beliefs helped me to be more knowledgeable about the teaching environment and more aware of the issues to look for as I collected data. While my background was an asset in this regard, I had to be cautious about how it influenced my findings. It is important that my own biases not lead me to look for data that just supports my beliefs, which would keep me from seeing possible themes outside of my own preconceptions (Ezzy, 2002).

The continuous data collection and analysis by the researcher make constant comparative analysis an appropriate tool. With this type of analysis, as each piece of data is coded, the researcher compares it to previous data with the same code (Glasser, 1969). In this way, analysis and coding occur simultaneously. Repetition of this process leads to the emergence of themes (Avery & Meyer, 2007). Eventually, enough comparisons occur that the codes have more identifying traits. Then, data is compared to characteristics of a code instead of other singular pieces of data.

The transcripts, field notes, and SRS database were coded for themes as they were collected. This was managed through software called HyperRESEARCH that puts all data into one database. Codes are created and then applied to appropriate pieces of the data. Multiple codes can be applied to the same data. After coding, a particular code can be selected to bring up all pieces of relevant data. Throughout the process, research questions, codes, and themes were continually reassessed. This was possible because data analysis was happening during data collection. In this way, the codes and themes had to emerge from the data instead of using preconceived ones (Charmaz, 2006).

After transcribing the teacher discussions and class sessions, analysis began by coding the data. Codes were developed as the data was reviewed and themes emerged. Student actions related to the SRS were evaluated to determine if they showed high or low cognitive engagement. To do this, a rubric was developed as shown below in Figure 2.

	generative thinking- ability to generate answer without ready made solution	**nature of explanations**	**asking questions**	**metacognitive activity**	**approach to task**
high cognitive engagement	Elaborate, richly descriptive with specific examples and references to real life. Interconnected. Stubborn and tenacious defense of ideas. Actions seek to solve problem. Sociocognitively collaborative.	Microscopic explanation based on non-observable entities as well as cause and effect. Macroscopic explanations referring only to what is visible. Stubborn and tenacious defense of explanations. Sociocognitively collaborative in development, used to solve problems.	Questions show wonderment, appreciation, and extend ideas to multiple sources outside of specific context currently used. Sociocognitively curious and tenacious. Sociocognitively collaborative. Seeks to solve problems, asks for help solving the problem not just in getting the answer.	Self-evaluate ideas ("I get it now"), recognize failure (I'm getting confused on..."), self-correct, considers range of ideas	Sociocognitively expedient. Stubborn and tenacious. Multi-focus of ideas. Manipulates variables to determine relationships. Persistent following up on ideas. Talks above procedures and observations, focusing more on concepts. Puzzles on information not understood. Generates own ideas for cause and effect relationships instead of relying on external sources.
low cognitive engagement	Evasive, related to question but does not actually answer it. Does not generate solution but instead says something like "I don't know."	Reformation without causal mechanism or of a black box variety. Sociocognitively passive with few verbal contributions.	Procedural or textbook based with simple solution. Basic, factual questions requiring only recall to answer. Sociocognitively passive with few verbal contributions.	Follows procedures without seeking to understand why the steps are required/ suggested. Relies primarily on memorized facts. Sociocognitively passive with few verbal contributions.	Quickly gives up on ideas. Non-sociocognitive/disruptive or sporadically contributes. Ignores information not understood. Off-task behavior. Relies on external sources. Single focus (such as on doing an activity but not what it means or why it is being done). Talk on procedures and observations only.

Figure 2: Rubric to evaluate student actions in terms of cognitive engagement

The codes developed generally relate back to the research questions presented in chapter one. To review, these are the research questions that were in use:

1. What are the traditional tools used by participant teachers to assess student engagement?
2. In what ways can an SRS serve as an additional tool for teachers to assess student engagement?
3. From the students' perspectives does use of an SRS provide them with opportunities to demonstrate their engagement not available in classrooms without the SRS?
4. How do the teachers' tools for assessment of engagement possessed prior to the introduction of SRSs impact their willingness to adopt new systems?
5. Given SRS adoption and usage over time, do teachers shape instruction to optimize the benefits of using the SRS?

Initially codes were based more on how data related to the research questions but that was refined upon each review of the data. Seven codes emerged from this constant comparative process. The codes are: SRS general, SRS cognitive engagement, non-SRS assessment tools, class characteristics, teacher characteristics, student perceptions of SRS, and non-SRS cognitive engagement. Each of the codes is shown below in Table 1 along with an explanation and example. In the example column, some class transcripts are shown. The T indicates a teacher was speaking, S symbolizes a student, and R is the researcher. The numbered days of observation and data collected each day are listed in Appendix A.

Code	Explanation	Example
SRS general	Any data collected while SRS were actively used or discussed	"T: All right, a lot of you chose a popular number, someone tell me why you chose A up here. S: That's the mole, the one I

		recognized. T: What is the definition that gives you this answer?" (Day 11 class transcript)
SRS cognitive engagement	Data related to the SRS that might give insight into cognitive engagement of students	"T: This is all for bonus anyways. OK, on this next one we should be at 100 percent, and we are. What is our clue that this is exothermic? S: Reactants are on top. T: There are more energy is reactants than products, very good." (Day 29 class transcript)
Non-SRS assessment tools	Data that involved the teacher discussing or using assessment tools as a part of their normal teaching without the SRS	"T: You knew this one, tell me what you were thinking, how did you know this was right S: Because the average, I don't know, because Tyler told me." (Day 11 class transcript)
Class characteristics	Observations and other data that describe the structure, attitude, or norms of either teacher's classroom	"Class is disciplines and working with out lots of explicit effort by him Students are free to ask him questions, a passive measure" (Day 3 field notes)
Teacher characteristics	Observations and other data that describe the teacher's instructional style, beliefs, and attitudes	"Before class, teacher said that he doesn't answer student questions, it is important to him that they be in a regimen, so he will refer them to places in their text and notes that the subject is covered. Also, they can expect some type of summative assessment every Friday." (Day 16 field notes)
Student perceptions of SRS	Data indicating student attitudes about the SRS. Derived from student comments during class and	"S: It is nice not to have to worry about erasing a scantron where it might mark things wrong.

	the semantic differential instrument	T: For me there is no answer key to make.” (Day 25 class transcript)
Non-SRS cognitive engagement	Transcripts and class observations that give evidence of the cognitive engagement of students while SRS were not used	“S: We don't have to fill the whole chart with elements right T: It asks you to come up with three on your own so just put a few there.” (Day 8 class transcript)

Table 2. Data codes, explanations and examples.

The results of self-report by students on the semantic differential instrument were analyzed by taking the mean response for each statement. Each class was kept separate to see if perceptions varied between them. The results from this were then combined into a summative graphical presentation where each statement is essentially a point in a graph. The points are then connected to give a visual representation for overall student perceptions of the SRS.

Conclusion

In this chapter, the theoretical framework influencing the study was examined. This included social constructivism, situated cognition, critical thinking, and the relationship between teaching and learning. Following that, the methodological framework was built from prior work on design studies. My own bias, experiences, and connections to the research were then discussed. This helps to show how my own experiences help customize and personalize the theories and literature in my framework.

Data collection and analysis have also been described in general. The teachers and classes in the study have been introduced. An overview of data analysis was presented beginning with a general discussion of grounded theory and constant comparative analysis then moving towards specific applications for this study. The data, analysis and what is learned from it are discussed in more depth in the coming chapter.

CHAPTER IV

DATA ANALYSIS

In order to give the reader a sense of how the results of this study are interrelated, the findings will be presented in a rough chronological order. Using this plan for the presentation of the findings, I hope to show how the findings related to each research question began to emerge across the weeks of data collection during the research. The instructional implementation of an SRS tool (i.e., clickers) is the overriding topic of this research study, but the non-SRS instructional tools used by the teachers were also important to this study. Each of the teachers had a variety of non-SRS instructional tools that were in-use for classroom purposes and some of these tools were ultimately substituted for with the adoption of the SRS tool. Teachers' initial perceptions of how they might use the SRS tool were recorded but it became clear that experience with the clickers was the most important shaper of their further instructional use. Ultimately, the data collected about the student use of the clickers did provide insight into the students' cognitive engagement. On the final day of data collections, students in the participating classes were given a chance to state their perceptions of how the clickers were and were not aids to their learning of science. The sections will be discussed in the following order: teacher assessment tools without SRS, initial teacher perceptions about SRS, evolution of SRS usage over time, SRS for cognitive engagement, and student perceptions of SRS.

Teacher Assessment Tools Without SRS

Before looking at teacher use of the SRS, it is important to first understand the student learning assessment tools employed in the teachers' normal teaching. The research focus of this subset of the findings is focused on verbal interactions between students and a teacher. However, non-verbal student actions such as nods of comprehension, looks of confusion, student engagement through eye-contact, having proper supplies out and completing work are all used by the teacher to formatively and informally assess students. This non-verbal data was not the focus of data collection, but Mr. Rein uses this information to guide his own classroom actions and in this way it served as one of his assessment tools.

Because each teacher in the study being reported here had a unique instructional style, the findings with regard to each will be presented separately. When relevant, the assessment tools are broken down into the size of the group they are used in. For example, some tools were used primarily when the teacher was speaking to the entire class, other tools were used when the teacher was working with a small group, and a third set of tools were most often employed in a one-on-one interaction between a student and the teacher. Within the classroom environments, some assessment tools involve the teacher action initiating student action, whereas others involve the student initiating action without a teacher prompt. Even when students initiate contact with the teacher, often the teacher has carefully crafted the environment that fostered the student action.

Mr. Rein's Assessment Tools

While interacting with the class as a whole, Mr. Rein often initiates contact with students with a variety of tools that elicit responses from students who are not randomly selected. These non-random tools allow students to report back specific content information, share information on a mathematical problem the class is solving, or gauge the comfort level of students solving a problem.

When discussing new scientific content, Mr. Rein often begins with a classwide discussion supplemented with notes on the board for students to copy. While he talks, he will often pause to allow students to complete his sentences or he will ask questions about the content he is introducing. Those completing his sentences or answering his questions may do so without being called on, and this can include more than one student simultaneously chiming in. Those who are interested in speaking in class take advantage of those opportunities when no one is called. At other times, a specific student is called on to complete the sentence. The students that he calls on may have been selected for a number of reasons. For example, he might be trying to get a student who has gotten distracted to become refocused or he might ask someone who does not often volunteer information to answer. These types of interactions were very common in the class, happening daily and often many times per day.

In all transcript notations, T stands for teacher and S for student. Contextual notes are provided in brackets. When a name is listed after the S notation, it indicates that a specific student spoke. The student name is a pseudonym that is used throughout the transcription to keep student identity confidential. When a number is given after the S notation, it indicates that a different student spoke but that it was unclear which person it was. The numbered students remain the same during a single conversation. So, S5 is the same person through a single day's transcript but S5 on a different day is likely another student. When a blurt is referenced, it denotes that a student responded without being called on.

The following exchange between Mr. Rein and several students from early in the data collection shows several of these common assessment tools used during whole-class discussions. In this class session, the teacher is lecturing on how to make best-fit lines from class density data collected the day before.

“T: Does everyone have two lines?

[Several students say “uh huh.”]

T: What do lines show?

S: As one goes up so does other. [This student was not specifically asked to speak.]

T: Right and with algebra we can be more specific about how much it goes up we can take the...[Waits for response.]

S: Slope. [Random student blurts]

T: Right, let's do that. What is the way to find slope...Courtney?

S: Rise over run.

T: It is. What is another way, Sam, oh your busy, Gabby [no response] not sure? Well there is change in y over change in x or y2-y1/x2-x1.

Have you seen this before? [A few students say “Yes.”]” (Day 4 transcript)

In this example of a fairly common exchange between teacher and students above, several of the learning assessment tools already described are displayed. First the teacher asks a question and allows several students to answer in the affirmative. As is often the case, Mr. Rein takes a response from a few students and applies it to the class as a whole.

He assumes that because a few students have indicated they are ready to move on, that the whole class must be ready to move on. Following that, he asks another question and one student offers an answer. Another student then completes one of his sentences. Several specific students are called on to answer questions and when one cannot, Mr. Rein moves on to another person. In this exchange, there is really no apparent method to why certain people are called on. While Tobin & Gallagher (1987) found that high school teachers often called on student who will have the most to contribute to a conversation, Mr. Rein often called on those students who did not know the answer or had little to add to a class discussion.

The mathematical nature of a high school chemistry course means that often the class is working on quantitative problems. Mr. Rein typically has the class work through new types of problems together initially and then gradually lets the class work more independently. While the teacher is working through a problem on the white board, he may pause to ask for a next step or explanation for why he did a previous step. Upon finishing an example, someone may be called upon to report a specific answer. After students have seen a problem worked out, Mr. Rein may also stop to give students an opportunity to ask any questions they have. In this setting, we again see a variety of methods employed to decide which student responds. Sometimes Mr. Rein calls on a specific student while at other times he ask a question and lets anyone in the class respond. The dialogue below is from a lecture on the concept of the mole.

> “T: I think we should do another, can somebody just put your hand up, give us another good mole to mass problem? Can be a compound or element.
>
> S: How many moles is in 24 grams or uranium? (students quietly solve problem)

T: Mike, did you get the answer yet?

S Mike: Not yet.

T: Can you tell me what goes in parenthesis?

S Mike: 38.00

T: Where does it go?

S Mike: Not sure.

T: What about you Rita? Where does it go?

S Rita: On bottom." (Day 10 transcript)

The above example shows a four of the common assessment tools employed by Mr. Rein. In the class dialogue, there is initially an opportunity for any student to speak up and give an example problem to solve. Following that, specific students get called on to answer a series of teacher questions about the sample problem. At the end of the transcript, Mr. Rein asks the class a few questions and lets several students simultaneously blurt answers, then calls on another specific student. As is typical for this teacher, some of the specific students were called on because they were not paying attention. This redirects the students. Others were called from the large percentage of students who were sitting quietly, attentively completing work and making eye contact. When one of these quiet, attentive students was called on, there was not a discernable pattern or method of how one student was selected over the others. This method of calling on specific students was not as systematic as his random student selection tools with index cards that will be discussed later.

Another area where Mr. Rein uses a variety of assessment tools is in gauging the comfort level of his class. While completing a problem in front of the class on the whiteboard, it was common for him to stop and ask if everyone is doing OK. Unless someone said no or asked a question, he would continue on with the problem. After finishing an example, he would also sometimes ask how comfortable the students are solving a problem of that type. Those questions would usually be left open-ended so that students in the class got to decide how to respond. At times, one or more students would chime in. At other times, several students in the class might just nod to indicate that they were comfortable solving that type of problem.

Occasionally, after asking the class how comfortable they are with a concept or solving a type of problem, Mr. Rein would poll the class. In this way, the teacher provided more structure and guidance to the class on how he was hoping for people to respond. In Mr. Rein's polls, students would raise their hand if they felt comfortable with the material the class had just discussed. This method allowed the teacher to get input from the whole class at once. He would then use that information to decide if it was time to move on to another topic. When there were several students in the class who were not comfortable, it was common for Mr. Rein to stop and ask additional questions so that he could better understand what problems the students were having with the new material.

The previously mentioned assessment tools all use non-random student selection. In them, Mr. Rein decides on a student to call on, lets anyone answer, or ask the whole class to answer. Allowing anyone who volunteers to answer might at first seem to be a random method. However, only about a quarter of the students in the class ever answered in this type of situation where they had to volunteer to speak this method essentially targets the group of students likely to respond. The teacher did have a few random student selection methods that he integrated into his assessment tools. He kept a set of index cards on his desk, each card with a different student's name written on it. These would be periodically shuffled and then a card would be randomly selected to decide whom to call on. Students selected with the index cards could be called on for a variety of tasks such as being asked to finish his sentence, answer a question, come show work to assigned problems, or ask for the next step in a problem. The index card as a student selection tool is highlighted in the transcript below. The conversation with Abby was initiated with the random selection of her name and then it continues with several follow-up questions.

> "T: Let's turn this question around to a mass to mole question. Think to yourself, what is a question like this. Tell me what to write Abby (selected from index cards).
>
> S Abby: How many moles is yadda?
>
> T: OK, give me a yadda.
>
> S Abby: How many moles is 16 grams.
>
> T: Grams of,
>
> S Abby: Carbon
>
> T: There you go, write down the question and then solve it." (Day 10 transcript)

The non-SRS assessment tools we have seen so far for Mr. Rein focus on things he initiates. Additionally, he creates an environment where students are free to initiate dialogue and ask questions when they do not understand. This environment is fostered by Mr. Rein when he occasionally asks the class as a whole what they need help with. Another common technique for the teacher was to ask students to raise their hand if they have a question with what the class had just discussed. Another type of student-initiated conversation is when students ask him a question without any type of direction or invitation from him. Teachers can create environments where students feel more welcome to ask questions, but ultimately this type of dialogue is outside the teacher's control and thus was not a focus of data collection.

