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The Effects of Classroom Response Systems on Student Learning and Engagement

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THE EFFECTS OF CLASSROOM RESPONSE SYSTEMS ON STUDENT LEARNING AND ENGAGEMENT

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ABSTRACT

THE EFFECTS OF CLASSROOM RESPONSE SYSTEMS ON STUDENT LEARNING AND ENGAGEMENT

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Classroom Response Systems (CRS) are devices that are relatively inexpensive and easy to use, yet allow full and anonymous participation by students while providing immediate feedback to instructors. These devices have shown promise as a tool to increase engagement in learners, an outcome that would be particularly useful among middle level learners. This study assessed the ability of CRSs to promote content among suburban, middle level students in science class, and it is the first known study of CRSs that used an alternating treatments design to improve the reliability of the findings. The study also assessed the acceptability of the technology. Quiz results did not support claims that that students learn more when using CRSs, but acceptability responses indicated that students preferred CRSs to traditional questioning practices, that students perceived their learning as greater when using CRSs, and that students felt somewhat lower levels of anxiety when using CRSs for review.

DEDICATION

To my parents who enabled me to complete this process, and my children Killian and Danielle, who always motivate me to be better.

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To my students, fellow teachers, and administrators, but particularly Brooke Pegher and Jay Moser, who made this research both possible and worthwhile. Also, to my committee and Dr. Schmitt, whose insightful comments and high expectations were essential to the quality of this research.

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CHAPTER I

Introduction

Teachers and researchers continue to seek out instructional techniques that can increase engagement. Many of these methods work by improving attention levels, increasing motivation, or promoting the active processing of a lesson. In order to achieve these results, some researchers have emphasized the use of specific tools like advance organizers, graphic organizers, mnemonic devices, or study guides to support engagement (Sencibaugh, 2008), while others utilize skill-based tactics such as teaching students metacognitive strategies (Eilers & Pinkley, 2006), reciprocal teaching (Aarnoutse & Brand-Gruwel, 1997), summarization (Gajria & Salvia, 1992), repeated reading and listening (Winn, Skinner, Oliver, Hale, & Ziegler, 2006), or story mapping (Idol & Croll, 1987). Unfortunately, the effectiveness of these methods often varies widely depending on age levels of the students involved, subject areas or topics, or other unique situational factors. Researchers therefore continue to search for methods that support engagement on a more universal and generalized basis, and research suggests that the most consistently successful ways of promoting engagement involve increased participation, feedback, or accountability, and that optimal teaching methods will prudently maximize all of these factors while taking into account the myriad of challenges that exist in a typical classroom (Black & Wiliam, 1998; Hattie & Timperley, 2007; Kluger & DeNisi, 1996; Jensen, 2003; Riggs & Gholar, 2009; Skinner, Fletcher, & Henington, 1996).

Significance of the Problem

Engagement. Engagement has been defined as the "active, enthusiastic, effortful, participation in learning activities" (Skinner, Kindermann, & Furrer, 2008, p. 495). Engagement strongly affects a student's commitment to a task (Riggs & Gholar, 2009), intrinsic motivation (Ryan & Deci, 2000), and even emotional state (Jensen, 2003). Paris and Paris (2001) describe deeply engaged students as having their hands up, ready to answer, often answering verbally, participating in discussion and "going beyond the requirements, exhibiting preferences for risk-taking, and showing greater commitment" (p.93). Although these aspects of engagement are clearly associated with success in the classroom, the concept of engagement goes even further. Specifically, although engaged learners consistently show high levels of attention, concentration, and effort, they are also more likely to feel emotions that are positive about school and learning (Jensen; Riggs & Gholar; Skinner, et al., 2008). These emotions include feeling optimistic, interested, and thinking that school is fun or enjoyable. Clearly, students who consistently participate, concentrate, enjoy the learning process, and eagerly look forward to academic pursuits are likely to experience greater success, and Skinner, et al. report that engagement "predicts achievement and completion of school" (p. 493).