Small group and individual interactions

At least twice a week, Mr. Rein had students work in small groups spread out across the classroom. Often the groups were selected using his set of index cards, and thus were another example of random assignment. The small groups completed labs but also collaborated on other class assignments such as solving problem sets. In this environment, Mr. Rein used three variations on the assessment tools from whole-class interactions that were discussed earlier. He would walk around the classroom to monitor student work and conversations. The first small group assessment tool was to ask the members of a group questions about why they had done work a certain way. For example, if students were solving a stoichiometry problem, he might look over their shoulders and ask them why they had done a gram to mole conversion. The second tool was to give the class advanced notice of what he would come around to discuss with them. That could take the form of a question to answer or notice to be ready to explain why their work was done the way that it was. The third tool was student-initiated. Mr. Rein would walk past small groups talking to each other and students would often ask him questions as he passed by. This provided a more private environment for a student to ask a question because most of the students would not be listening to the question asked.

In the following example, the class is working on concept maps of the vocabulary terms in a unit on energy. Before being split into groups using index cards to select group members, Mr. Rein informed the students that each group would be asked to explain why they had arranged their vocabulary terms the way they did. The conversation between the teacher and a student illustrates a common small group interaction for the class. In this specific case, the student has attempted to state that temperature and specific heat are synonymous.

> "T: If they were at the same temperature, what would be different about the two things?
>
> S: The masses.
>
> T: Well, let's say they have the same temperature and mass. What would be different about them?
>
> S: Specific heat
>
> T: Right, so what other thing will be different, if they are the same temperature, same mass and have different specific heats?
>
> S: The material itself is different.
>
> T: What do they do different from one another based on specific heat?
>
> S: The amount of energy.
>
> T: That's exactly right, the amount of thermal energy is different because they have different specific heats.
>
> S: So, the one with the higher specific heat is a better conductor?
>
> T: I don't know if it is about better or worse conductor, it is about the amount of heat that can come in or go out of that material." (Day 16 transcript)

The above dialogue shows Mr. Rein walking the student through a progression of questions. The result is that the student states that objects with different specific heats have absorbed different amounts of energy if their masses and temperatures are the same. In this way, Mr. Rein has challenged the student's original notion that temperature and specific heat are synonymous.

Mr. Rein's assessment tools in large group, small group, and individual settings have been explored. These employed both random and non-random student selection. After completing observations in Mr. Rein's class, I had a discussion with him to debrief. In this talk, he described his own view of his assessment strategies.

> "R: In what ways do you assess student engagement while teaching without the clickers?
>
> T: Engagement is very subjective, but I try to assess it via my eyes and ears. Do students have important material in front of them? Book, notebook, calculator, et cetera. Are they writing information I feel is critical? Are they using their calculators in tandem with me? Are they talking to one another about chemistry content? Also, I am listening for noise level and noise type. There is a difference between productive noise and non-productive noise both in volume and in character. Regarding the character of the noise, it is very subjective, but I know it when I hear it." (Day 22 transcript)

Mr. Rein's response indicates that he views his own tools in a more limited and less systematic way than what I observed. He is not always aware of all the ways he is gathering information on student progress and comprehension. The focus of the tools described was on traits observed during class. An addition tool that did not exhibit itself then was the use of homework. Mr. Rein assigned homework almost daily and always graded all parts for accuracy. As he graded, he was then aware of what parts students were struggling with. That information could then guide his future lesson plans. This area will be discussed in later sections relating to the SRS. Now that Mr. Rein's non-SRS assessment tools have been examined, the non-SRS assessment tools used by Mr. Harrick will be described.

Mr. Harrick's Non-SRS Assessment Tools

Mr. Rein interacted with his students while they were in large group, small group, and individual settings. Conversely, Mr. Harrick's teaching style featured primarily whole class interactions and fewer types of assessment tools. He would rarely interact with students during small group work. Instead, the students were expected to complete assignments independently during that time while he worked at his desk. If students had a question, they could ask, but he did not initiate conversations with them. Instead, the only thing used to assess students during that time was the written work submitted for grades. Even then, those assignments were graded only based on completion and not for accuracy. Because Mr. Harrick primarily interacted with his class as a whole and not in smaller groups, his assessment tools are only used in whole class settings. This contrasts sharply with Mr. Rein's use of small group and individual interaction in addition to whole class discussions.

The assessment tools used by Mr. Harrick appeared in four main actions initiated by the teacher: asking questions, asking students if they have questions, asking for students to raise hands as a response, and inviting students to the board. Each of these will be described in more detail in terms of how the teacher used the tool, the ways students could respond, and what the teacher did with the received student information.

Lectures were a common teaching style for Mr. Harrick. He would usually remain behind his desk, occasionally write notes on the board for the class to copy, and every few minutes he would stop to ask a question. Sometimes a specific student would be called on to answer but the most common method was to allow anyone to respond. If no student responded, he might answer his own question or move on without providing an answer at all. The response from a student was typically either validated or corrected quickly and then the teacher would return to his lecture topic. The following discussion shows a common student teacher exchange:

> "S: Mr. Harrick, so the greater the distance on the periodic table, the more ionic?
>
> T: Yes, I am going to draw and tell you exactly what I am looking for.
>
> S: Oh, I got it.
>
> T: You are getting smart. This is going to be fact. Any group one or two element bonded to a group 16 or 17 element makes an ionic compound." (Day 28 transcript)

Notice how Mr. Harrick quickly confirms that the student was correct and then discourages further questioning by telling the class that he is about to tell everyone exactly what to write down. The teacher strongly disliked being interrupted when he was trying to write notes on the board. He also seemed to get easily distracted and had trouble getting back to his notes once distracted so that may partially explain his disdain for any disturbances from the planned lecture. The following exchange shows Mr. Harrick going through a series of questions that are primarily answered by one student, Lizzy.

> "S: Is this supposed to be anti-ion?

T: No, it is anion, an anti-ion would destroy any ion, like matter anti-matter. Are these very strong bonds?

S Lizzy: Yes.

T: These are very strong bonds. [students write silently]. How do we know they are strong bonds?

S Lizzy: It has to do with what group they are in.

T: Close, remember how I said we put dangerous ones together to make salt.

S2: Wait, I have a question about that first part.

T: Not yet." (Day 28 transcript)

When the second student tries to ask a question the teacher essentially does not allow the question. Mr. Harrick says not yet, but there is not a point when the student is permitted to go back and ask the question. The question was viewed by the teacher as an interruption. The teacher did not usually respond well to these interrupting questions. Instead, the responses can be characterized as short, negative, and discouraging of future disruptions. There was some patience on the part of the teacher in that the students who were talking were allowed to progress through a series of questions to better understand the class notes. The presence of dialogue was dependent on Mr. Harrick. If he did not want it to occur, he gave a short answer and moved on. However, when he wanted a dialogue, he was able to progess through a series of questions with the class.

While lecturing, Mr. Harrick would sometimes stop and ask if anyone had a question. If a student did have a question that he answered, it was initially coded as a teacher assessment tool. During the coding process, three distinct types of responses from Mr. Harrick emerged. First, he might just quickly answer the question in a few words and move on. Second, he would direct the student to where they could find the answer, such as what page to check in the textbook. His goal in doing this was to teach his students to answer their own questions. The third type of answer involved having a patient dialogue with the student to help the child better understand the topic of discussion. This conversational approach was rarely used.

A third assessment tool used by Mr. Harrick involved student "hand raising." He would ask the class a question and then ask the class to respond by a show of hands. This technique was used in to ways by Mr. Harrick. First, it could be content-based such as asking for anyone who thinks HCl is a base to raise their hand. As an instructional tool, it was also used to gauge student comfort relative to a specific topic or concept by asking everyone who is confident in solving a problem type to raise their hand. A shortcoming here is that it is difficult to know if those not raising their hand are indicating the other response or simply not participating.

The fourth assessment tool used by Mr. Harrick was to invite students to the board to show work. This was not a commonly implemented tool but instead was seen more toward the end of the data collection period. At times he would ask for volunteers to come to the board and at other times he would call on specific students to come up. Students who came to the board would then write down their work on the board for everyone else in the class to see. After students at the board finished writing, he would go through and correct the work on the board so that everyone in the class could see the correct method to work the problem as well as the correct answer.

By examining the teacher assessment tools without SRS, we have seen that teachers primarily using verbal interactions with specific students. They must then assume that the information gain from one or more students applies to the class as a whole. A benefit of SRS is that they allow teachers to quickly and easily collect responses from all students in the class. Next, we will look at the initial SRS perceptions of teachers as they began teaching with the clickers. Each of their views on the usefulness of the SRS is based in part on their non-SRS assessment tools.

Initial Teacher Perceptions About SRS

Mr. Rein's Initial SRS Perceptions

Before I began working with Mr. Rein on using the SRS, he received basic training on the devices from me. This training lasted about 90 minutes and walked him through the basics of operating the SRS. Mr. Rein then had access to the SRS for a few days at the start of the semester prior to data collection directly involving students. This was at his request because he wanted to get somewhat comfortable with the devices before I asked him to use the clickers in specific ways. I observed Mr. Rein teach during these days before data collection with students and was able to note that he found the SRS to be primarily an assessment tool. He thought they were useful for a few specific purposes: to know when students are ready to move on to the next topic, for pre and post-tests, and for basic item analysis.

The first time the class used the SRS, they began with a pretest with the system that asked basic questions such as their favorite color. The purpose of this was to let them get used to responding before asking questions actually related to the chemistry class. As this initial SRS quiz began, Mr. Rein told the class that he would use the information to identify when the class understands and is ready to move on. He also mentioned that if the system showed they were ready to move on earlier, it would let them proceed faster.

The pretest method Mr. Rein used with the SRS was not a feature of his typical teaching. He reported that it took too much time. However, the system allowed him to quickly give the quiz, and more importantly to the teacher, it could be immediately graded. He analyzed the questions to see what topics the class as a whole didn't seem to need more help on. That information was used in his lesson planning to reallocate time to areas he felt needed it more based on pretest results. I was surprised to observe the students still being required to record paper answers and submit those in addition to the SRS submission. This seemed to indicate a lack of complete trust in the SRS to accurately denote and keep record of student responses. After a few uses, Mr. Rein stopped requiring this duplication of answer submission.

The pretest scores showed that on six out of eight questions, at least 80 percent of the students answered the question correctly. The following day after the lab, the students took the post-test . The two other questions from the pretest where fewer than 80 percent of the class members chose the correct answer both had over 90 percent accuracy on the post-test. However, the material covered basic lab safety like what to do with free time and how to respond to a spill so there was not much opportunity for the teacher to accelerate class time based on results.

On day 8 of data collection, Mr. Rein used the SRS to give an ungraded quiz to students. The topics were elements and compounds as well as chemical and physical changes. There is no discussion during or after the quiz. Mr. Rein indicated that he gave the quiz to provide the students a means to assess know how well they understand the topic. He further told the students to use this information to decide whether to seek out help outside of class. After the class day described above, I began to work with Mr. Rein on using the SRS for facilitating cognitive engagement. Now we will look at Mr. Harrick's first impressions of the devices.

Mr. Harrick's Initial SRS Perceptions

Mr. Harrick expressed enthusiasm at the beginning of the project for using the SRS devices in his classes. However, he was very slow to get the required software installed on his computer. Ultimately this process took about one week. During that time we used my laptop. When we first started using the system, he was timid in that he deferred to me for operation and to lead class discussion. He wanted me to be the one to start the program and direct the class progress through the questions. The teacher did not lead any discussion either during or after using the SRS. After the initial SRS use with the class on day 26 of data collection, he asked the class how they liked taking a clicker test. This comment shows how he saw the clickers as a testing tool to let students know how well they understand class material. A few days later, Mr. Harrick further elaborates on how he saw this as a testing tool.

> "T: You may have your resources out but you may not have anything else because we will be giving you the clickers. I wrote the questions so you will not have forever to answer. There will be a cutoff time. They are all multiple choice. We will pretty much do this every day. The names are a little off this time because some people were absent. We will look at the results, and we will show you what they are momentarily. Did you think the quiz was easy? [Yes]. Do you think you

understand ionic and covalent well enough that we can get some good information tomorrow?" (Day 29 transcript)

Mr. Harrick's questions at the end of this dialogue about whether or not students know the information well enough to give good information reveal his thoughts on the SRS. Essentially, if the kids do not understand material well enough to score high, it is not worth it to him to use the devices. This reveals a view of the clickers as primarily a summative assessment tool.

We have now seen how the teachers assessed their classes without the SRS and their initial views upon receiving the devices. Now, we will turn our attention to how teaching changed over time with exposure to clickers and while I worked with them to use the devices in ways that let students show cognitive engagement.

Evolution of SRS Usage Over Time

The teachers in the study being reported here had initial perceptions of SRS and these perceptions impacted how the devices were actually used. As I continued working with the teachers and as the teachers got additional experience with the clickers, their actual classroom usage changed. Additionally, their perceptions of the SRS changed over time. In this section, each teacher's progression through using the SRS will be described and analyzed.

Mr. Rein's Evolution of SRS Usage Over Time

Week One

Each teacher in this study was to be trained by a staff member of the Educational Technology Center. However, Mr. Rein joined the study at the last minute and a time could not be found to arrange the training prior to data collection. In lieu of the planned training, I met with Mr. Rein on day one of data collection, the day before the start of the spring semester, and showed him how the Classroom Performance System (CPS) software. CPS is a brand of SRS. Both teachers used software version 3.52 of CPS. The training for Mr. Rein included demonstrations on how to create a class group in the CPS software, how to create a prepared lesson with questions in advance, and how to ask what the software called verbal questions. A verbal question is one that does not have text or images already prepared in the software in advance. Thus, the question can be asked verbally, but might also be written down for the students on the board of a sheet of paper. The types of questions that can be created include a variety of response formats. They can be multiple choice with two to eight options, yes/no, chalkboard, or true/false. The multiple choice questions can be setup with as few as two options, A or B, or there can be up to eight multiple choice options, A through H. The remote control response devices students have include eight buttons labeled A through H. The A and B buttons also are labeled to serve as yes/no or true/false respectively. Chalkboard questions let teachers draw a question on either the whiteboard in the classroom or an interactive whiteboard. Images can be included with each answer of a multiple choice question or a single one that accompanies the question text.

Some other features of the SRS software that Mr. Rein was initially introduced to included the random student picker, PowerPoint import, Exam View import, and fastgrade. These features are used in the following ways. The random student picker will either select a random clicker number or show a student name if the class roster is loaded into the software. Mr. Rein did not find this especially useful (or novel) because he already used index cards with each students name on a card to quickly select random students. The PowerPoint importer allows the SRS to be used in conjunction with a slide show. If there is a slide with a multiple choice, yes/no, or true/false question, the SRS is able to record responses of students. It is advantageous because the teacher is able to keep a PowerPoint presentation displayed continuously instead of stopping to display the question through the CPS software. This feature was of interest to the teacher because of his extensive PowerPoint files that he had already created to use with his class. Exam View importer is a feature of the CPS software that allows test questions from an Exam View electronic database to be imported for use with the SRS. Exam View is a software program that accompanies some high school textbooks that allows teachers to create tests from its question bank. While Mr. Rein has an Exam View question database, he did not typically use it with his class prior to SRS use so he did not anticipate it being helpful with the SRS either. The final feature of the CPS software that Mr. Rein was introduced to during the orientation prior to SRS use was fast grade. Fast grade allows students to answer a series of questions using the clickers. Each student in this mode can move at his or her own pace. This is accomplished by displaying on the board all remote control numbers in the class and what question number a student is on. The goal of this initial training was to give him a basic understanding of the system in ways he can immediately use. In the days that followed, I introduced and redisplayed features of the CPS software that were useful and appropriate for that particular lesson so that the teacher might be able to use them at that time.

Week Two

For the remainder of the week, I had jury duty and was unable to observe the classroom. During that time, Mr. Rein did attempt to use the SRS. However, he had technical difficulties and was unable to. After resolving this technical issue, Mr. Rein did use the clickers for the first time later that day. The students took a pre-lab quiz with the SRS using a prepared set of PowerPoint questions. The same PowerPoint presentation had been used in previous years by the teacher but only as a post-lab quiz. The students were not shown the correct answers after the pretest and there was not a discussion either during or after the quiz. Instead, the questions were used to point out areas on which the students were to focus during the lab. Mr. Rein hoped that if students knew the questions that would be asked on the post-lab quiz, they would be more likely to focus on and learn the answers those questions while completing the lab.

The next day, the students finished the lab report from the prior day and submitted it. Surprisingly, Mr. Rein not use the clickers for a post-test. He saw that most students had gotten a majority of the answers correct initially and he was pleased with the work he saw during the lab so he did not feel it would be beneficial. Instead, he wanted to use them for another pretest. This time, the quiz consisted of eight problems that he had assigned as homework in past iterations of the class. The questions offer two choices and ask students to classify a named substance as an element or compound initially. The later questions describe an object undergoing change and ask whether it is a chemical change or a physical change. Mr. Rein did not show the correct answers to students during the pretest nor did he have any discussion after each question when the CPS software showed the percentage of the class that selected the correct answer. For example, on one question, 27 percent of the class got the incorrect answer. This means that no one in the class knew if their answer was right or not after each question but the class as a whole knew how well the group performed. After class, I reminded him of my interest in seeing discussion while using the system and also afterward once results are calculated. From then on, he changed a setting to allow the CPS software to show the correct answer to students.

The following day, the class did complete the post-test with the eight classification problems. Students recorded answers on paper as well as with the clickers because Mr. Rein was still not comfortable relying on the SRS to accurately track student responses for grading purposes. The class did improve from 71 percent correct on the pre-test to 84 percent correct on the post-test. As before, the correct answers were not shown during the quiz, but Mr. Rein planned to have a class discussion afterward based on my request for it the previous day. What Mr. Rein had intended to be a discussion was actually a monologue on his part where he talked for a few minutes about the topic in general and then focused where the class did not do as well, the chemical and physical change examples. His attempt to discuss SRS results with the class is a step forward but the goal I am moving him towards is having students verbally involved during and after SRS usage. Using pretest and post-tests was not a common tool for Mr. Rein prior to receiving the SRS, but he did find pre and post-testing useful and easy with the clicker system.

On Friday, the class breaks back up to finish a paper lab from yesterday with dimensional analysis cards. Mr. Rein and I had discussed this on the previous day when I said we could use CPS to gauge understanding and see why students are making decisions with cards. He isn't opposed to the idea but shared that he finds it more efficient just to walk around and see how they are doing. However, he did say that it would be a good use in a large lecture class.

Week Three

While discussing the lesson plans for the week, Mr. Rein and I agreed that I would prepare some questions to use throughout the chapter. This way Mr. Rein could have access to a wealth of SRS questions before beginning the unit. In the following dialogue, he mentioned his preference for prepared questions as opposed to verbal ones made while teaching. Additionally, Mr. Rein highlighted that his ultimate desire in SRS usage was to gauge the content knowledge of his students.

"R: You can also always make up a verbal question on the fly too.

T: Yeah, but I like to have a visual record for the kids

R: So you don't have to write it on the board.

T: Yeah.

R: To summarize your goals is it safe to say you want to know how well they know the content?

T: I just want to know what they know." (Day six transcript)

From my analysis of the above example, Mr. Rein is showing some of his beliefs and preferences for SRS usage. He prefers prepared questions over the verbal ones, so this gave him the opportunity to plan in advance to use the system. Mr. Rein's stated focus is on seeing comprehension. He wants to know if students know the correct answer. To make sure the system is used, I will create some of these questions like he wants while also crafting more discussion oriented ones that will allow students to show their cognitive engagement.

On Monday, while students worked, I showed him how to create questions in CPS. He had copied over from PowerPoint and we decide it is easier to create them initially in CPS or just use them in PowerPoint. The main drawback with using PowerPoint in conjunction with the CPS software is that the CPS software does not note the correct answer so reports are limited. I also showed him how to view reports from his post-lab quiz last Thursday. These are all things we went over before the study began but it seems to take on new meaning since it is actual content and class data for him, less abstract than when I reviewed it before. He showed me what he is planning to cover in class. He did not plan to use the CPS until the last few days of the week. He wants to take things one step at a time, using the base features of CPS initially and expanding to more complex and varied uses as he gets more comfortable.

In this conversation between Mr. Rein and myself, the teacher expresses his thoughts about how the SRS affects where he physically is in the classroom while teaching.

> "T: It is a little aggravating to me to be tied down here (at the computer in front of the class). I know there is an option where one of those can be a chalkboard, something like that with a wand. It would be great to spontaneously come up with questions and write it instead of just saying it." (Day seven transcript)

Mr. Rein mentioned that he does not like feeling tied to his computer while questioning with the SRS. In his normal teaching, he walks around a lot while asking questions. A wireless slate was offered to him to minimize the need to be at his computer but he wanted to wait until he got more comfortable with the technology we were already introducing. Mr. Rein stated to me that he is not interested in verbal questions because he has Individual Education Plans that require things be written. I kept mentioning that with a verbal question we could actually write things on the board but it did not change his perspective.

As I continue working with the teacher, additional tools and uses of the CPS software were slowly introduced. The conversation that follows shows Mr. Rein beginning to see the full benefits of creating questions within the CPS software. After this day, he no longer used PowerPoint with the clickers.

> “T: So this was made in the program (PowerPoint) itself?
>
> R: Yes, the beauty of this is, we already have the correct answer put in. We don't have to show the students this right when we put end. But then later on in the reports it is easier to see how individual students did as well as the class as a whole. From my point of view, I'm more interested in those discussions that happen right as the question is asked and right after they see the results. You could pull up the graph right after but you don't have to.
>
> T: No, I like the immediate feedback, that's nice.
>
> R: We could have one long lesson full of these or a separate lesson for each one.
>
> T: This helps me, before I knew how many said true or false but it wasn't pinpointing who said what.” (Day seven transcript)

The following day the class does use the clickers again with a PowerPoint, but it is the post-test quiz involving distinguishing physical and chemical changes that the class had begun the previous week. All SRS use after that did not involve PowerPoints. This post-test was much like prior uses in that there was no discussion during or after the quiz. The clickers do not end up being used the rest of the week.

At this point, the SRS were used for only a very limited part of classtime. As I continued meeting with Mr. Rein before class, I emphasized that I would like to see them used at least two to three times per week. Also, we discussed how I hoped to see student discussion both during each question and after all questions had been asked. It was suggested that the remotes be left out so that Mr. Rein could use them quickly when an opportunity arose. The teacher was not interested in this setup, preferring instead to only bring them out when he had planned in advance to use them. His decision to only use clickers at specific times seems to really limit the use. He asks questions all the time but doesn't want to get student feedback from all students with most of these. Analysis of data related to teacher perceptions of SRS showed that at this point in time, Mr. Rein viewed clickers as an additional thing to do instead of a tool that was being integrated into what he was already doing.

Week four

The week began with Mr. Rein having prepared five review questions to use with the class prior to the paper quiz they were taking later in the class period. He had me enter them into the CPS software to use with the class. After most questions, Mr. Rein stopped to ask students questions about why they selected certain answers. This was a new usage for him and in keeping with what I had asked him to do. The content of the student responses will be discussed in the cognitive engagement section later in the chapter. During our planning time, we looked at a review game I made for the chapter. Mr. Rein showed excitement about using the game in class and opportunities did come up to play it with the students. We also discussed having students respond in groups instead of individually with the remotes. He was partially open to the idea initially but expressed concern because ultimately he wanted to find out what each student knew about the content he was teaching.

In the discussion shown below, Mr. Rein shared some of his insights at that point about how useful the clickers were and the barriers to further implementation.

> "T: Well, I would like to give you a lot of positive feedback about the clickers, but I can't do that right now because they are more work than they are worth. I'm trying hard to come up with ways to make them not more than they are worth.
>
> R: I don't think they are supposed to be like that but I have heard that before. There is a learning curve on the front end, which is tough.
>
> T: My initial impression is that with really large groups where you can't touch base with everybody that they are highly beneficial to the teacher. I think the kids like them and that is a good thing. They really enjoy that interaction. There faces just lit up yesterday the second time we went back through." (Day 12 transcript)

Mr. Rein's belief that the devices are more beneficial in a large group setting reveals why he is hesitant to use them for spontaneously asking questions during lectures. He does not find them easier or more useful than his index card method.

The SRS provide a lot of information to teachers about student performance. Mr. Rein initially did not change much of his teaching upon seeing areas students did not understand. However, this was changing a few weeks in as he began to have more discussions with the class when the clickers showed that students did not understand something as well as he thought they did. Later in the same discussion just quoted, Mr. Rein explains how he decides when to pause and have a discussion and when to keep moving on.

> "R: When you figure out that they don't know something, what does it take to make you change what you are doing? You know, when you can tell one kid doesn't get it or like we saw yesterday that lots didn't get it with the clickers. How does that influence what you do?
>
> T: I weigh the necessity of [students] getting it (correct) towards their success at the next level. If it is really important for the next level, then we will stay there.
>
> R: The next level in this class?
>
> T: Yes, the next level in this class. If it is something that they will have to build on then I will spend a lot of time making sure that they have got it. You will see me do that when we have ions and charges and they are trying to write compounds and name ionic compounds. We'll spend several days and do several activities, well two or three activities is several for us, that is a whole week's worth of work. But the stuff we did yesterday is not real critical for the next step, it was just a moment in time and I know I can pick it back up later when it is more critical, when I really do hit solutions a bit harder towards the acids and bases chapter." (Day 12 transcript)

The class played their first review game the following day. It was of interest because it was a new use of the SRS, but Mr. Rein's response afterward was even more intriguing. He had a discussion with class at end on two key areas students seemed to struggle with while going through questions. This was the first time he has had a recap discussion based on results from the SRS quiz. Afterward, Mr. Rein shared some of his thoughts about the review game and subsequent discussion.

> "T: And this thing spontaneously elicited from Carolyn a question on the difference between physical and chemical changes, that is exactly the kind of thing we want to pull out, to know that deep understanding is not there. We couldn't have gotten that without the CPS.
>
> R: And I thought your discussion after that were both great because they wouldn't have happened without the device, even though while they were being used students were silent and just clicking in." (Day 13 transcript)

During a discussion the following day, Mr. Rein became open to asking clicker questions that are more process based as long as the students have already had some exposure to the material. In particular, we looked into having questions where students must select the next step in a stoichiometry calculation.

At the end of the week, we discussed how the SRS could be used to check homework for accuracy. He always grades homework for accuracy, but this is an area where the SRS could be a time saver. I believed it could also lead to interesting discussions but my primary goal was to present a way that the devices could save him time since he felt he was losing time with them in other areas of his lesson planning.

Week five

During a discussion before class on Monday, the teacher noted how he found SRS uninteresting when used to ask traditional multiple choice questions. I agreed and tried to discuss some more about how I'd like to see them used. He wanted discussion about topics like what he gets at the end of labs and in a few other activities but did not feel that would happen with what he had seen of the system so far. I told him again of how I have seen people give one clicker per group and discuss before. He asked if he could setup a new class with clickers per group instead of per person, so I discussed how he could. Also we discussed how you can get discussion before even if everyone has a clicker since the groups won't likely reach a consensus. He was open to that type of use and did attempt it later.

Mr. Rein also told me that he was unsure how to get the class to share their thoughts before responding. They are so conditioned to see a question and then immediately provide an answer. In response, we again discussed putting students in groups and having them discuss a question before he starts the CPS question that allows responses. This would force groups to agree on an answer and have just one person per group click an answer.

On Tuesday, the class was split into groups for SRS quiz. This was an actual quiz grade where all group members share the grade. Before the quiz, the groups got a few minutes to make a notes sheet to be used during the quiz. The questions were ones that I made where students are given a stoichiometry problem and select the next step. This did not generate useful discussion because it was a quiz and they are told to all whisper to each other. This process was repeated a few minutes later for a quiz on section 2. On the second question for quiz two, shown below, no one got the question right so Mr. Rein made a note to return to the topic later, which he did. For this question and any subsequent one displayed from the CPS software, the asterisk indicates the correct answer. That ten-minute discussion on specific heat happened after the clickers were put away, but it would not have happened if the SRS had not pointed out that it was a weak area for the class.

"2 The specific heat of water is much higher than other substances. What does this indicate about water?

Answers

*A water does not change temperature easily

B water has a higher temperature than things around it

C small amounts of heat change the temperature a lot

D none of these

Response Percentage 0 17 28 56" (Day 17 SRS file)

Week six

On Monday, the class did a review game before taking test. During the game, he used the random student picker and also stopped to have some discussions after individual questions when it is clear several students do not understand. In particular, question seven, shown below, was only answered correctly by 63 percent of the class. These were both new levels of integration for Mr. Rein. While progress was slow, it is clear he made progress in changing how he taught with the SRS over time.

"7 Select the correct method to convert 273K to Fahrenheit

Answers

*A 9/5(273)+32

B 5/9(273-32)

C 9/5(273)+32

D 5/9(273-32)

Response Percentage 63 11 16 11" (Day 21 SRS file)

I was scheduled to be at the other school starting the next Monday. Mr. Rein wanted to finish using clickers on day 21 of data collection since he was wrapping up a unit that day. The rest of the week was a new unit and he did not want to use the SRS for only part of a unit. I offered to let him keep the SRS for the remainder of the semester but he declined. They were interesting to him but ultimately more time consuming to him than he thought they were worth. Now we will look at how Mr. Harrick used the clickers.

Mr. Harrick Evolution of SRS Usage Over Time

Week seven

During the seventh week of data collection, which was the first week in Mr. Harrick's classroom, he expressed interest in using the SRS. Despite that, he did not load the software on his computer during that time. I offered to let him use my computer, which already had the software, but he did not allow that until the following week. So, for the first week, there was no usage of the SRS even with me being present to create questions and potentially operate the system. This contrasted sharply with Mr. Rein, who used the system several times the first week he had it including an attempt to use the clickers prior to my arrival.

Week eight

On Monday, the students completed a density lab where they selected an object, measured its mass and volume by water displacement, then calculated the density. They had previously practiced solving density problems out of their textbooks. After the lab, the SRS were used to give the class six questions on density. Mr. Harrick did not take initiative using the system. Instead, he had me setup the system, run the software, and even lead the class through the questions. My goal was of course to have him use the SRS himself so this was just a starting point of integration. Mr. Harrick had a conversation with the class afterward on their thoughts about using the clickers. I later clarified how I primarily want to hear students discuss the content of the questions and their own reasoning for selecting answers.

The next day the SRS are again used. This time, five questions are given on reaction types. These were created by me just as previous ones had been. I made them straightforward questions where students identified a reaction as one of four types. Question two, shown below, is typical of the questions asked.

"2 Classify the following reaction:

MgCl2 +

Na2O --> 2 NaCl + MgO

Answers

A synthesis

B decomposition

C single replacement

* D double replacement

Response Percentages 0 14 7 71" (Day 27 SRS file)

While going through this second set of questions with the class, Mr. Harrick did lead the class this time instead of deferring to me. However, there was no discussion during or after the SRS session. The goal in these questions was to slowly integrate the system into Mr. Harrick's teaching. So they are not high-level questions but focus on the information he requested we get from them. Based on my work with Mr. Rein, it was my belief that if I could make the system seem useful to the teacher, the teacher would then be more likely to use them and I could gather information more directly related to my own research interests.

Wednesday Mr. Harrick and I have some time to plan. During the prep time I show the teacher the five questions on bond types that I have prepared similar to what will be covered on the graphic organizer and worksheet he assigned his class. He also printed the Georgia Performance Standards for physical science and showed me what has been covered, the depth he plans to cover bonding and that he will be teaching on solutions the next few weeks. As a former high school physical science teacher, I am familiar with the topics and standards. This allowed me to anticipate the types of questions he would like to ask of his students.

Later that day during class, the students again answer SRS questions. However, as before, Mr. Harrick required the activity be in complete silence. After the last question, the teacher was walking to his desk and was planning to let the students sit at their desks for the last few minutes of class. I used the random student picker to pick a student whom I call on and ask why they had selected the answer they did on the last question. This was not a planned intervention on my part but instead reflected my frustration at the slow pace of SRS integration with the teacher. I was attempting to model for him some of the methods that I was interested in seeing.

By Thursday, Mr. Harrick had finally installed the CPS software on his computer. This was useful because that was the computer he already had hooked up to the projector.

It also meant he could start to use the system more on his own. My computer that we had been using has a different operating system than he is accustomed to and this clearly limited how much he wanted to try using the software. He had also created some questions that he gave the class later that day. There was no student discussion during the session. Afterward, he did ask the class if they thought they understand ionic and covalent well enough that he can get some good information the next day. By this, he was asking the class if they knew the material well enough that they would score high on similar SRS questions the next day. A few in the class mumbled yes in reply and that was the extent of the class discussion. So while the discussion is not particularly interesting, Mr. Harrick had now downloaded the software, written his own questions, and attempted a class discussion after using the system.

Week nine

Monday morning Mr. Harrick let me know that he had not written any questions but he did ask me to come up with five questions based on the vocabulary homework students had over the weekend. It was common for Mr. Harrick to come to class with no preparation, which made it difficult for me to work with him on quality SRS questions. On this particular assignment, it was difficult to give students opportunities to show high cognitive engagement while checking vocabulary. On the fourth question, five of the 18 students got it incorrect, yet there was no discussion or change in plans on the part of the teacher. This would have been a good opportunity to explore the source of student confusion and use the SRS information influence time allocation for the rest of the lesson. Instead, students are explicitly asked not to speak while using the clickers.

> "T: Do not give away the answer to everyone. Remember, you have to have line of sight to click in to the receiver. There you go, go ahead and start clicking. I do not want any chitchat. Everyone ready to move on (several in class say no)? All right. Now let's go to the next. Go. Just waiting on number 51. So we go to next, start, go ahead. Shhh.
>
> S: I haven't gotten one wrong yet.
>
> T: Quit playing with the clicker." (Day 31 transcript)

Mr. Harrick did not value the tool as a way to direct class conversation. He told the students that these quiz grades would be used by him as a discretionary bonus to help students who may need it. This reflected how the teacher viewed the SRS more as a summative assessment tool than a formative one. With both Mr. Rein and Mr. Harrick, I repeatedly said that I was interested in them questioning students to figure out why they have answered the way they have in the hope of generating a dialogue where student justifies answers and describes possible misconceptions or areas of misunderstanding. When I did this, the teachers would nod and agree but were not generally excited about it or engaging in that conversation. These teachers value the system but not for the specific type of input that I do so it should not be surprising that they gravitated towards using it in different ways. This has important implications for those who are considering purchasing devices for teachers as well as those who will be training teachers to use these devices. Mr. Harrick especially values the quantitative data, though he also values that type of data in general and thinks more in those terms.