Conversely, students who do not participate, are not interested in learning, and do not enjoy coming to school are considered disaffected. Disaffected students not only struggle to achieve, they also are likely to exhibit disruptive or defiant behaviors (Skinner, Kindermann, & Furrer, 2009). Moreover, disaffected students are likely to show signs of "passivity, giving up, mental withdrawal, dejection, apathy, and ritualistic participation such as lack of attention and going through the motions" (p.496). And although students exhibit varying degrees of engagement, middle level students and students with learning disabilities may have greater difficulty in engaging than other students (Beamon, 2001; Montague, 2006) and may be particularly susceptible to feelings of anxiety or embarrassment (Brown & Knowles, 2007). Furthermore, such feelings of anxiety undermine motivation and engagement levels (Freeman, Blayney, & Ginns, 2006; Ryan & Deci, 2000; Zimmerman, 1989). Therefore, researchers recommend instructional methods that promote anonymity (Draper & Brown, 2004; Ryan & Deci, 2000), minimize public comparisons (Paris & Paris, 2000), increase opportunities for success (Jensen, 2003), and allow learners to become more active and feel more volition in their participation (Ryan & Deci, 2000).

As a result of the importance of student engagement, there is an abundance of research to identify effective methods of increasing student engagement levels. These methods often focus on methods of improving attention, heightening concentration, facilitating student participation (Jensen, 2003; Riggs & Gholar, 2009) promoting students feelings of competence (Riggs & Gholar, 2009; Ryan & Deci, 2000) or increasing accountability (Jensen,2003). For example, interventions that successfully heightened concentration levels included increasing students' sense of urgency include using tape recorded problems to motivate students to answer more quickly (McCallum, Skinner, Turner, & Saecker, 2006) or using stopwatches to quicken responses (Skinner, Pappas, & Davis, 2005; Evans-Hampton, Skinner, Henington, Sims, & McDaniel, 2002). Similarly, other methods addressed the problem of student attention by breaking assignments down into smaller tasks (Skinner, 2002; Wallace, Cox, & Skinner, 2003), using creative systems to re-direct student attention to rules and instructions (Fudge, Skinner, Williams, Cowden, Clark, Bliss, 2008) or requiring students to actively reflect on activities (Paris & Paris, 2001). On the other hand, Ryan and Deci note that engagement levels also increase when students internalize external pressure to perform and become willing participants and that achievement and enjoyment levels are also increased when a student becomes more self-motivated and feels empowered in this way.

Other studies focus less on the delivery of instruction, and more on maximizing the effectiveness of reinforcement to promote engagement. In a review of research, Skinner, Pappas, and Davis (2005) state that tangible rewards like food or prizes are powerful, and that games can sometimes be just as powerful as these tangible rewards. Alternatively, prudent use of less powerful rewards like task completion can also be effective. However, because it can be difficult to provide rewards like these frequently enough to be effective for every student, Popkin and Skinner (2003) suggest a system of randomized group rewards that effectively addressed this issue with secondary math students. Finally, an essential part of most of these methods that focused on reward system was the provision of effective feedback to go along with the reward. Furthermore, feedback itself can act as a reinforcer, and researchers have found that providing quality feedback is one of the best ways to increase student engagement (Bandura, 1989; Jensen, 2003; Paris & Paris, 2001; Ryan & Deci, 2000).

Feedback. As the previous discussion suggests, engagement is most readily affected by manipulating either the methods of instructional delivery or the effectiveness of reinforcers, and both rely heavily on the existence and quality of feedback. Skinner, Pappas, and Davis (2005) state, “with all else held constant, students are likely to choose to engage in the behavior that results in more immediate reinforcement, higher rate reinforcement, or higher quality reinforcement” (p.396). In classrooms, the most common type of reinforcement comes in the form of feedback, and providing feedback is one of the most consistently effective methods in all of educational research (Black & Wiliam, 1998; Boston, 2002; Butler, Karpicke, & Roediger, 2008; Criswell, 2005; Hattie, et al., 1996; Hattie & Timperley, 2007; Kluger & DeNisi, 1996). Feedback has been studied at great length, and its form, intensity, and effectiveness varies, but it has been shown to raise achievement as reliably and successfully as any educational intervention. Not only does feedback provide information to the learner in terms of correctness of responses, the nature of mistakes, and guidance for improvement, the very existence of feedback can increase motivation and self-regulation in learners – two factors known to be of critical importance for success in learning.