Students completed a lab on Tuesday. Mr. Harrick shared with me that he was disappointed in lab reports from yesterday. It is an interesting statement to make because it is based on general comments made on lab reports as he flipped through them. The performance on the lab reports was not summarized in any way to help make a general assessment. With the SRS, it does deliver a quick and easy to access summary of how students really performed instead of leaving it to the teacher to anecdotally summarize data. A teacher without SRS is gathering data spontaneously, such as having one student correctly answer a question, to conclude that the class is ready to move on. However, teachers are used to that whereas they aren't used to taking instant data on every student and reacting to it. This creates a learning curve with SRS. I felt like a professional development person in that I was trying to show and have them use the device in a way they aren't naturally interested in. I had expected a more collaborative spirit where we both worked together to achieve the same goal but both teachers are more excited about using the CPS than using it specifically to facilitate cognitive engagement.

As class ended Tuesday, Mr. Harrick and I got a few minutes to discuss plans for the next day. He showed some improvement in SRS usage in how he was already planning in advance for a potentially higher-order thinking question.

> "T: What I am going to show tomorrow is the solubility of the gas. I'll talk to them about why there are no trout this far south in the Chattahoochee River whereas in the north you can commonly fish and catch trout. I think that would be a good question, after we've discussed it, to put on the mini quiz. To say, OK, instead of a long drawn out answer, we give them a long multiple choice." (Day 32 transcript)

The next day, the class did not end up using the SRS for the fishing question. Instead, while Mr. Harrick discussed solubility he wanted me to create about five

SRS questions with solubility curves, but not quantitative ones because he thought it might be tough to view. Those questions were used to start class on Thursday. Before we used those questions with the class, I adjusted some settings in the CPS program so that a histogram of student responses automatically came up after students had finished responding to each question. My hope was that this would help guide discussion by more visually showing the accuracy of student answers. Instead, it flustered Mr. Harrick and once he figured out how to make it go away, he would quickly close it each time. The teacher does not value this type of information in his regular teaching so it should not have been surprising that he did not value it when the SRS provided it. The histogram did help students evaluate their answers more easily. On one particular question, shown below, indicated that a lot of the class thought that solid solubility depended on the chemical, that it didn't just increase with temperature. One student in particular said "but some went down." The teacher did not comment on it, and instead just moved on.

"2 What happens to the solubility of solids as the temperature increases?

Answers

A decreases

* B increases

C remains constant

D depends on compound

Response Percentage 6 33 6 56" (Day 33 SRS file)

In the exchange shown below, note how Mr. Harrick begins to try to have conversations with the students on specific questions. The dialogue is not necessarily exemplary teaching, but it is an improvement over his typical silence during SRS usage.

> "T: Read the question carefully, we talked about this exactly yesterday. Come on, all you have to do is look at the graph, follow the line until you get to the symbol.
>
> S Shay: I cannot see the graph.
>
> T: Well, just look here, which one has the highest solubility at low temperature, will it be at the bottom or top?
>
> S Kerry: top
>
> T: Right and there is only one thing at the top, everybody finished? We will end. Then we will go to the next question, which is here. This is the same thing we talked about yesterday, the exact same thing. Well, y'all didn't do too well on that one, let's move on to the next one, number four. [there is no talking between some questions] Alright, y'all did well on those." (Day 33 transcript)

Week ten

During the tenth week of data collection, I was not able to be in the classroom due to a schedule conflict. Mr. Harrick and I discussed this and planned a few lessons involving the SRS. However, he did not end up using the devices during that time. He said that he had a computer problem where he could not start his computer so that prevented him from running the CPS software. His computer issues were frustrating. I had a laptop he could have kept to use or we could have loaded it on his school computer. He very much preferred his personal laptop and felt it was the superior machine. I ended up offering to leave that laptop with him after I left so that he could have a backup computer to use to run the SRS but he continued to prefer his own personal one.

Week eleven

By this point, the teacher trusted me to create questions for the SRS because of what I had already created for him over the last three weeks. He gave more direction initially and often wanted them to cover specific terms or test reactions in a specific way like identifying the reaction type. During this time, I began trying to branch out a bit more and use higher level questioning. This was especially appropriate since the students had just taken a mid term on the topics we were making SRS questions for. While I made SRS questions, Mr. Harrick did have some requests on the format that I used. He highly valued all options being similarly worded so as not to lean a student to respond in one way or another and he also valued having four options without a none of these option or anything like that.

After realizing how little progress was made last week with the SRS while I was not present, I felt a sense of urgency to take the usage of the system to a higher level. I believed the teacher needed me to push him to use the SRS in specific ways otherwise we would continue to use it in the same way we had previously. The questions we began the week with asked for the reason or way a student knows how to classify a reaction. Mr. Harrick continued to use the clickers without discussion and it was interesting to see frustration growing in some of the students. They, like me, wanted more feedback on their performance.

“S: Can we get it to see if we are wrong or not after the question?

> T: I'll show you when we are done with the questions. (After the last question, students are shown scores and clicker numbers. The students match their clicker number to scores and all talk about how they did.) This shows how many got each one right so you can see how you compare." (Day 36 transcript)

This was the first time Mr. Harrick allowed the individuals in the class to view their own performance on the overall assignment. He did not discuss the results with them or give them anything to do if their scores were low, but it was a small step towards using the clickers to drive discussion because students were now aware of their overall performance on the topic.

Planning continued to be a struggle because of Mr. Harrick's need to prepare for class only during the time right before the period started. During announcements on Wednesday, he asked me to make some SRS questions on naming and we then quickly reviewed them together. While we discussed the questions, I mentioned again that I would like to see us going over the student responses. At this point, how students responded did not influence the direction of class much. After the class struggled with the naming questions, the teacher went to the board to go over the topic again. He then stated, "If y'all want help, this is it." This typifies his notion that he can explain things and that during that time, students need to pay attention to understand it. He saw the SRS as a chance for students to actively engage with the material and confirm whether or not they know something. When someone in class does not understand something, he expects them to come get help outside of class even though that almost never happens in practice.

One example of this lack of interaction with students happened after a naming question. One question asked for the formula for aluminum chloride. 11 of 15 got it wrong and picked AlCl. I pointed this out to him because he usually just moved on. Even then, this led to a lecture and notes session on naming (repeat for them) without a specific reference to that question. So, he sees this as something too big to address with a quick talk and the system up. Leading a discussion after SRS was a step Mr. Rein also reached when integrating the system into his teaching.

While using the SRS this day, Mr. Harrick asked me if he could just click the histogram button and look at that with the class for each question. I let him know you can for each question right after you end it; otherwise you need to look at report that has it (question report). He says OK and has me pull up question report for class to look at. After completing a set of questions with the class, he quickly flipped through each question to see what the right answer was before going to the graph for each one. The question is not left up long enough to know what the question is asking, just to see the right answer. Then they looked at the graph and see how everyone did in general. I would have found a discussion on why the popular wrong answer was wrong or why the correct answer was correct even on the one where only one student picked it. However, what they did was basically get a broad graphical sense of how the class did on the overall topic. The teacher would often make comments about how the class as a whole did on a question but rarely addressed the specific content of the question. A typical conversation from that day is shown below. This was not useful to the students when there is no time spent looking at exactly what that question asked. However, this was an improvement on the past uses that typically involved no discussion at all.

"T: On this question, the correct answer was a.

S Missy: I forgot what I put.

T: So evidently you aren't as comfortable naming compounds. I am going to click each time to move to each question. This question number one, we did pretty well on this question. The correct answer was C on that one, D, so, yeah. Next, correct answer C, hmm. So, you did good on this one. Correct answer is A, hmm. All right, so, hold on to your clickers, get out a sheet of paper. This will be your assignment, we will review a bit.

S Missy: I do not get it.

T: That is why I am going to go over it." (Day 37 transcript)

Following this discussion, Mr. Harrick lectured on naming compounds some more. Then after they went over it a bit, they did another clicker quiz using the same questions. The conversation below happened during this second run through the SRS questions on naming.

"S Missy: How do we know if it is ionic or covalent?

T: If it has two nonmetals it has to be what?

S Missy: Covalent.

T: And if there is a metal?

S Missy: I don't even know.

T: Hurry up everyone so we can get this before the bell rings." (Day 37 transcript)

In this dialogue between Missy and Mr. Harrick, we see a student initiating conversation with the teacher when the SRS has helped her see that she does not understand bonding types. Mr. Harrick does have a short conversation with her but does not go far with her because he is more concerned about finishing the questions before the bell rings. This shows a small move by Mr. Harrick towards having conversations with the class based on SRS data.

On Thursday, Mr. Harrick asked that we do a review game with clickers for the last half of class, but that time ended up being used by him to organize the class set of textbooks instead. The teacher did not always value instructional time and would occasionally allow the class to sit at their desks while he planned or organized the room. Days like this slowed down the study because they negated the already minimal amount of planning time available.

Friday, as was typical for Mr. Harrick, he walked in a few minutes before first period and created a plan for class that day. This meant we were unable to plan much in advance. He was comparing midterm results with his peer next door, as they often do in a friendly grades competition. Mr. Rein had lower scores and was questioning the results. He found the other teacher had cleaned up the formatting of the test out of the examview bank so that it did not have boxes around multiple choice and odd line breaks. Mr. Rein decided to give the midterm to his class again using this cleaned up format. He asked if there was a way to use the clickers to input results. In particular, he was thinking of just giving them the questions containing graphics using the clickers so that the graphic is displayed on screen. That would allow him to compare results. I have shown and discussed fastgrade several times with him, but I suppose he needed the information when it was relevant to what he was planning to do. I explained how we could easily do fast grade since he already had paper tests for everyone. That would be for the whole test, not just the questions with graphics. He thought it sounded fantastic and asked me to prepare it, so I did.

Mr. Harrick was very excited about fastgrade once we used it. In particular, he was interested in using it for homework checks and also comparing the results of this class to the scantron ones in his other class periods. He and I debriefed after using the SRS for fastgrade. An excerpt of that discussion below highlights how Mr. Harrick views the SRS as primarily a summative assessment tool.

> “R: It is definitely easier on your end as far as management since you did not have to grade it.
>
> T: I would like to try it a few more times. I think if we could get them used to a mini-quiz at the start of every day, we could probably get rid of the quiz altogether. As far as classroom management we could get rid of the quiz altogether and this gives them immediate feedback. I don’t have to go down there and do this then tell them why. They can look at this or we can together to see what happens. Can I print the individual students?
>
> R: A sheet for each student, yes, like a study guide going over what they missed.
>
> T: That is the best use of it so far.
>
> R: The fast grade today?
>
> T: Yes, that alone would prompt me to purchase it.” (Day 39 transcript)

Week twelve

In this final week of data collection with Mr. Harrick, he continues to make slow progress in using the SRS more and more. On Tuesday, he gave the clicker quiz to the class without talking, then went back question by question to review the correct answers and discuss with students. Prior discussions after SRS usage had been primarily holistic in that they focused on the overall quiz whereas this discussion allowed for student input on each question.

> "S Molly: You explained it weird, you said subtract but what do you subtract to get that?
>
> T: The ending volume minus the starting volume because what you dropped in there made it go up and you want to find the change. OK, this question, the water displacement, you have seen that same one before, it is pretty straight forward. Which of the following best describes molecules of water vapor. Are they packed together [no] are they free but need a container [no] they are just wherever. The gases in this room, does it require the size and shape of the room to hold the gas? Can we move the gas out of the room?
>
> S Molly: So what is the answer, C?
>
> T: No, definite volume or shape…18, what did I tell you, all you have to do to create a name for ionic?
>
> S Molly: Change ending to ide.
>
> T: Change the ending to ide.
>
> S: So D.
>
> T: Calcium chloride. If it was covalent it would have the prefixes." (Day 41 transcript)

Later that day, the class again uses the SRS. This time, the questions are on a short global warming article students had just read. A student was actively seeking help and more discussion after using the clickers. However, Mr. Harrick discouraged the conversation. This example shows that the progression of Mr. Harrick towards using the SRS to generate discussion was by no means linear. He had just used it to generate discussion earlier in the day, yet here he did not. The question being discussed is shown above the transcript.

“4 What effect did the Industrial Revolution have on the Earth's atmosphere?

Answers

* A released more CO_2 than could be removed and created a thick blanket around Earth

B released more pollution that made clouds darker, blocking the sun from the earth

C decreased the amount of CO_2 so that plants did not have enough for photosynthesis

D released more CO_2 than could be removed, raising the surface temperature 11.5 degrees

Response Percentage 92 8 0 0” (Day 41 SRS file)

“S Molly: I don't see why anyone guessed B because if anything, I would have guessed D because that is also true.

T: We are going to talk about that.

S Molly: But why is that right?

T: We are going to talk about that, the article is not the end all be all.

S Molly: I know but it had it in there.

T: You got 75% correct average so that is not bad.” (Day 41 transcript)

The next day I had a chance to talk with Mr. Harrick before class about why he did not like to address issues when the system showed students did not understand. He felt time pressure with the upcoming End-of-Course Test and wanted them to focus on bigger issues instead of particular questions, so he took that information from the SRS and let it inform where he focused time during discussions. Ideally, students would see that they did not understand something and then go seek him out later. He admitted this rarely happens.

Mr. Harrick began taking further initiative using the SRS. He requested I let him get system booted up, which he is mostly able to do on his own. I had been wanting him to take initiative so this is great. During the SRS session, he stopped and asked students to raise their hand if they had selected the right answer, which was all but one. This was a new step for him and indicated that he was interested in who knew the answer. The technique is more what would be expected with a teacher who did not have SRS software. The system can quickly indicate who got the correct answer without requiring students raise hands. After the second question, he again stops and looks at overall results, notes that most got it right, then moves on. Typically he is in such a hurry it seems that he doesn't even take time to look at things like the results on a particular question.

Because the students do not talk while using the clickers, the teacher walked over and talked to me. He said he always tries to teach with three opportunities to learn. Usually he has a lecture, foldable or lab and then a worksheet. But he told me that the clickers are replacing the worksheet activity for him. Afterward, there is a brief attempt at discussion based on student results.

"T: Class average 94 percent.

S: What is a plasma?

T: We will talk about that today.

S Kerry: Plasma is in Halo [the video game]

T: It is in these light bulbs, we will talk about it today. Hush. Go. This is pretty close to how it will be setup Friday. We will have a review game tomorrow. How did we do, 94 percent. Last one. How many of you are thinking the clicker is better?

S: Clicker is fun.

T: The thing I want to tighten up on is how much talking you all do while we use this." (Day 42 transcript)

On Thursday, the class used the SRS for a review game. This was the only time the teacher used the review game. He put students in pairs to discuss answers but his directions were unclear and the discussion portion did not really happen. Regardless, this was an attempt by the teacher to use the system in a new way both in terms of utilizing the game feature of the software and in asking students to discuss answers in pairs prior to clicking in a final response.

The review game was the last observation I had in Mr. Harrick's classroom. I offered to let him keep the equipment the rest of the semester. He declined the laptop but did keep the SRS and the projector another month. The bulb in the projector burned out at that point so he met with me to return the equipment. At that point, he told me that he had not used the SRS since I left his class. During our conversation that day, he did mention that he found the SRS useful in that it increased student motivation to get involved and provided instant feedback. Also, he felt it provided a more accurate assessment because it targets students right after learning it. Conversely, he also felt that they were more time consuming and made it easier to cheat because it is hard to control talking while using them. In terms of changing his teaching, Mr. Harrick said that the SRS made him place more value on immediate feedback to students.

Facilitating Cognitive Engagement

In chapter three, a rubric, shown below in Table 3, was presented to evaluate the cognitive engagement of students. This rubric will now be used to examine the cognitive engagement of students. Initially, we will look at student evidence of cognitive engagement in normal day-to-day teaching of Mr. Rein and Mr. Harrick. Following that, the focus will be on how the SRS can be used to facilitate cognitive engagement of students.

	generative thinking- ability to generate answer without ready made solution	nature of explanations	asking questions	metacognitive activity	approach to task
high cognitive engagement	Elaborate, richly descriptive with specific examples and references to real life. Interconnected. Stubborn and tenacious defense of ideas. Actions seek to solve problem. Sociocognitively collaborative.	Microscopic explanation based on non-observable entities as well as cause and effect. Macroscopic explanations referring only to what is visible. Stubborn and tenacious defense of explanations. Sociocognitively collaborative in development, used to solve problems.	Questions show wonderment, appreciation, and extend ideas to multiple sources outside of specific context currently used. Sociocognitively curious and tenacious. Sociocognitively collaborative. Seeks to solve problems, asks for help solving the problem not just in getting the answer.	Self-evaluate ideas ("I get it now"), recognize failure (I'm getting confused on..."), self-correct, considers range of ideas	Sociocognitively expedient. Stubborn and tenacious. Multi-focus of ideas. Manipulates variables to determine relationships. Persistent following up on ideas. Talks above procedures and observations, focusing more on concepts. Puzzles on information not understood. Generates own ideas for cause and effect relationships instead of relying on external sources.
low cognitive engagement	Evasive, related to question but does not actually answer it. Does not generate solution but instead says something like "I don't know."	Reformation without causal mechanism or of a black box variety. Sociocognitively passive with few verbal contributions.	Procedural or textbook based with simple solution. Basic, factual questions requiring only recall to answer. Sociocognitively passive with few verbal contributions.	Follows procedures without seeking to understand why the steps are required/ suggested. Relies primarily on memorized facts. Sociocognitively passive with few verbal contributions.	Quickly gives up on ideas. Non-sociocognitive/disruptive or sporadically contributes. Ignores information not understood. Off-task behavior. Relies on external sources. Single focus (such as on doing an activity but not what it means or why it is being done). Talk on procedures and observations only.

Table 3. Cognitive Engagement Rubric

Facilitating Cognitive Engagement Without SRS

The data used for cognitive engagement assessments without the SRS are primarily from conversations between the teacher and students. Student work also could have shown cognitive engagement. However, examination of student work to evaluate cognitive engagement would be time intensive and was not a focus of the study. The following examples of high and low cognitive engagement provide a baseline for the type of work common in the classrooms observed. This will allow the reader to have a deeper understanding of how the SRS offers cognitive engagement opportunities not otherwise available. Often more than one area of cognitive engagement is shown. For example, students can show engagement through approach to tasks and in questions asked simultaneously. Also, at times one student might show low cognitive engagement while another shows high levels. Despite these complications, examples will initially focus on primarily low cognitive engagement before moving to higher engagement. When the data allows, each area of cognitive engagement will be presented.

Low cognitive engagement without SRS

Low cognitive engagement proved difficult to assess from the data collected because so often it is evidenced through limited verbal contributions. The problem with this is that sometimes the teacher asks a question that only requires a brief answer. If the correct answer is provided, it is difficult to say whether high or low cognitive engagement was displayed. This issue meant that many common discussions during class did not provide valuable information for evaluating engagement for this study.

In the excerpt below, a student ask questions that reveal the student's primary focus is getting the task completed. The focus is not on understanding the material covered but instead on getting the worksheet filled out correctly. This shows low cognitive engagement in both the types of questions asked and also in the approach to the task.

"T: These balls have different numbers of wholes on it. You are just making a choice about what you want it to be. This part is just discovery, you can make it anything you want.

S: And this chart is for the other part?

T: Yes, you can make this anything you want.

S: We don't have to fill the whole chart with elements right?

T: It asks you to come up with three on your own so just put a few there." (Day nine transcript)

Later that same day, the class is being introduced to stoichiometry. As Mr. Rein debriefs with the class after a stoichiometry lab, he calls on a few students and asks them to explain how they solved a problem. The first student called, Ashley, shows low generative thinking when she fails to even speculate on the answer. Ashley and her partner Miguel then further show a low level approach to the task in admitting that they got their answers to the questions from another student. Even the final student who did calculate the correct answer shows low metacognitive activity in describing how the atomic mass was found off the periodic table. The explanation shows that procedural steps are being followed without connecting them to a larger concept.

"T: With lab 2b you were asked to calculate the formula mass after you had formed the model. You were shown a process for figuring out the formula mass. Ashley, what did you do to find formula mass?

S: I don't know.

T: How did you get the numbers?

S: I got them from Miguel.

T: Oh, awesome. Miguel, how did you get your numbers?

S: I got them from her (another student).

T: OK, how did you find the formula mass (asking third student).

S: You look at the chart, the numbers on the chart (periodic table).

T: What specifically do you look at?

S: The atomic mass." (Day nine transcript)

Towards the end of the same class period, a student showed low cognitive engagement during a discussion on how to solve a specific heat problem. In the sample problem the class was working, mass, specific heat, and heat are given while temperature change needs to be calculated. The mass unit is kilograms while the specific heat unit is Joules per kilogram degree Celsius so the mass needs to be converted to grams.

"T: you've got to convert to grams do you know why?

S: So the grams can cancel out.

S: I have no idea what you are doing. I don't even know what to ask.

T: Don't fuss if you aren't writing anything down.

S: I don't need to write it down if it doesn't make any sense to me. Do any of you understand?

T: Everyone has the opportunity to understand." (Day nine transcript)

The student shows low cognitive engagement in both metacognitive activity and approach to task here. She is following a procedure without seeking to understand why the steps are required. In suggesting that the grams might cancel out, she is following a step the class had done in earlier problems but the step does not apply to this situation. Additionally, the approach to the task is at a low level when she decides not to take notes on anything she is unclear about.

The next example is from Mr. Harrick's class. The class is having a pre-laboratory discussion. The student involved here is being asked to write a procedure for the experiment on determining the density of an irregular object.

"T: How are you going to determine the mass of the material?

S: Graduated cylinder?

T: You'll need the triple beam balance, for the irregular shaped object you'll have to put it on a piece of paper. So you need the mass of the paper, the mass of paper and mass. Then for your calculations you can subtract out the mass of the paper. To get the volume, take the starting volume from the new volume and that is the volume of the material. You do the same thing with the mass.

S: So all we are doing is answering number two? (Number two asks why are we doing the lab.)

T: No you are writing up all of these parts." (Day 24 transcript)

Because the student is being asked to discuss a procedure for determining mass, a two word answer is of insufficient detail. This low level of verbal contribution indicates the student is sociocognitively passive at that point. Later, the question asking if only number two needs to be answered shows the student is looking for a simple procedural solution that will let the task be completed with as little effort as possible. This type of behavior focused on finishing task quickly regardless of comprehension was common in Mr. Harrick's class.

During a lab practical students were finding the density of objects. The student speaking in the transcript below asks questions that are again primarily procedural. They show low cognitive engagement in the areas of asking questions, metacognitive activity, and approach to task.

"T: Anyone have any questions?

S: So we write our observations here? [On the paper]

T: Yes. Are there any questions? If you are talking to another group, you get a zero. The only person you should talk to are the people in your group or pair. Do not take drinks or anything except what I told you to, paper, calculator that is not a phone but iPod is fine, something to write with. Write what it feels like, collect the data. You only need to do one object, not both at the lab station. You get to choose which one you are going to do. You three go over here to station 12. You all here go to station seven. Are y'all a group, go to nine. And give me one more group, come on, give me a group, over here, station four.

S: Can we have a group of four?

T: No, I said a group of two or three. Remember, choose one. You do not have to do both regular and irregular shaped objects." (Day 26 transcript)

Even the final question about group size showed the student trying to have a larger group than was allowed. This would let four people do the work that was supposed to happen for only two or three people. Thus the goal of the student was to do less work.

The types of questions Mr. Harrick asked often required short answers. This made it difficult for students to show high cognitive engagement. Regardless, the next dialogue shows a series of questions where Mr. Harrick is asking students to indicate the labels on the graph axis that he is displaying. The nature of the student explanations lacks a causal mechanism. They seem to just be stating vocabulary words from the course in the hope of stumbling upon the correct answer.

> "T: The higher this number (teacher points to y-axis with solubility labeled) the higher the…?
>
> S: Temperature.
>
> T: No, that is on the x-axis
>
> S2: Mass.
>
> T: No.
>
> S3: Solubility." (Day 32 transcript)

The next excerpt continues to show sociocognitively passive behavior by several in the class. While this is going on, the students are creating graphic organizers using notes on the board and their textbooks. It is a reinforcement of activity of terms the class has already been using for several weeks.

> "S: What does covalent mean?
>
> T: What types of elements make up covalent compounds
>
> S: Liquids?
>
> T: No, nonmetal
>
> S: So things at high temperatures?
>
> T: No, ionic is solid and liquid, regardless of temperature.
>
> S2: How do you get the answer to c?

T: How do covalent compounds dissolve? You will have to look those up in your book.

S2: What is covalent, I forgot?

T: What types of elements make them up?

S: Metals.

T: No, not metals.

S: So just at high temperatures." (Day 32 transcript)

It shows low cognitive engagement in asking questions when the second student asks what covalent is just moments after Mr. Harrick had explained it to the first student. Also, instead of focusing on what defines an element as a metal, the first student has tried to develop an overly simplistic procedure that they can use to try and define metals. This is shown when the first student twice tries to claim that nonmetals are elements at high temperatures.

The final example of low cognitive engagement was while Mr. Harrick's class was taking notes and working example problems on nomenclature. Mr. Harrick is explaining how to determine the name of NaCl.

"S: Should we write that down?

T: Yes, that is one of your rules and there are not very many [the rule is to write everything the teacher writes on the board] So, the only thing that we really changed as far as naming ionic compounds is what, we only changed one thing?

S: the second one

T: What about it.

S: Changes depending on how many

T: No, that is covalent. We go from ine to...[no student responds as he hoped] we go from chlorine to chloride." (Day 36 transcript)

This student shows low cognitive engagement in approach to task and the nature of explanations given. When asked what changed from the names of the elements, sodium and chlorine, to the name of the compound, sodium chloride, the student just notes that something changed in the second word without stating what had changed. This then necessitates a follow up question from Mr. Harrick as he tries to coax a complete answer from the student.

High cognitive engagement without SRS

Class activities where students showed high cognitive engagement without the SRS happened at similar times as the low cognitive engagement examples. They tend to be large group discussions and are usually between the teacher and one or two students. This is not to say that there is not high cognitive engagement in small group settings, during individual work, or when several conversations happen simultaneously. During those times, it is simply difficult to document and analyze student engagement using the data that was collected and the rubric that has been created for this study. Another common theme is that most of these times are when the class is being introduced to a new topic but it is an area where lots of students in the class already have some related knowledge. When many in the class are learning completely new information or when already learned material is being reinforced, students were less likely to display cognitive engagement.

In the next example from Mr. Rein's class, they had just completed a lab where they attempted to determine the percent by volume of sand in a mixture of sand and water. There was one large container that each group in the class took samples of. The student responses tend to show high cognitive engagement in the areas of generative thinking, nature of explanations, and questions asked.

> "T: While you are completing the lab, I'll compile the data so we can see what everyone got. While I am doing that, let me ask you, what do you think it should be? Should everyone have the same percentage of sand or different?
>
> S: Around the same (from several in class)
>
> T: Anna, why around the same?
>
> S Anna: Because they all came from the same mixture.
>
> T: Kyle, why do you think the same?
>
> S Kyle: Kind of like she said, even though the masses are different, it came from the same mixture so the percents should be the same.
>
> T: OK, anybody else with a different idea about why they should be the same? (no response) Anybody have a different point of view about why they should be different? (Two students raise hands, he calls one of them)
>
> S3 : Some spots might be mixed up differently.
>
> T: So do you think it should be different if there was an error made but otherwise it should be the same?
>
> S3 : Some spots will just have a higher sand content.
>
> T: So you think certain areas will just randomly have higher concentrations. OK, Anna, what do you think?
>
> S Anna: how much you get might make a difference

T: The number of spoonfuls might make a difference? OK so if someone got two spoonfuls they might find a different percent than someone who got three or four. Is that what you are saying? (student nods agreement) OK.

Another student jumps in

S4 : What about the water? Some people had to use a lot to get it to filter.

T: You think how much water you used might have an effect. OK. I'm interested to see what the variability is, if there is any. I'll put it up on the screen and we can revisit it at the end of class. We'll have a discussion to see if the data reflects what we believe." (Day 22 transcript)

During class on day 10 of data collection, Mr. Rein is giving a lecture on the mole concept. He has several containers full of various objects. Each container has one mole of its respective object. Through this interaction, students show high cognitive engagement through the questions they ask. The students are sociocognitively curious and seek to understand the concept, not just to know enough to correctly answer questions.

"T: There is something (the objects he is holding) all have in common.

S: They all have one mole

T: That is exactly right.

S: How do you know that?

T: Great question. Each has 6.02×10^{23} of that item, I didn't count them. How might I have done it.

S: Weight." (Day 10 transcript)

When the class was being introduced to the concept of specific heat, a student went through a series of questions with Mr. Rein that showed high cognitive engagement. In particular, the question on conductivity is seeking to relate this new concept to a source outside the specific context.

> "S: Is specific heat always the same, whether you have 10 or 100g?
>
> T: Yes, for a given substance. If we have two materials at same temperature and same mass, what is different about them?
>
> S: The material itself.
>
> T: Yes, but what could we measure, what is different about them based on the heat?
>
> S: The amount of thermal energy.
>
> T: Exactly,
>
> S: Does that mean one is a better conductor or not?
>
> T: Not necessarily, it is more about how easy it is to change something's temperature." (Day 16 transcript)

The student has likely asked this because insulator and conductor are terms for the concept map and he is seeking to understand how they relate. This shows high cognitive engagement because he is asking this way and not just asking where it needs to be placed. The student is trying to understand idea of terms and will relate them to each other on his own. Later that same day, Mr. Rein had the class work in groups to create a concept map of key ideas in a chapter on heat and energy. Students knew in advance that he would come around to each group and ask them to explain the arrangement they used. The nature of explanations below shows a stubborn and tenacious defense indicative of high cognitive engagement.

> "S: And when temperature is, that involves heat transfer. With heat transfer, we have conductors and insulators. Insulators absorb heat and conductors allow heat.
>
> T: OK.
>
> S: You can use an equation to find temperature, involved in that equation is total energy and heat is also related to temperature. The units are calorie, Kelvin, and joule. A joule is a British unit.
>
> T: Interesting. Joule and BTU are not the same thing, but you might be able to put something in there that allows you to still have them together. OK, very nice. I see some things, now of course you did this without us ever really discussing, there may be some things that later on you want to come back and fix, but for now it is a good start." (Day 16 transcript)

After the concept map activity, Mr. Rein led the class through a discussion on the historical origin of the Fahrenheit and Celsius temperature scales. The student in the excerpt below shows high metacognitive activity in expressing curiosity about the origin of the 9/5 fraction in the temperature scale conversion equation. Also, the question asked showed a desire to more deeply understand the concept.

> "T: We can divide this fraction 180 over 100 by ten. What else can we divide it by?
>
> S: Two.
>
> T: Divide by two. That is where the nine fifths comes from. Sometimes it is five ninths. That is where it comes.

S: I always wondered where that came from.

T: That is where it came from.

S: Where did you get the 180?" (Day 16 transcript)

One day while Mr. Rein's class was working through specific heat problems, a student showed high cognitive engagement in the level of question asked and approach to task. Mr. Rein is working through problems on the board that the class has already worked at their seats. The student speaking below does not just want to have the correct answer, she wants to understand why what she has is not correct. This actually leads to her being able to correct a small error in decimal placement the teacher had made. From my own experiences teaching high school science, I was always impressed when a student corrected my mistake. It meant that they were paying attention and generally understood what was going on.

"S: How come it is not grams degrees Celsius?

T: We aren't looking for specific heat, we are looking for temperature.

S: On that 126 isn't is supposed to be 12.6?

T: Yes, thank you (student noted her answer didn't match the work, compared the two, analyzed why and found the error)." (Day 19 transcript)

Similarly high levels of metacognitive activity and question asking are shown the following day. One of the students, Cynthia, realizes she is not getting the same answer and suspects that she does not know the correct order to calculate the numbers once she has setup the problem.

"T: Are you getting the same answer as I am.

S Cynthia: I am not. Do you multiply the bottom ones before you divide?

T: Make sure that you use parenthesis. Your calculator will not understand that everything on the bottom is supposed to stay together.

S: Would you use that formula on all these?

T: Anytime you have heat transfer and specific heat." (Day 20 transcript)

Now some examples of high cognitive engagement in Mr. Harrick's class will be shown. His teaching style did not afford the same opportunities for students to display engagement as was present in Mr. Rein's class. Mr. Harrick taught physical science, a more basic subject than chemistry, and also preferred to teach only at the depth he saw tested on the state created End-of-Course Test. This level was often even more basic than the minimum required Georgia Performance Standards.

Mr. Harrick's class had a discussion to create the lab procedure they would use to find the density of irregularly shaped objects through water displacement. During this talk, a student made a few comments showing high cognitive engagement in the nature of explanation, asking questions, and approach to task.

"T: Why does it matter how much water you put in? (With water displacement measure for volume.)

S: Too much and it will go over the top, too little and you won't be able to tell what happened. But what will be the density measure? mL of water?

T: No, that is just the total volume, we still need to subtract out the original water volume and we need the mass." (Day 23 transcript)

The explanation requires the student imagine the proposed setup and predict a possible result in advance, that the water level could flow out of the container or fail to completely cover the object inserted in the graduated cylinder. Additionally, he tries to relate the volume information back to the larger goal of finding density instead of just focusing on the required procedure to complete the lab.

In the final example of high cognitive engagement without the SRS, there is a lengthy dialogue between Mr. Harrick and two students, Adam and Kerry. At times, both the teacher and student go off on brief tangents. However, the students do show generative thinking in how they try to connect the ideas Mr. Harrick is discussing with areas of their lives they do have some knowledge about. In particular, they draw on their prior knowledge about objects melting and burning.

"T: How about dry ice? Does it ever turn into a liquid?

S Kerry: It blows stuff up.

T: No, it turns straight from a solid to a gas. This is a phase change diagram, it doesn't only go one way; it goes either direction. What would happen as soon as I started heating you up?