Providing feedback effectively requires instructors to consider many factors about the students, the task, and the environment (Hattie & Timperley, 2007; Marzano, Pickering, & Pollock, 2001). For example, it is known that fast paced activities can increase student engagement (Evans-Hampton, Skinner, Henington, Sims, & McDaniel, 2002). On the other hand, Skinner, Wellborn, & Connell (1990) caution that pressure to perform can reduce student engagement. Similarly, although choral responding and response cards have been found to increase student response rates under some circumstances, Skinner, Fletcher, and Henington (1996) note that these strategies can be loud, difficult to monitor, and hard to individualize.

Moreover, some types of feedback can actually harm student learning, and some feedback that is beneficial for one student may have a detrimental effect on another. At least partially due to these factors, the amount and quality of feedback in today's schools is inadequate (Black & Wiliam, 1998; Hattie & Timperley, 2007; Marzano, et al., 2001), and researchers agree that new methods of providing feedback should attempt to deliver the beneficial aspects of feedback while minimizing the potential for feedback to further disaffect students. Skinner, Fletcher, and Henington suggest that participation could be increased by developing “procedures which allow for unison responding” (p.319),whereas other researchers focus on providing feedback in ways that reduce anxiety, increase frequency, or increase immediacy (Bandura, 1989; Beamon, 2001; Brown & Knowles, 2007; Paris & Paris, 2001; Ryan & Deci, 2000; Zimmerman, 1989). Interestingly, Classroom Response Systems (CRS) are an emerging technology which is perfectly suited to do just that.

Classroom Response Systems

CRSs are remote control devices that enable all students in a class to respond to questions simultaneously and immediately receive feedback about those responses. Similarly, the system allows instructors to instantly gauge class-wide and individual levels of understanding, enabling them to quickly adjust instruction or provide individualized feedback. While these characteristics of CRSs have obvious advantages, Nightingale (2008) notes that the benefits of using CRSs depend on the classroom setting and audience. Instructors in higher education settings may be most interested in CRSs' ability to efficiently engage and check comprehension of large numbers of students in large classrooms or lecture halls (Draper & Brown, 2004; Fies, 2005; Greer & Heaney, 2004; Guthrie & Carlin, 2004; Freeman, et.al., 2006; Nightingale, 2008; Sharma, et.al., 2005), whereas K-12 teachers seek to improve levels of attentiveness, engagement and participation, particularly among reluctant or struggling students (Penuel, Boscardin, Masyn, & Urdan, 2005; Swan, van' t Hooft, Kratcoski, Schenker, & Miller, 2007).

Whether the instructional goal is to increase engagement, self-regulation, or check comprehension, the fundamental trait of CRSs that facilitates those goals is the increased amount and anonymous nature of available feedback. Although the types of tasks that CRSs can assess and the amount of corrective information provided is generally limited to discrete choice questioning, evidence suggests that there is good reason to explore the utility of CRSs as a feedback mechanism (Conoley, 2005; Hill, Smith, & Horn, 2004; Freeman, Blayney, & Ginns, 2006; Greer & Heaney, 2004; Guthrie & Carlin, 2004; Horowitz, 1988; Sharma, Khachan, Chan, & O'Byrne, 2005).

Need for the Study

CRSs are widely believed to have great promise as a learning tool, but the research base on CRSs has limitations. For example, some researchers have found that the use of CRS promoted achievement (Conoley, 2005; Horowitz, 1988; Kennedy & Cutts, 2005; Sharma, et al., 2005), but others found no such gains (Fies, 2005; Nightingale, 2008). Additionally, many studies supporting the use of CRSs relied heavily on self-report data (Freeman, Blayney, & Ginns, 2006; Greer & Heaney, 2004; Guthrie & Carlin, 2004; Hill, et al., 2004). Furthermore, of the few studies that found measureable achievement gains, Kennedy and Cutts (2005) had no control group, Conoley (2005) used different assessments to test students during the control period versus the treatment period, and Horowitz' experiment was a sample of management employees at IBM, which limits the conclusions about K-12 education that one can draw from the study. Moreover, all of these studies had instrumentation threats due to a variety of limitations of the assessments used. The current study explored the use of CRSs to increase student engagement and achievement by using an alternating treatments design comparing a condition in which students raised their hands to answer questions to a condition which adds the use of CRSs during questioning. We will refer to the hand-raising condition as NCRS and the condition using CRS as the CRS condition. This was also the first known study that used an alternating treatments design to improve experimental control relative to other CRS studies. Furthermore, the present investigation expanded the existing research base by using immediate learning as a dependent variable and studying the use of CRSs with middle school students.