S Adam: We would burn.

T: Why is that?

S Adam: Because our skin has…

S Kerry: We just burn.

T: The fire triangle says that you have to have a fuel source, oxygen and something to start the fire. The reason that you will burn is

S Kerry: Because we have oxygen.

T: If there were no oxygen, like in space, if I heated you, you would melt.

S Kerry: So if you took someone to space and started heating them then they would melt?" (Day 41 transcript)

These examples have shown how students in both classes displayed both high and low cognitive engagement. This provides a tangible view for the reader of what the class environents provided without aid of the SRS. We will now turn our attention to how the SRS was used in ways that gave teachers insight into the cognitive engagement of their students.

Cognitive Engagement with SRS

The SRS can be used in ways that let students show their cognitive engagement. The times when this happened in this study fit into three categories. First, the teacher would view the student answers to a question and then pose a follow-up question. That question might be to the class as a whole where anyone could respond or it might be focused on a specific student or group of students. Second, the students, upon seeing feedback from the SRS on their answers individually and collectively, decided to ask the teacher a question to clarify the concept being discussed. Third, the answers selected by students can give insight on the cognitive engagement of a person even without discussion from anyone in the class.

After using the clickers for a few weeks, Mr. Rein began to use data from the system to inform class discussions. The question below was presented to students with the SRS.

"1. Which statement about the mole is correct?

One mole of a substance always has the same mass as one mole of another substance

Answers

* A One mole of a substance always has the same number of particles as one mole of another substance.

B One mole of a substance always has the same mass as one mole of another substance." (Day 12 SRS file)

The question was flawed because option B appeared directly below the main question, then both options were presented at the bottom. Mr. Rein told the class he had accidentally left that part twice while copying and pasting. Many in the class took it as an indicator that B was the correct answer even though it was not. Upon seeing that only three students answered correctly, Mr. Rein decides to start a discussion with the students about the content of the question.

"T: Somebody tell me, one of you three (who got it correct), tell me how you know it to be the truth.

S: It is an amount of something not a weight.

T: One mole is an amount of something. That is a good way of putting it. Did you read that the mole is called the chemist's what? The chemist's dozen. How is a mole related to a dozen?

S: It can be used to measure a lot of things.

S2: It is always the same amount no matter the substances.

T: Right, we can have a dozen of many things or moles. The mole is the same way. I would like to hear something from you 18 here.

S3: I guessed.

T: Somebody else.

S4: I always pick B when I do not know." (Day 12 transcript)

Students one and two show high cognitive engagement in the nature of their explanations and generative thinking. They are able to relate the mole concept to other quantity units they know from their everyday life such as a dozen. Also, they can differentiate what the mole is, a quantity of something, from what it is not, a weight. Meanwhile, students three and four show low cognitive engagement through their generative thinking and approach to the task. They do not show evidence of trying to deeply process the content of the question before selecting an answer.

Another day, the class was playing a review game when this question came up:

"10. 50 grams of magnesium = __ moles of magnesium. What should 50 grams multiplied by?

Answers

A 1 mole/6.02 x 1023 grams

B 24.305 moles/6.02 x 1023 grams

C 24.305 moles/1 gram

*D 1 mole/24.305 grams

Response Percentage 14 14 24 48" (Day 13 SRS file)

Upon seeing that less than half the class got it right and that each incorrect answer got a large percentage, Mr. Rein decides to discuss the problem with the class.

"T: Anyone want to talk about this one?

S: No, it all makes sense now.

S2: Why does it have to be on bottom?

T: Grams have to cancel out. So grams is on top and we want moles. This is what is on the table about magnesium." (Day 13 transcript)

Student two asked a question showing a desire to understand the process that leads to the correct answer. This type of questioning is indicative of high cognitive engagement. When the review game was finished, Mr. Rein picked out two ideas to discuss further, physical changes and periodicity. These were areas where he noticed students generally struggling on. The conversation below focuses on physical changes.

"S: You can't change it back if it is a chemical change.

T: You can't change it back if it is a chemical change. OK, so like the breaking chalk, can I change that back?

S: Yes.

T: You can?

S2: No, but it is still the same substance.

S3: With superglue you can.

T: OK. With superglue you can.

S4: But if they all have the same properties as first.

S5: It is still the same thing.

T: It is still the same...

S6: Still the same substance.

T: Still the same substance. That is what you want to pay attention to. What about the melting of ice?

S: You can refreeze it back.

T: It is reversible and it is still...

S: Water." (Day 20 transcript)

The generative thinking and explanations offered by the students show that they are cognitively engaged. Six different students were an active part of this discussion. With the rest of the class, it is difficult to determine their engagement based directly on the conversation. However, each person was able to evaluate his or her own comprehension throughout the activity based on the immediate feedback of the SRS.

The final day of observation in Mr. Rein's class, he did a review game. This was question 15 from that review:

"15 Which process will cook vegetables faster?

Answers

A Boiling them

B Steaming them *

Response Percentage 5 95" (Day 21 SRS file)

After students finished responding, Mr. Rein discussed the results with them.

"T: Which will heat up faster, steamed or boiled food? Who answered B, correctly and how can you explain that?

S Grant: It is more joules.

T: What do you mean, why?

S Grant: Because the energy for the atoms bounce off each other more

T: You are right, the atoms in the vapor state have more energy, so once they contact the surface of the vegetable, they release more energy than the hot water parts. Have you ever gotten a steam burn? They are much more severe because of this, they have the heat of vaporization in them unlike liquid water." (Day 21 transcript)

Mr. Harrick’s teaching style, as already discussed, did not offer the same opportunities for students to display cognitive engagement. Regardless, note below how Missy takes initiative to try and better understand bonding type classifications.

“S Missy: How do we know if it is ionic or covalent?

T: If it has two nonmetals it has to be what?

S Missy: Covalent.

T: And if there is a metal?

S Missy: I don't even know.

T: Hurry up everyone so we can get this before the bell rings.” (Day 37 transcript)

In this dialogue between Missy and Mr. Harrick, we see a student initiating conversation with the teacher when the SRS has helped her see that she does not understand bonding types. Missy’s questioning shows high cognitive engagement and is especially impressive given the classroom environment did not invite student initiated questions. This next question occurred after an SRS question on bonding types.

“S: Why do we have to learn the coefficient things if we aren’t using it in the future?

T: Do you want to learn how to think? This isn’t just about balancing equations. Which of the following is a single replacement?

S Kerry: A.

T: Can A have two different compounds?

S Kerry: How can you know there are two different compounds?

T: If there are two or more

S Molly: B. You know it is not C or D" (Day 40 transcript)

In the above exchange, a student mentions the activity is hard and that he is unclear on how to do it. Yet there is no other effort taken by the student to figure out the concept so it shows low cognitive engagement. The student is content with not understanding the concept. Conversely, Molly and Kerry show high cognitive engagement. Molly does through her explanations on how to name. She is able to apply broad nomenclature rules to the specific examples given. Kerry, while not clear on what a compound is, seeks out a deeper understanding through questions that focus on the concept of a compound instead of focusing on how to get an answer to the specific problem the class was looking at.

An example from a global warming activity has already been seen during the section on Mr. Harrick's evolution as a teacher using the SRS. However, we will view it again in terms of student cognitive engagement. Below we see the fourth SRS question asked after students had completed a worksheet. Immediately after seeing the results of student responses, Molly and Mr. Harrick exchanged dialogue.

"4   What effect did the Industrial Revolution have on the Earth's atmosphere?

Answers

*A   released more CO2 than could be removed and created a thick blanket around Earth

B   released more pollution that made clouds darker, blocking the sun from the earth

C   decreased the amount of CO2 so that plants did not have enough for photosynthesis

D released more CO_2 than could be removed, raising the surface temperature 11.5 degrees

Response Percentage 92 8 0 0" (Day 41 SRS file)

"S Molly: I don't see why anyone guessed B because if anything, I would have guessed D because that is also true.

T: We are going to talk about that.

S Molly: But why is that right?

T: We are going to talk about that, the article is not the end all be all.

S Molly: I know but it had it in there.

T: You got 75% correct average so that is not bad." (Day 41 transcript)

Molly again shows great curiosity and tenacity in seeking out the answers to her questions. This exhibits high cognitive engagement on her part. It is interesting that she is pondering why some would have chosen other answers because that is exactly the type of question I was trying to get the teacher to ask the class. Similar behavior is shown by both Molly and Kerry later in the same activity.

"S Kerry: How do you know if it is more acidic, the higher the number?

S2: No, the lower the number.

T: What is acid, what range, 0-7, what about basic?

S Molly: 7-14.

T: And what is 7? [neutral]. Whichever has the lower number is more acidic. OK, materials with pH values between 0 and 7 are considered acid, number 33.

S Kerry: how do you know what is more acidic?

T: The lower the number the more acidic and the higher the number the more basic. Now, which is a property of a base?

S Molly: Slippery." (Day 41 transcript)

While answering SRS questions on activation energy as a part of a review, Mr. Harrick stops to discuss the topic with the class.

"T: What affect does catalyst have on activation energy? No effect. Well, look at the EA, what is happening?

S: I don't know how to look at the graph, I don't get it.

T: On the left you have the base energy. Then on the right is it more or less. So either way, what does the catalyst do to the energy? [lower it]

S Molly: So this one will raise it?

T: OK, one more question.

S Molly: I don't get it." (Day 43 transcript)

The students here show lower cognitive engagement in just stating they do not understand but failing to take other action to better comprehend. The analysis of the student behavior is complicated by Mr. Harrick's lack of deeper interaction with the students. He fails to explore what precisely the students do not understand.

SRS questions that show cognitive engagement

The questions shown in Appendix B did not have discussion related to them that gave indications of cognitive engagement. If the teachers or students had chosen to initiate those discussions, it certainly would have provided more insight. Regardless, these questions require high cognitive engagement to get the correct answer. The solutions to the problems require students think critically, take action to solve problems, manipulate variables to determine relationships, and/or determine cause and effect relationships.

Student Perceptions of SRS

Students generally seemed excited when the clickers were brought out in both Mr. Rein's and Mr. Harrick's classes. On day 39 of data collection, Mr. Harrick asked the students their thoughts about taking a test using the clickers to respond in lieu of scantrons.

"S Molly: I think we should start doing like we just did (with SRS).

T: One person at a time who wants to make a comment just raise your hand. [no one does] who likes it better, raise your hand. Sara, will you count please? If you like this better it could enhance my decision to get one, which will impact you. 14 out of 17 preferred it. If you liked it better, raise your hand and tell me why?

S: It means I don't need pencils.

T: There will always be an essay part.

S: It is nice not to have to worry about erasing a scantron where it might mark things wrong." (Day 39 transcript)

Some in the class expressed that it is easier to keep track of what problem you are on in a large test when submitting answers with the SRS. They also cite a preference for not needing a writing utensil and the faster grading.

Both classes were given a semantic differential on the last day of observation. It had a variety of statements about the SRS with an extreme statement of agreement on one side and an opposing viewpoint on the other. Students were able to indicate which statement more closely reflected their belief. There were five boxes on each line. The boxes on each end indicated strong agreement with the statement nearest it. The box in the middle was neutral and the other two boxes indicated moderate agreement with the statement. The more positive statement was sometimes on the left and at other times on the right. This was done to encourage students to consider each position more instead of quickly marking down one side of the page. Figure 3 below shows an aggregate of student responses.

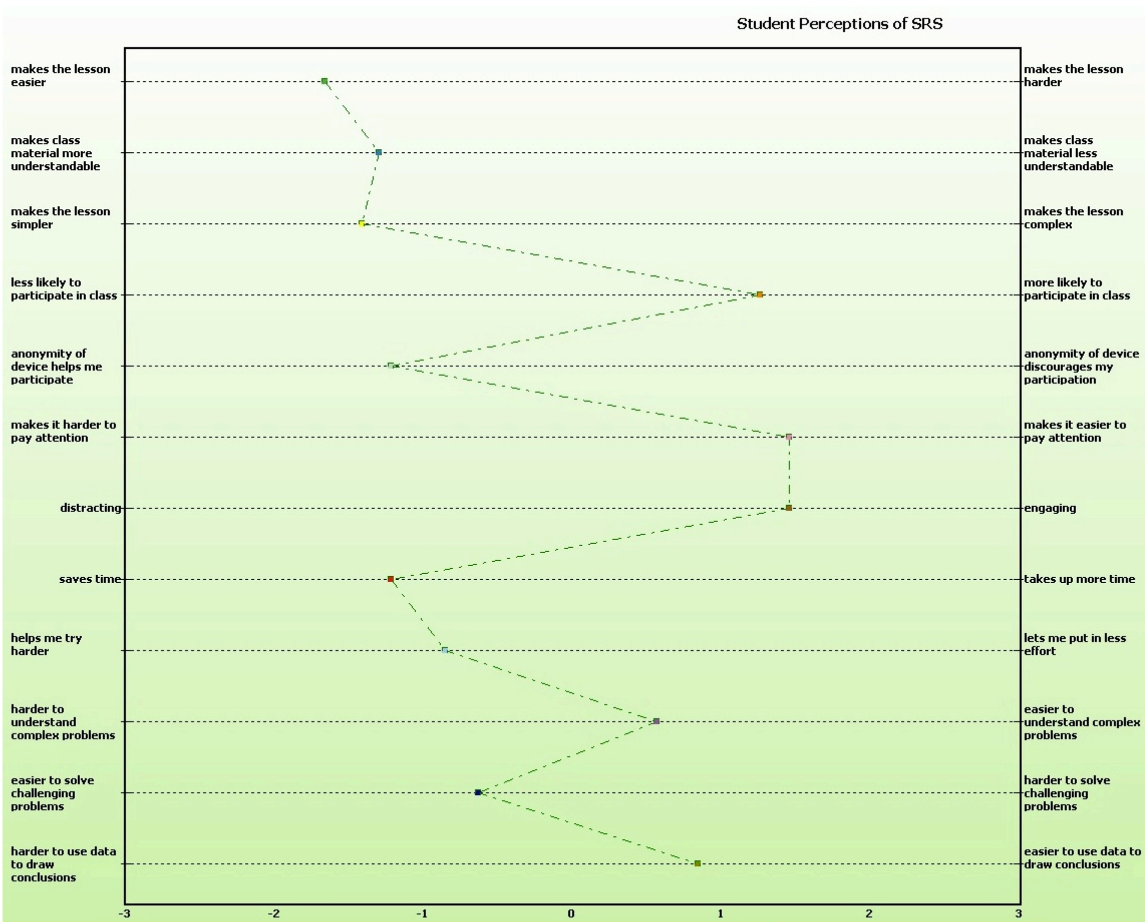

Figure 3. Aggregate of Student Responses to Semantic Differential.

While students show generally positive perceptions of the clickers, particularly high marks are given in areas of increasing engagement, participation and making the lesson material easier to understand. Students did not feel the clickers were as helpful with making more challenging problems easier to solve. The overall score of each area is shown in Figure 4 below. Negative numbers simply mean the responses favored the left side while positive numbers mean the statement on the right was favored.

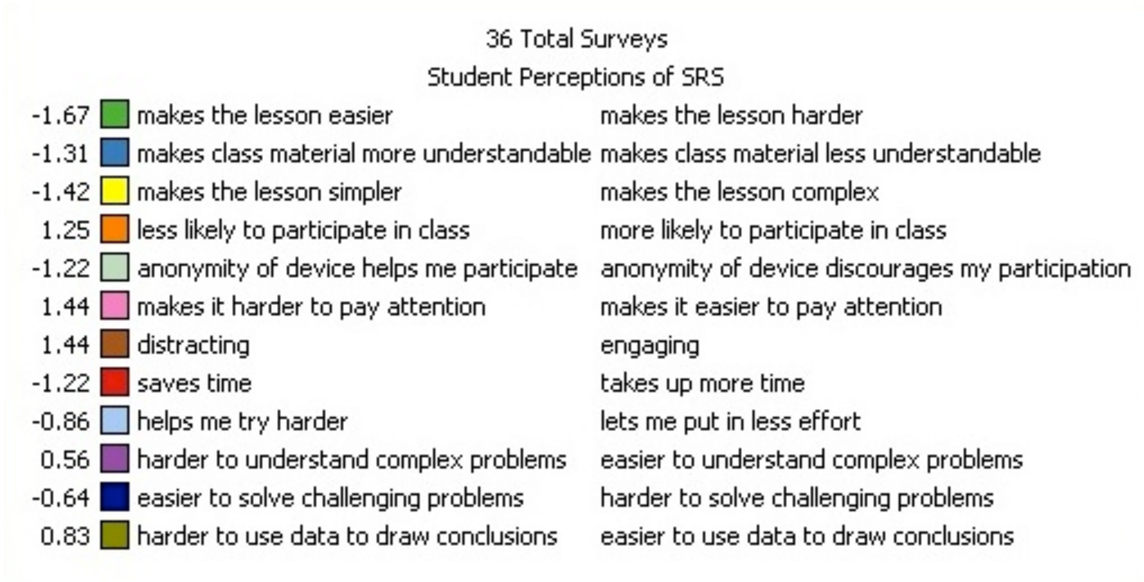

Figure 4. Semantic Differential Scores.