Problem Statement

The purpose of the current study is to build upon previous research on student engagement and CRSs. Earlier research suggests that frequent, immediate feedback can have a positive effect on learning, but that anxiety created by the feedback process can be detrimental to learning. Importantly, CRSs provide feedback that is frequent and immediate but anonymous, and may therefore address the problem of anxiety during participation. Existing research on CRSs relied heavily on self-reported data, and control conditions were either limited or non-existent. The current study addressed these limitations by using an alternating treatments design and using an assessment tool that is widely accepted as a measure of learning gains. This was the first known study of CRSs to use an alternating treatments design in an attempt to exercise such experimental control.

Research Questions and Hypotheses

Research Question 1: Does the use of CRSs increase the content comprehension of students participating in a middle school science class?

Hypothesis 1: When quizzed about a science reading passage on comprehension questions reviewed earlier in the same class period, the CRS condition will result in a greater number of questions answered correctly compared to the NCRS condition.

Hypothesis 2: When quizzed about a science reading passage on comprehension questions not previously reviewed, the CRS condition will result in a greater number of questions answered correctly compared to the NCRS condition.

Research Question 2: Will students find the use of the CRS acceptable?

Hypothesis 1: Students will report greater involvement during the CRS condition than during the NCRS condition.

Hypothesis 2: Students will report that they learned more during the CRS condition than during the NCRS condition.

Hypothesis 3: Students will report that they experienced less anxiety when participating during the CRS condition than during the NCRS condition.

Hypothesis 4: Students will prefer the use of CRSs to traditional questioning strategies.

CHAPTER II

Review of Literature

In classrooms, engagement levels are largely affected by the attitudes of students and the instructional methods used by a teacher. Instructional methods that increase levels of attention, participation and accountability and reduce the public competition aspect of learning activities may promote engagement and learning, particularly for adolescents, girls, and low achieving students. The potential value of CRS clearly lies in their ability to address these issues by increasing levels of participation, providing immediate feedback, and doing so in a non-threatening, anonymous manner. To that end, this section discusses relevant research in each of these areas as well as a review of experiments using CRS with findings related to engagement.

Feedback

Motivation is often defined in terms of how one's actions help meet one's needs (Gibson, 1981). Academic learning of the type that happens in schools would be described as a secondary need because it does not directly relate to immediate survival, but is important to the person. Gibson explains that motivation includes drive, which is essentially a reason to pursue a particular task, and direction, which is the person's understanding of some possible method of meeting a need or solving a problem.

It is self-evident that increased motivation generally increases the likelihood of success in any endeavor, and learning tasks are no exception. Moreover, one of the best ways to promote motivation in classrooms is through the wise use of feedback (Butler, 1988; Craven, et.al., 1991; Dweck, 1986; Dweck & Leggett, 1988; Hidi & Harackiewicz, 2000). Furthermore, due to its effect on motivation and its role as an instructional guide for learners, many researchers suggest that feedback is a critically important tool for effective teaching (Black & Wiliam, 1996; Criswell, 2005; Hattie, et.al., 1996; Hattie & Jaeger, 1998; Hattie & Timperley, 2007; Kluger & DeNisi, 1996; Lysakowski & Walberg, 1982; Marzano, et.al., 2001; Rushton, 2005). Hattie and Timperley define feedback as "information provided by an agent (e.g., teacher, peer, book, parent, self, experience) regarding aspects of one's performance or understanding" (p.81). Although feedback can be a continuous and complex process, it is essentially the way that individuals find out how well they are doing or how well they understand something. As Hattie and Timperley state, "feedback has no effect in a vacuum: to be powerful in its effect, there must be a learning context to which feedback is addressed" (p.82). In other words, feedback must be about a previously completed task or performance of some kind.

Types of feedback can be placed into four basic categories: feedback about the task, about processing, about self-regulation, and about the self (Hattie & Timperley, 2007). Feedback about the task simply tells a learner how well they are doing. Grades without corrective feedback or grades that only show the correct answer but not how to derive it would be examples of feedback about a task. Feedback about processing focuses on skills required to complete a particular type of task and may include informing a student about how to notice when mistakes are made. If a learner was confusing area and perimeter, feedback about processing would re-direct the learner to the definitions and formulas with each and perhaps note places in the assignment where the student apparently confused the two. Feedback about self-regulation goes beyond merely teaching a student how to recognize a mistake and includes an intention to increase the student's effort in completing a task and the development of systematic self-assessment processes in a learner. These types of interventions often focus on trying to increase attention, reflection, and effort. Although the effectiveness of self-regulation feedback interventions is mixed, self-regulation remains a topic of high priority because of its strong relationship to achievement. Feedback about the self is more commonly known in its positive form as praise or its negative form as criticism.

Given the importance of motivation for learning and the clear relationship of feedback to both motivation and the learning process, it is not surprising that researchers have amassed a wide body of research describing and explaining the effects of feedback and prescribing its most prudent usage. Not only is it clear that feedback can promote achievement, feedback interventions appear to be superior to many other alternative methods of improving learning. Hattie and Timperley (2007) reviewed over 500 meta-analyses of learning interventions and found that the average effect size of interventions that focused on providing feedback was very strong (0.79). This was twice the average impact of learning interventions overall. Furthermore, this correlation was comparable to other factors that had strong relationships to achievement. For example, the teaching methodology known as direct instruction had an effect size of (.93). Direct instruction involves teaching a skill such as finding perimeter, then having students try the skill with assistance (guided practice), and then requiring students to try the skill on their own (independent practice). It is not surprising that this assisted repetition methodology is a very powerful way to improve student achievement, but it is interesting to note that despite great variability in the methods and effectiveness of individual experiments on feedback in Hattie and Timperley's meta-analysis, the effectiveness of feedback as a generalized methodology was nearly as powerful as direct instruction. Put another way, a reasonable person would likely predict that practicing probability problems should improve a student's later performance on similar probability problems. This is what the direct instruction research does in fact show. It is a more striking finding that feedback interventions, with all of the effects of successful and less successful studies measured as a collective whole, should produce an effect that is close to the size of direct instruction. Furthermore, feedback had a stronger relationship with increased achievement than did a student's prior cognitive ability (.71), acceleration (0.47), socioeconomic influences (0.44), and homework (0.41). These would also appear to be somewhat surprising results.

Kluger and DeNisi (1996) noted that although feedback takes many forms, it is always positive or negative relative to a goal. In cases when the feedback is negative and the person perceives that their performance is less than desirable, Kluger and DeNisi suggest that individuals may take one of four possible courses of action. The most common strategy is to increase effort, but when successful completion of tasks seems impossible, individuals often adopt an alternative strategy of abandoning the standard or goal. This alternative, which essentially involves a complete cessation of effort toward completion of the task, is sometimes called learned helplessness. A third alternative of modifying the standard happens when the standard is perceived to be unlikely to achieved, but the individual is reluctant to completely abandon the standard. The fourth alternative is to reject the feedback. In this case, individuals choose to disagree with the accuracy of the feedback and conclude that their performance is satisfactory despite the negative feedback. Importantly, this sort of strategy does not happen in response to self-discovered feedback. That is, much feedback is metacognitive in nature, wherein a person assesses their own performance and self-regulates their effort. It does not appear likely that one would dismiss one's appraisal of one's own work. On the other hand, when feedback is given by another person such as an instructor or a peer, one may attribute negative feedback to some deficiency or mistake on the part of the person giving the feedback.

The most effective forms of feedback. Kluger and DeNisi's (1996) meta-analysis found that the most effective types of feedback typically had some combination of the following characteristics: task-related; computerized; immediate; and corrective. That is, feedback should be typically given as soon after an assessment as possible and should do more than tell a student whether a response was right or wrong, but should actually suggest how to fix any mistakes. Additionally, task-related feedback refers to feedback about the activity attempted as opposed to feedback about the self or ambiguous feedback such as "good job", "nice work", or "try harder". Hattie and Timperley (2007) supported Kluger and DeNisi's report, finding that the best feedback "provides cues or reinforcement to learners", is "in the form of video-, audio-, or computer-assisted instructional feedback", or "relate to goals" (p.84). Lysakowski and Walberg (1982) performed a synthesis of 54 studies and noted that corrective feedback is beneficial because it prevents students from wasting time repeating faulty strategies. They also suggest that feedback should be given as soon as possible after task performance and that subsequent instruction should address the learner's situation. Lysakowski and Walberg's results indicated that corrective feedback promoted achievement in nearly all cases and among all groups of learners. However, although a later meta-analysis by Hattie, et.al (1996) found that feedback was one of the most effective teaching strategies to improve achievement, these researchers found that low-ability students did not seem to respond to interventions and that this inability to improve the lowest achieving groups was a problem in virtually every study. The researchers also found that simple feedback strategies like mnemonic devices have the clearest impact on improved performance whereas interventions designed to improve higher order thinking were "not effective" (p.128).