Some of the statements had more varied ranges of responses while others had fairly consistent viewpoints shared by students. Table 2 below shows how many students selected each option.

	-2	-1	0	1	2	
Makes the lesson harder	24	12	0	0	0	Makes the lesson easier
Makes the class material less understandable	18	12	5	1	0	Makes class material more understandable
Makes the lesson simpler	17	17	2	0	0	Makes the lesson complex
Less likely to participate in class	2	1	5	6	22	More likely to participate in class
Anonymity of device helps me participate	17	11	7	1	0	Anonymity of device discourages my participation
Makes it harder to pay attention	0	2	2	10	22	Makes it easier to pay attention
Distracting	1	0	4	8	23	Engaging
Saves time	17	12	6	0	1	Takes up more time
Helps me try harder	11	13	9	2	1	Lets me put in less effort

Harder to understand complex problems	2	4	11	10	9	Easier to understand complex problems
Easier to solve challenging problems	8	8	19	1	0	Harder to solve challenging problems
Harder to use data to draw conclusions	1	2	11	10	12	Easier to use data to draw conclusions

Table 4. Semantic Differential Responses.

It is interesting that the students generally found the SRS saved time in class. The teachers both felt that the devices took more time on their part. There is more planning time required to initially create questions but it seems that clickers help class run more efficiently once the SRS questions are created.

Conclusion

At the beginning of the chapter, the traditional tools used by participant teachers to assess engagement were examined. Both teachers would ask the class questions while leading discussions. Due to time constraints, they had to apply the answers from a few students to the class as a whole. Other non-verbal measures included looking to see that students generally had out the correct supplies and were working on the assignment. Hand-raising was used at times to let multiple students give input to the teachers. Mr. Rein utilized index cards to randomly select students to answer questions and for lab groups. He also moved around the room frequently using his close proximity to foster smaller group discussions. Meanwhile, Mr. Harrick primarily remained at his desk while teaching and rarely interacted in smaller group settings with students.

As the teachers began using the SRS, both found it immediately useful as a summative assessment tool. They found it an effective way to increase student engagement and give class members a way to gauge their own understanding of class topics. However, it was not used early on as a discussion tool or for higher-level questions. Over time, both teachers found value in the clickers for review activities and branched out into other uses. Mr. Rein in particular evolved his use to let the results of SRS data drive class discussions both during clicker use and immediately afterward. He also attempted to use the SRS in group settings where students would discuss a question and agree on a response before submitting their answer. As Mr. Rein's chemistry class began solving stoichiometry and energy problems, he used the SRS to let students select the next step in a problem instead of just the answer. This different type of questioning gave him insight into how students were arriving at answers. That information would not have been possible on a large scale without the SRS. Mr. Rein already used his index cards to ensure he received student input from a variety of class members and he also walked throughout the classroom to observe student work. When he was equipped with the SRS, this system enhanced his ability to get lots of input from all students. Therefore, it is not surprising that he changed his teaching more over time than Mr. Harrick.

Meanwhile, Mr. Harrick made attempts to use the SRS for discussion but this was in sharp contrast to his teaching style without clickers. On account of this, students in his class had limited opportunities to show cognitive engagement whether clickers were present or not. Ultimately, both teachers did change instruction over time to optimize the benefits of the SRS. Mr. Rein, whose teacher style already more closely aligned with optimal clicker use, was able to change his teaching more than Mr. Harrick. For Mr. Harrick, it appears optimal clicker usage would have required too large of a change in his teaching. He did not place much value on the level of comprehension from the class nor did he use systematic practices that let him get input from a variety of students. As a result, smaller changes in his teaching were observed.

Students in both classes reported positive perceptions of the clickers. They found it encouraged their participation and kept them further engaged. When it came to answering higher level and more difficult questions, the students found the SRS useful. However, they did not have as favorable impressions in this area compared to the engagement and participation areas. The findings reported here on both student and teacher use of clickers will be further discussed in the next chapter. Additionally, there are implications for further research, policy, and professional development in regards to SRS that will be explored as well.

CHAPTER V

DISCUSSION

To conclude this report of a research study, this chapter will provide a review, summary and implications that result the research reported here. To begin, I will present again the purpose and research questions of the study. Following that, an overview of the study and its findings are presented. Finally, a discussion of the research findings, implications for practice and recommendations for further research are provided. This study looked the instructional uses of one SRS system and how that system could be used to facilitate cognitive engagement of high school students in chemistry classes. The researcher worked with two classes for several months providing training to the teacher and observing the students. Student actions were evaluated against a rubric to determine whether high or low cognitive engagement was being exhibited.

Original Intent

While preparing to begin the study, it was hoped that this research would highlight potential uses of one particular system of Student Response System, that tool that is colloquially known as clickers, to promote high cognitive engagement of students. As students within science classes were observed over time, the researcher also hoped togain insight into how teachers change their practice over time using this particular SRS. Ultimately, this would reveal how clickers can become an additional assessment tool used by teachers.

Purpose

Research has shown that SRS are not currently well integrated into the K-12 classroom (Songer, 2008). Further, other research suggests that teachers need guidance before they can integrate clicker use into their teaching practice (Trees & Jackson, 2007). Using the research literature as a guide, I concluded that classroom teachers also need assistance integrating SRS use into specific lesson plans within the chemistry curriculum. Another factor that served as a foundation for this study dealt with assessment tools that teachers intentionally implement during instruction. While teachers already have assessment tools they use with students, clickers are so different from other common assessment tools that they require a profound shift in teaching philosophy and strategy. This study seeks to inform teachers on effective uses of SRS in specific contexts to help determine how well students are meeting instructional goals. The following research questions were the focus of this study:

Research Questions

1. What are the traditional tools used by participant teachers to assess student engagement?
2. In what ways can an SRS serve as an additional tool for teachers to assess student engagement?
3. From the students' perspectives does use of an SRS provide them with opportunities to demonstrate their engagement not available in classrooms without the SRS?
4. How do the teachers' tools for assessment of engagement possessed prior to the introduction of SRSs impact their willingness to adopt new systems?

5. Given SRS adoption and usage over time, do teachers shape instruction to optimize the benefits of using the SRS?

Intended Benefits of This Approach

The design study approach allowed the researcher to integrate his goals with the instructional goals of each teacher. The researcher sought to find ways to use the SRS so that students would display cognitive engagement whereas the teachers, as their primary goal, wanted to use the SRS as a means to determine how students learned the content taught in each respective course. Instead of seeing how clickers could be used in a controlled research environment, situating this study in actual classrooms provides practical insight into how the devices can be used to affect teaching and learning. By conducting research over several months, students had an opportunity to become accustomed to the clickers. Teachers also had a chance to get comfortable with a range of instructional uses for the SRS and adjust their teaching over time to optimize the benefit of the devices. The intended benefits of this approach were that they would show how teachers can use SRS to encourage cognitive engagement in students. By using classes at different schools and where teachers had different instructional styles, a variety of integration methods could be shown. By analyzing usage by both teachers, the researcher hoped to provide best practices that all science teachers could use with SRS.

Summary of Findings

Data collection took place in a chemistry classroom taught by Mr. Rein and a physical science classroom taught by Mr. Harrick from January 2010 until April 2010. Each teacher was provided with a laptop computer, LCD projector, and class set of SRS. Additionally, they received initial training on using the equipment prior to classroom use.

The researcher was present daily to observe the class and help plan ways to use the SRS to meet the goals of both the teacher and the study. Data collected consisted of video recordings, a database file with all SRS usage, and semantic differentials detailing student views of the devices. The data was coded for themes relating to the research questions.

Teacher Tools Without SRS

Mr. Rein used a variety of tools to assess his students without the SRS. For instance, during large group times, he would ask questions to the class as a whole or a specific person. In those instances where he selected a specific person, that individual would sometimes be randomly selected using a set of index cards with student names written on them. During a variety of class activities, Mr. Rein would frequently walk around the class asking students questions based on the work that he saw them doing. Homework was collected almost daily and graded for accuracy to assess how well students understood the material covered on the assignment. Students were asked for questions periodically to allow those who did not understand a topic to take initiative on getting help from the teacher. Mr. Rein also used non-verbal indicators from students such as head nods, looks of confusion, what materials students had out, and how actively they appeared to be working.

Mr. Harrick's assessment tools were far more limited. He rarely walked around the room to monitor student work nor did he have any type of systematic method to ensure a variety of students were called on. Instead, when he asked questions, it was almost always to the class as a whole where anyone could decide to answer. There were a small handful of about five students who primarily participated in answering questions. Student work was only graded for accuracy on quizzes and tests. When this work showed lots of inaccuracies, students were expected to arrange additional help outside of classtime.

Teacher Change Over Time with SRS

Both teachers in the study did change their teaching over time as they worked with the SRS. While adjustments from one week to the next were not always obvious, the total change from the beginning of the research study with each teacher to the end showed significant changes. These changes were not in quantity but instead in type of usage. Mr. Rein initially used the SRS to see variation in pre and post-test scores on clicker quizzes related to a lab or lecture topic. The device served primarily as a summative assessment tool and the results were not discussed with students. By the end of the portion of the study with Mr. Rein, he was pausing after specific SRS questions to ask students why they had responded in particular ways. Additionally, after finishing a clicker quiz, he would stop and discuss areas that the class as a whole struggled with. Instead of only using the device as a summative assessment tool, it was also employed for review activities and more formative assessment.

When Mr. Harrick first attempted to use the SRS in his classroom, he struggled getting the software installed and operating the devices. He often required me to setup the software and run the quiz. He did not interact with the students during the quiz and the results did not influence future class activities. By the end of the study, Mr. Harrick had used the SRS to give a mid-term exam using the fast grade feature. He also used the clickers for review activities and as a formative assessment tool during lectures. It slowly became more common for him to discuss answers with students during a quiz as well as the overall results upon completion of an SRS quiz.

Shaping Instruction to Optimize SRS

Ultimately, both teachers did adjust their teaching to try to optimize the benefits of the SRS. This optimal usage occurred when the teachers initiated discussions with students based on the feedback provided by the SRS. This rarely occurred for either teacher in the first several weeks of working with the researcher. The optimal usage was limited in quantity to only a few times towards the end of working in each respective classroom. Limitations on this type of usage depended on each teacher's non-SRS assessment tools. For Mr. Rein, he already felt that he had effective tools that required less time investment from him than the clickers. These included the index cards and monitoring student work. He felt that the clickers would have been a more powerful tool for him if he taught more students and could not interact with each of them. Mr. Harrick, on the other hand, did not place much value in student input or performance. So when the SRS showed areas where students had not accurately answered something, he was not naturally led to investigate the cause of that further.

SRS as an Additional Assessment Tool

The SRS served as an additional assessment tool for both Mr. Rein and Mr. Harrick. Some uses of the clickers duplicated assessment tools already present within their instructional repertories. That was particularly true with Mr. Rein as discussed above. The most beneficial use of the SRS as an additional tool were when students were asked for reasoning on selecting various answers on clicker questions. The students had an opportunity through their responses to indicate their cognitive engagement. Some questions asked with the SRS also gave indication of student cognitive engagement purely from the responses collected. A common example of that type of question was when students had to select the next step in a problem. For a student to answer this type of question correctly, high cognitive engagement was required. The power of the SRS as an additional tool in these areas is that all students can quickly and simultaneously provide feedback. All students also get to immediately receive feedback on their performance for each question and the series of questions as a whole. Often this feedback led to students asking additional questions they would not have otherwise asked.

Student Perceptions of SRS

Student perceptions of the SRS were collected using a semantic differential given on the last day of data collection in each class. The viewpoints of the students were combined to provide a holistic view. While students show generally positive perceptions of the clickers, particularly high marks are given in areas of increasing engagement, participation and making the lesson material easier to understand. Students did not feel the clickers were as helpful with making more challenging problems easier to solve.

Implications

SRS are becoming increasingly common in the K-12 environment. As additional resources continue to be allocated to provide funding for this instructional technology, teachers will need training on how to best use the devices. While teachers already have a host of non-SRS assessment tools they use, clickers are quite different from these other tools in that they require more planning time in advance. However, they also provide additional benefits not otherwise available through allowing all students to answer questions and get immediate feedback. Teachers need training on how to process this wealth of data to guide class time.

For schools and districts interested in providing SRS to teachers, it may not be practical to purchase clickers for every teacher. If only some teachers are to receive them, those who are willing to commit to extensive professional development will benefit most. Also, those teachers who already value student feedback will be able to optimize SRS use more quickly. On account of this, schools and districts should consider teachers' instructional style and commitment to professional development when deciding who will receive SRS.

The ideal teacher to use SRS would be one that values student feedback and is interested in the cognitive engagement of students. Kennedy & Cutts (2005) discuss how there are two main ways to use SRS in the classroom, as something to increase cognitive engagement of students and also as a teacher tool to formatively assess students and adapt teaching based on results. My teachers may have offered lip service to both of these, but ultimately did not use the SRS data much to adjust lessons. Instead, they viewed it as a tool for students to self assess. The method they used it in did not allow for the researcher or teacher to get much insight into the student cognitive engagement. Instead, it was assumed that if students saw they did not understand, they would seek additional help outside of class. In practice, no student in either class sought this outside help based on SRS.

The content of higher-level classes such as a chemistry course have more opportunities to create SRS questions that can gauge cognitive engagement. Five to ten questions per class appears optimal. In more introductory classes like physical science, the SRS can more easily be used to give students feedback on the accuracy of answers. These findings on the ideal number of questions per class and differences in SRS use in higher level classes are supported by the earlier findings of Crossgrove & Curran (2008) in biology and genetics courses at the college level.

Plans for implementation of SRS should take into account that teachers must learn how to operate the devices and also how to teach with them. In this study, when a researcher was present to assist daily, it still took several weeks to notice major changes in teaching style with SRS. Teachers are able to quickly use the device to quiz students. It takes more time to figure out what to do with the results of these quizzes while in the middle of teaching a class. The time required to prepare SRS lessons in advance served as a barrier to clicker use. If several instructors of the same subject were able to collaborate and share SRS quizzes, this would minimize the time requirements for each teacher and could increase SRS usage.

Recommendations for Future Practice Based on Findings

Based on the findings of this study, the following recommendations are made for future practice.

1. Schools and districts seeking to provide SRS to teachers should first provide the devices to those most likely to use them in optimal ways. This could be accomplished by reviewing teacher evaluations to find candidates that already let student input and performance drive class time. Also, ideal candidates should be prepared to commit to weekly professional development on SRS usage. When possible, several teachers of the same subject should each receive an SRS and be given common planning time. That will allow for them to divide the work of creating SRS questions so that the time requirements for each individual teacher

are reduced. With less time requirements during planning, usage of the SRS will be higher than it would be otherwise.

2. High school teachers who have access to SRS should develop questions to ask with the devices that give students an opportunity to indicate their cognitive engagement. Questions that require critical thinking to answer and those that focus on the next step in a complex process are examples of ideal questions. After asking an SRS question, students should be asked about how they arrived at the answer they selected, whether correct or not. Students should occasionally be selected for question by using a random student picker available in the SRS software. This ensures that all students will have a chance to verbalize their thinking. Upon completion of an SRS quiz, teachers should discuss areas where students either did not perform well or had lots of questions.

Implications for Further Research Based on Findings

Based on the findings of this study, the following recommendations are made for further research.

1. Additional research of this nature should be conducted in other secondary science classrooms to see how teachers integrate the SRS into their teaching. This study was exploratory and gave insight into how two particular teachers interacted with the SRS. It would be beneficial to see how the SRS is used in additional class subjects and with teachers who have different teaching styles and assessment tools. With more research in this area, it would be clearer how teachers with a variety of assessment tools are likely to use the SRS. Also, it would become

clearer what type of professional development would foster optimal use of the SRS.

2. While it is clear that the SRS can be used as a tool to let students show their cognitive engagement, additional research should be conducted on additional methods to use the SRS in this way. This research would provide more clarity on the ways SRS can be used to give indications cognitive engagement. The study reported here offered some methods based in a particular context. A more robust collection of research in this area would help confirm the findings of this study.

Conclusion

As technological advances continue to be made, teachers will have access to an increasing number of devices with which to teach. It is important that instructors be given guidance on how to best teach with these new technologies. The SRS is able to provide exponentially larger amounts of data to teachers in real-time on student performance. It also provides students with exponentially more opportunities to participate in class and get immediate feedback. This great increase in participation and data needs to be directed in ways that will improve learning.

In our current K12 educational setting, school accountability and student achievement are required by things such as No Child Left Behind and Race to the Top. To help our students improve learning, it will be helpful to understand how they are processing new material being introduced to them in class as well as any barriers that might be limiting their understanding. Teachers can gain some understanding in this area through traditional assessment tools like asking questions and evaluating student work. However, these methods are time consuming and cannot immediately offer insight on each student. The SRS is able to provide this immediate information if teachers ask questions that require high cognitive engagement to answer them and if students are asked to verbalize the processes used to arrive at answers.

This study showed what can be accomplished when a researcher partners with teachers to use instructional technology like the SRS in innovative ways. Teachers need guidance on how to use the tools at their disposal to improve student learning. As research of this nature continues, teachers will gain even more insight into how students learn complex science topics and how they can use 21st century tools to optimize that learning.