In addition to being prompt, corrective, and simple, most good feedback is also specific (Criswell, 2005). The least corrective form of feedback would merely indicate that a student response is incorrect whereas the most corrective feedback generally includes written instructions regarding how to complete a task correctly or why a current response is incorrect. Similarly, more specific feedback explains mistakes more clearly and refers to positive examples within student work indicating a rationale as to what elements distinguished sub-standard from excellent performance. More specific feedback is more thorough than less specific feedback and is consequently time-consuming. This presents a quandary because although Criswell suggests that feedback should be prompt, the timeliness of feedback is necessarily offset by the length of time it takes for an instructor to make feedback sufficiently specific and corrective. Moreover, Criswell admits that the specific wording of feedback is a challenging task, stating that "the most difficult part of developing specific feedback is crafting statements that are precise enough to be corrective without giving away the answer" (p.26).

Given this predicament in terms of the time-intensive nature of providing good feedback, rubrics present a partial solution. When using a rubric, instructors typically score student work based on specified qualities or categories. For example, suppose an instructor grades a project based on spelling and grammar, word choice and style, transitions, and adherence to a format such as introduction, body, and conclusion. Each of these qualities of the project would have a number of criteria upon which their score is based, and students would be provided the criteria in the form of a rubric. Then, although the instructor would only give feedback in the form of a score, the student could review the rubric and receive corrective feedback by comparing the rubric's criteria to the student's work. Although Criswell (2005) agrees that rubrics can provide some effective feedback, he suggests that students do not always understand the criteria within rubrics and that the criteria themselves may not be enough to show students how to improve their work. Criswell recommends that written corrective feedback should generally be used in combination with rubrics to make the feedback most effective.

Challenges to providing effective feedback. Poorly designed feedback can actually undermine learning. Kluger and DeNisi (1996) suggested that feedback that is repeatedly and/or excessively negative can cause a learner to doubt their ability for long-term success. Additionally, even positive feedback like praise can harm learning when it is construed by some learners as a sign of artificial support by an instructor. Reviewing 131 feedback studies, Kluger and DeNisi concluded that feedback in the form of praise and feedback that threatens self-esteem tend to decrease performance. Hattie and Timperley (2007) add that students like praise, but its ability to raise achievement is doubtful. The disappointing overall results for studies on praise may be attributed to some potential negative impacts of praise that may offset its beneficial influence. For example, older students often consider praise as a sign of low ability. That is, students believe that teachers give praise to students who need support whereas higher achieving students neither need nor receive excessive praise. Furthermore, some studies have shown that students interpret and inaccurately interpret oral feedback which may also decrease the effectiveness of praise. Finally, Hattie and Timperley state that praise can lead to such negative outcomes as “self-handicapping, learned helplessness, or social comparison” and that any corrective feedback associated with such praise is often “discounted or dismissed”(p.97). Perhaps because of this tendency, Hattie and Timperley found that giving no praise is more effective than giving praise when either is combined with corrective feedback. Another interesting finding suggests that negative reinforcement or criticism works better when students are not internally motivated to complete a task, but praise works better when students do have existing motivation to succeed. That is, criticism may erode interest and excitement in a student who is already interested in a topic, but the same criticism may increase achievement for students who would not have tried otherwise.

The effectiveness of feedback is also highly contingent upon situational variables. Marzano, Pickering, and Pollock (2001) found that providing feedback immediately after tests is best, but not immediately after each item on a test. The researchers stated that “in general, the more delay that occurs in giving feedback, the less improvement there is in achievement” (p.97). Marzano, Pickering and Pollock also found that the timing of the test relative to the completion of the learning activity on which the test is based is important. Specifically, they state that “giving tests immediately after a learning activity has a very negligible effect on achievement”, whereas “giving a test one day after a learning situation seems to be optimal” (p.98). It is possible that when students understand that tests will typically follow learning situations by one day, then improvements in achievement may be ascribed to increased attentiveness during teaching or studying after teaching due to the expectation of testing. Additionally, when a person is still learning the steps of a complicated process, immediate feedback probably helps students avoid learning incorrect habits or unproductive frustration. On the other hand, one may suspect that immediate feedback during summative events might preclude a learner from developing self-regulatory and higher order problem-solving strategies that might arise from a prolonged immersion in a task without outside assistance.

Despite the apparent effectiveness of feedback for learning, Hattie and Timperley (2007) found that the amount of feedback given by teachers is low, even for good teachers. Furthermore, despite the fact that praise is the least effective form of feedback, it is the most common form of feedback given by classroom teachers. The researchers state that most feedback is "self-related or at best corrective" (p.100). Additionally, learners appear to be justified in their notion that praise by a teacher indicates that the student receiving such praise has low ability, as teachers do tend to give students rated as low achievers more praise. Furthermore, although self-regulatory feedback appears to be a more effective type of feedback than self-related feedback like praise, such feedback appears to have very low rates of incidence in most classrooms. Moreover, Hattie and Timperley found some evidence that teachers are more likely to give self-regulation focused feedback to boys, suggesting to boys that their failures are due to low effort while implying that poor performance by girls is due to low ability.

In general, the research presents a problematic situation with regard to feedback in classrooms. Although feedback has very powerful effects on achievement, the process of providing feedback effectively and in ways that match the learning situation and learners involved is complicated. As Criswell (2005) noted, although more corrective and specific feedback is best, it is also more time consuming and therefore must be balanced against equally desirable goals of making the feedback immediate and frequent. Furthermore, teachers appear to provide very little feedback of any type, and the feedback that is given is most often in the form of praise, the weakest type of feedback. Finally, more powerful forms of feedback like feedback on processing or self-regulation is minimal, and at worst appears to tend to reflect stereotypical or prejudicial thought processes.

Self-Regulation

In order for feedback to be effective, students must participate in the learning process and think about and process the feedback. Self-regulation refers to how well a one thinks, reflects, assesses, and adjusts one's own performance, and is dependent upon a student's current ability to self-regulate and commitment to the task. Zimmerman (1989) states that, "students can be described as self-regulated to the degree that they are metacognitively, motivationally, and behaviorally active participants in their own learning" (p.329). Self-regulation requires "autonomy, self-control, and self-discipline" (Hattie & Timperley, 2007, p. 93) and enables "seeking, accepting, and accommodating feedback information" (p.94). Kuhn (2005) states that self regulatory processes or "learning to learn" (p.60) may be the most important goal in education and Facione (1998) notes that it is a particularly critical element with respect to critical thinking skills. Based on a Delphi Study in which many of the nation's top experts on critical thinking collaborated to create a definition of critical thinking, Facione ranked self-regulatory processes like metacognition above all other critical thinking skills. Specifically, whereas many educators are very familiar with instructional goals like application, analysis, synthesis, and evaluation that are found in Bloom's taxonomy (Bloom, 1984), Facione would suggest that a person's aptitude and drive with respect to monitoring, appraisal, and honing one's own ability to apply, analyze, synthesize, or evaluate would generally be more valuable than one's natural talent level with regard to any one of these skills. Moreover, quality of self-regulation can be promoted by increasing participation rates or effectiveness of feedback (Brewer, 2004; Draper & Brown, 2004; Greer & Heaney, 2004; Roselli & Brophy, 2006; Zimmerman, 1989) and by teaching self-regulation strategies (Winne, 1997; Zimmerman, 1989). Feedback affects self-regulation by enabling students to understand differences between current and desired performance levels and use that information to reach the goal (Boston, 2002), and Criswell (2005) adds that the value of feedback as an aid to students' self-regulation is "universally accepted" (p.23).

Self-regulation may be described using an example of a learner who is asked to recall the capitals of the 50 states. A learner who thinks about why they scored poorly when asked to recall such information is likely to improve more than a student who never considers that issue. Moreover, the amount, immediacy, and quality of the feedback presented to the student will affect their ability to learn from their mistakes. Additionally, if two students both consider their scores on such a test, one who is familiar with mnemonic devices and who understands that such a memory device could be applied to recalling capitals is likely to out-perform the student who does not have that knowledge. Finally, commitment to a goal is a separate factor that impacts self-regulation because greater commitment causes students to attempt to reflect and regulate with more intensity and more frequency for any given level of self-efficacy or quality of self-regulatory skills. As Bandura (1989) states, “goals motivate by enlisting self-evaluative involvement in an activity” (p.730).