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APPENDIX A

TIMELINE OF DATA COLLECTION

Observation Day Number	Type of Data
1	Field notes
2	SRS file, field notes
3	SRS file, field notes
4	SRS file, field notes
5	Field notes
6	Field notes, transcript
7	SRS file, field notes, transcript
8	Email, field notes, transcript, SRS file
9	Transcript, field notes
10	Transcript, field notes
11	SRS file, field notes, transcript
12	Field notes, transcript
13	SRS file, transcript, field notes
14	Field notes, transcript
15	Field notes, transcript
16	Field notes, transcript
17	SRS file, field notes, transcript
18	Field notes, transcript
19	Field notes, transcript
20	Field notes, transcript
21	SRS file, field notes, transcript

22 week seven	Field notes, transcript
23	Field notes
24	Field notes
25	Field notes, transcript
26 week eight	Field notes, transcript
27	SRS file, field notes
28	Field notes, transcript
29	Field notes, transcript
30	Field notes
31 week nine	SRS file, field notes, transcript
32	Field notes, transcript
33	Field notes, transcript
34	SRS file, field notes, transcript
35	Field notes
36 week eleven	Field notes, transcript
37	Field notes, transcript
38	Field notes
39	SRS file, field notes, transcript
40 week twelve	SRS file, field notes
41	SRS file, field notes, transcript
42	Field notes, transcript
43	SRS file, field notes, transcript
44	Field notes, transcript

45	Field notes

* Days 1-22 were in Mr. Rein's class. The remaining were with Mr. Harrick.

APPENDIX B

SRS QUESTIONS ABLE TO INDICATE COGNITIVE ENGAGEMENT

1 25

4. How many moles are in 100 grams of sulfur (S)?

The correct conversion factor to use in this instance is _____.

Answers

A 1 mol S = 32 atoms S

B 1 mol S = atomic number of S

C 6.02 x 1023 g = 1 mol S

D 32 g S = 1 mol S1

*

Response Percentage 5 19 67 10

5. How many grams of calcium (Ca) do you need to have 2.50 moles of

The correct conversion factor to use to solve this problem is _______

Answers

A 6.02 x 1023 atoms Ca = 1 mol Ca

B 1 mol Ca = 40.078 g Ca

*

C 1 mol Ca = atomic number of Ca

D 1.66 x 10 24g Ca = 1 mol Ca

Response Percentage 5 43 5 48

Session: chapter 2 Review 1/27/2010 10:40:09 AM

Class: chem 3rd spring

Class Points Avg:14 out of 100.00 (72.14%)

1 An element has the atomic number 18. What type of element will like

properties?

Answers

* A an element in the same group

B an element in the same period

C an element with a close atomic number

D an element with a close atomic mass

Response Percentage 76 0 19 5

2 Is the burning of magnesium ribbon an example of a chemical or physi

you know?

Answers

A physical change because it is easily reversible and still

B physical change because magnesium is an element

* C chemical change because it is not easily reversible and h

substance

D chemical change because magnesium always undergoes chemic

Response Percentage 19 19 57 5

7 How is the periodic table arranged?

Answers

A alphabetic order

B by increasing atomic mass

C by increasing atomic number

*

D I don't know

E metals on the left, non metals on the right

F gases on the right, solids on the left

Response Percentage 0 57 29 5 10 0

10 50 grams of magnesium = __ moles of magnesium. What should 50 grams multiplied by?

Answers

A 1 mole/6.02 x 1023 grams

B 24.305 moles/6.02 x 1023 grams

C 24.305 moles/1 gram

D 1 mole/24.305 grams

*

Response Percentage 14 14 24 48

11 Explain why the breaking of chalk is an example of a physical change change

Answers

A because chalk is a compound, it is just being broken down is made of

B because each smaller piece still has the same composition

*

C because chalk is a mixture and thus cannot be broken down chemically

D because it is irreversible, the chalk cannot be put back

Response Percentage 5 76 0 19

16 How many oranges are in 1 mole of oranges?

Answers

A 1.66 x 1024

B 9.10 x 1025

C it depends on what type of atoms are in the orange

D 6.02 x 1023

*

Response Percentage 14 5 24 57

19 Explain why the breaking of chalk is an example of a physical change

change

Answers

A because chalk is a compound, it is just being broken down

is made of

B because each smaller piece still has the same composition

*

C because chalk is a mixture and thus cannot be broken down

chemically

D because it is irreversible, the chalk cannot be put back

Response Percentage 0 95 5 0

2 2

Session: 3.1

Class: chem 3rd spring

Class Points Avg:89 out of 100.00 (88.89%)

(Includes only students who took assessment)

1 How is the kinetic energy of a system related to its temperature?

Answers

A temperature and kinetic energy are inversely related

* B temperature is the average kinetic energy of all the part

C they are identical, the kinetic energy is the temperature

D kinetic energy is the average temperature of all the part

Response Percentage 0 94 0 6

2 Describe how the motion of atoms and molecules is related to tempera

Answers

A as the temperature decreases, atoms and molecules move sl
non random motion

B at low temperatures atoms and molecules do not move

C atoms and molecules move randomly, so temperature is unre

D as the temperature increases, atoms and molecules move fa

* motion

Response Percentage 0 0 0 100

3 Normal human body temperature is about 98.70F. Which of the followi

way to calculate this temperature in Celsius?

Answers

A 9/5(98.7+32)

B 5/9(98.7 32)

*

C 9/5(98.7 32)

D 5/9(98.7+32)

5 How do you convert 200C to Kelvin?

Answers

A 9/5(20) +32

B 20 273

C 20 + 273

*

D 5/9(20 32)

6 Select the correct method to convert 273K to Fahrenheit

Answers

A 9/5(273 273)+32

*

B 5/9(273 273 32)

C 9/5(273+273)+32

D 5/9(273+273 32)

2 2 3. 2quiz

1 To calculate the heat absorbed by an object, what information is nee

specific heat?

Answers

A volume and temperature change

B mass and heat added

* C mass and temperature change

D volume and heat added

Response Percentage 0 0 100 0

2 The specific heat of water is much higher than other substances. Wh

Answers

A water does not change temperature easily

*

B water has a higher temperature than things around it

C small amounts of heat change the temperature a lot

D none of these

Response Percentage 0 17 28 56

3 Select the correct calculation to find how many joules (J) are neede

temperature of 15.0g of lead from 200C to 400C. Pb=0.128J/g0C.

Answers

A 0.128 / [15.0(20 40)]

B 0.128 / [15.0(40 20)]

C 15.0(0.128)(20 40)

D 15.0(0.128)(40 20)

*

Response Percentage 0 6 6 89

4 If 856J of heat was absorbed by a block or iron (Fe=0.44J/g0C) with

would you find the change in temperature?

Answers

A 856 / (55.0 x 0.44)

*

B 856(55.0) / 0.44

C 55.0(0.44) / 856

D 55.0 / (0.44 x 856)

Response Percentage 94 0 6 0

5 How would you find the specific heat of a metal if 387J of heat rais

of it from 300C to 500C?

Answers

A 387(50)(50 30)

B 50(50 30) / 387

C 387(50) / (50 30)

D 387 / [50(50 30)]

*

Response Percentage 0 39 6 56

6 Water has a higher specific heat than alcohol. If both are heated a

the following is true

Answers

A the temperature of the water will rise faster than alcoho

B the temperature of the alcohol will rise faster than wate

*

C both will heat up at the same rate.

D (No Answer Stem Entered)

Response Percentage 22 72 6 0

Results

7 What is happening when two materials reach thermal equilibrium?

Answers

A the two materials do not exchange energy.

B the two materials are at the same temperature.

C heat stops flowing between the two materials.

D all of the above

*

Response Percentage 0 11 0 89

Interesting one here because it does not involve numbers

10 Which conversion factor below is NOT correct?

Answers

A 1 cal = 4.184 j

B 1 Cal = 4,184 j

C 1 food calorie = 1 physical calorie

*

D 1 BTU = 1, 055 j

Response Percentage 6 61 33 0

2 8

3 When a substance is heated...

Answers

A all of its molecules begin to move faster

B fewer of its molecules move faster

C most of its molecules lose energy to their surroundings

* D the average motion of its molecules increases

Response Percentage 47 0 0 53

4 The specific heat of water is much higher than other substances. Wh

Answers

A water does not change temperature easily

*

B water has a higher temperature than things around it

C small amounts of heat change the temperature a lot

D none of these

Response Percentage 84 16 0 0

6 How would you find the specific heat of a metal if 387J of heat rais

of it from 300C to 500C?

Answers

A 387(50)(50 30)

B 50(50 30) / 387

C 387(50) / (50 30)

D 387 / [50(50 30)]

*

Response Percentage 32 11 16 42

8 Which statement is true about phase changes?

Answers

A During melting energy is released and bonds are formed.

B During vaporization energy is absorbed and bonds are form

C During melting the temperature does not change.

*

D During freezing energy is absorbed and bonds are formed.

Response Percentage 0 5 21 74

9 The heat energy required to melt 1.0g of ice at 00C is 333J. If one piece of ice is 58.0g, and you have 12 ice cubes, how would you find how much energy them all?

Answers

A (333J/1g) x (1 ice cube/58g) x 12 ice cubes

B (333J/1g) x (58g/1 ice cube) x 12 ice cubes

*

C (1g/333J) x (58g/1 ice cube) x 12 ice cubes

D (1g/333J) x (1 ice cube/58g) x 12 ice cubes

Response Percentage 21 74 0 5

3 4

1 What compound has the highest solubility at low temperatures?

Answers

* A KI

B $NaNO_3$

C NaCl

D $KClO_3$

Response Percentage 89 6 0 6

2 What happens to the solubility of solids as the temperature increase

Answers

A decreases

* B increases

C remains constant

D depends on compound

Response Percentage 6 33 6 56

3 What solid compound has the lowest solubility at high temperature?

Answers

A KI

B NaNO3

C NaCl

* D KClO3

Response Percentage 6 22 39 33

4 As temperature increases, what happens to the solubility of gases?

Answers

* A decreases

B increases

C remains constant

D depends on the compound

Response Percentage 94 6 0 0

5 What compound has the lowest solubility at low temperatures?

Answers

A KI

B $NaNO_3$

C NaCl

* D $KClO_3$

Response Percentage 11 6 17 67

3 24

1 As heat is added at point B, what phase change occurs?

Answers

A freezing

* B melting

C boiling

D condensing

Response Percentage 6 94 0 0

APPENDIX C

SEMANTIC DIFFERENTIAL

Based on using the clickers in class, select one of the five boxes for each row that best describes your experience.						
Makes the lesson easier	☐	☐	☐	☐	☐	makes the lesson harder
makes class material more understandable	☐	☐	☐	☐	☐	makes class material less understandable
makes the lesson simpler	☐	☐	☐	☐	☐	makes the lesson complex
Less likely to participate in class	☐	☐	☐	☐	☐	more likely to participate
anonymity of device helps me participate	☐	☐	☐	☐	☐	anonymity discourages my participation
makes it harder to pay attention	☐	☐	☐	☐	☐	makes it easier to pay attention
distracting	☐	☐	☐	☐	☐	engaging
saves time	☐	☐	☐	☐	☐	takes up more time
Helps me try harder	☐	☐	☐	☐	☐	lets me put in less effort
harder to understand complex problems	☐	☐	☐	☐	☐	easier to understand complex problems
Easier to solve challenging problems	☐	☐	☐	☐	☐	harder to solve challenging problems
Harder to use data to draw conclusions	☐	☐	☐	☐	☐	easier to use data to draw conclusions

APPENDIX D

IRB APPROVAL FORMS

PROJECT NUMBER: 2010-10388-0
TITLE OF STUDY: A design study of a student response system for assessing student cognitive engagement in high school chemistry instruction
PRINCIPAL INVESTIGATOR: Dr. J. Steve Oliver

Dear Dr. Oliver,

Please be informed that the University of Georgia Institutional Review Board (IRB) has reviewed and approved your above-titled proposal through the exempt (administrative) review procedure authorized by 45 CFR 46.101(b) (1) Research conducted in established or commonly accepted educational settings, involving normal educational practices, such as (i) research on regular and special education instructional strategies, or (ii) research on the effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods.

You may now begin your study. Your approval packet will be sent by mail.

Please remember that no change in this research proposal can be initiated without prior review by the IRB. Any adverse events or unanticipated problems must be reported to the IRB immediately. The principal investigator is also responsible for maintaining all applicable protocol records (regardless of media type) for at least three (3) years after completion of the study (i.e., copy of approved protocol, raw data, amendments, correspondence, and other pertinent documents). You are requested to notify the Human Subjects Office if your study is completed or terminated.

Good luck with your study, and please feel free to contact us if you have any questions. Please use the IRB number and title in all communications regarding this study.

Regards,

Mrs. LaRie Sylte, M.H.A, M.A., CIP
Human Subjects Office
University of Georgia
www.ovpr.uga.edu/hso/

The University of Georgia

BA OOLS

December 10, 2009

Mr. Joe Cozart
255 Tara Way
Athens, GA 30606

Dear Mr. Cozart,

I am delighted to offer this letter of support for your research project, A design study of student response system for assessing student cognitive engagement in high school chemistry instruction, and hereby give you permission to conduct this research in the Barrow County School System.

I understand that all required protocols regarding human subject research and informed consent/assent will be followed. I am approving the research with the understanding that teachers, students, and principals in Barrow County Schools are in no way obligated to participate because of my approval. This looks like a very interesting project and I look forward to receiving information regarding the findings of this research project.

Sincerely,

Claire Miller

Claire Miller, Ph.D.
Barrow County Schools
Assistant Superintendent

Institutional Review Board
Phone: 706-542-3199
Human Subjects Office
Fax: 706-542-3360
612 Boyd GSRC
Email: irb@uga.edu
Athens, GA 30602-7411

IRB CONTINUING REVIEW/AMENDMENT FORM

Principal Investigator (PI): **Dr. J. Steve Oliver**	
Co-Principal Investigator (Required, if co-PI is a student): **Joe Cozart**	
Project #: **2010-10388-0**	Title of Study: **A design study of a student response system for assessing cognitive engagement in high school chemistry instruction**

PLEASE ANSWER ALL QUESTIONS (Use the text boxes for explanation/additional information or attach a separate cover letter)		YES	NO
1	**Have you started data collection for this research project?**	☒	☐
2	**How many total participants have been accrued since <u>the beginning</u> of the research project? (*Note: This corresponds to the number of individuals who gave consent; this number should include withdrawals but actual number of withdrawals is reported in #7 below.*)**	29	
3	**Do you plan to continue to <u>recruit</u> participants for this research project? (If you answered** YES**, please skip to Question #6.)**	☐	☒
4	**If you answered** NO **to question #3, do you plan to continue to <u>collect</u> data with previously recruited participants?**	☐	☒
5	**If you answered** NO **to questions #3 and #4 above, do you plan to continue to <u>analyze</u> previously collected data that is individually-identifiable?**	☐	☒
6	**Have there been any complaints about the research since the protocol was approved by the IRB? If** YES**, please provide complete information on the complaints made.**	☐	☒
7	**Have any participants withdrawn, dropped out, or were lost to follow-up from participation since the protocol was last approved by the IRB? If** YES**, please indicate the number and provide detailed information/reason(s).**	☐	☒
8	**Have there been any adverse events or unanticipated problems involving risks to the participants or others since the protocol was last approved by the IRB? If** YES**, please contact the IRB office immediately to request an adverse event/incident report form.**	☐	☒
9	**Have there been any changes to the study population? If** YES**, please explain changes.**	☐	☒
10	**Have the <u>procedures</u> changed in any way since the protocol was last approved by the IRB? If** YES**, please explain.**	☐	☒
11	**Have any <u>materials or instruments</u> changed in any way since the protocol was last approved by the IRB? If** YES**, please explain.**	☐	☒
12	**Have changes in the scientific literature, or interim experience with this or related studies, changed your assessment of potential risks or benefits to**	☐	☒

	study participants? If YES, **please explain and attach any relevant literature.**		
13	**Have the <u>consent documents</u> changed in any way since the protocol was last approved by the IRB? If** YES, **please explain and attach copy of the revised document(s).**	☐	☒
14	**A** <u>clean</u> **copy of the current version of the consent document(s)** <u>must</u> **be submitted with the request to continue** if you plan to recruit new participants, or if a revised consent document is necessary as a result of an amendment. **Have you attached a clean copy of your current consent document(s)?**	☐	☒
15	**Have there been any changes to the members of the research team (e.g., change in PI; addition/deletion of co-investigators)? If** YES, **please describe personnel change(s). Note: All new personnel must complete the CITI training.**	☐	☒

Principal Investigator's Signature: For electronic submission, a check in this box is acceptable as a signature: ☒	Date: 4-20-2010

<u>Important</u>: If research activities involving human participants will continue five years after the original IRB approval, please submit a new IRB Application for initial review. **<u>Exceptions</u>:** If the research is permanently closed to the enrollment of new subjects, all participants have completed all research-related interventions, **<u>and</u>** the research will remain active only for long-term follow-up of subjects; or if the remaining research activities are limited to analysis of individually-identifiable private information.