Although self-regulation is a very complicated process, Winne (1997) describes two distinct modes of self-regulation. One type, random trial and error, describes a student who completes sequential tasks without considering the success of the previous trial. In this case, a student who completes two separate tasks, and experiences success in one and failure in the other, is no more likely to repeat the strategy used in the successful task than the one used in the unsuccessful task. Winne refers to the other type of process as recursive planning. A recursive planner, valuing success, tends to recall and repeat strategies that have worked in the past. Particularly upon experiencing failure, a recursive planner relies upon tried and true methods. Of course, real students fall into a continuum of levels of skill in recursive planning. Few students ignore past results, but the intensity and frequency with which a student considers results and the efficacy with which a student applies useful strategies to similar and dissimilar tasks is undoubtedly highly variable. As Winne suggests, all students engage to more or less degree in “a personal program of empirical research, continuously revising and extending earlier forms of SRL to elaborate and adapt a personal paradigm about what learning is and how to do it”(p.398). It is the relative effectiveness of these personal programs combined with absolute levels of ability that lead to differences in achievement.

For learning, the effectiveness of self-regulation is largely dependent upon instructional methods. Moreover, since self-regulation is important to learning and feedback has a strong effect on quality of self-regulation for the learner, the interaction between feedback and self-regulation is extremely important. Zimmerman (1989) suggests that effective motivational tactics like increasing accountability or creating more interesting lessons may increase levels of self-regulation in students but adds that "there is evidence that anxiety can impede various metacognitive processes" (p.333). One way to promote self-regulation may be to enable anonymous responding, because "many students do not seek help because of perceived threats to self-esteem or social embarrassment" (Hattie & Timperley, 2007). Moreover, the choice to self-regulate once may result in increased success, making future self-regulation more likely. Conversely, if environmental and personal factors rarely lead to the self-regulation to success pathway, a student will be less likely to self-regulate. Zimmerman (1989) suggests modeling and verbally persuading students to use self-regulation strategies whereas Bandura (1989) notes the importance of allowing for many chances for success, stating "efficacy validating trials not only serve as efficacy builders, but also put to trial the value of the techniques being taught (p.734). Finally, Winne suggests that much important self-regulation is not deliberate and that an individual's patterns of self-regulation are extremely complex and based on personal history.

Student Attitudes and Motivation

Goal Setting

Although self-regulation plays a crucial role in learning, student attitudes are also affected by environmental factors like feedback, and have a strong relationship to achievement. Student attitudes in school are described by goal-setting researchers and many researchers distinguish between two main types of goals known as mastery goals and competitive goals (Dweck, 1986). Students with competitive-type goals emphasize relative performance and earning of recognition. This sort of student is motivated and affected by gaining the self-esteem associated with earning high grades or publicly out-performing his or her peers, or conversely may be embarrassed by low grades or a relatively low estimation of ability. Alternatively, students with mastery goals are less interested in public recognition or relative abilities, and measure their success based on their own improvement or growth. Moreover, these mindsets change over time and can be affected by instructional methods like feedback.

Most researchers agree that mastery goals are preferable because students who adopt such goals are generally more likely to be persistent in the face of obstacles than students who set performance goals (Dweck, 1986). Dweck defines mastery goals as goals in which learners are most interested in being able to “understand or master something new” whereas competitive goals are goals in which “individuals seek to gain favorable judgments of their competence or avoid negative judgments” (p.1040). For example, Dweck states that the effort-driven mastery-goal type of learner “is characterized by challenge-seeking and high, effective persistence in the face of obstacles” (p.1040) whereas students who adopt competitive goals tend to avoid challenges and “evidence negative affect (such as anxiety) and negative self-cognitions when they confront obstacles” (p.1041). Dweck notes that students who set mastery goals are more likely to select more challenging tasks, be more persistent in the face of obstacles and difficulties, be more satisfied with learning outcomes, and enjoy learning more than those who set competitive-type goals.

Despite a great deal of evidence favoring the mastery outlook, research indicates that competitive goals can be effective for some learners in some situations and that an accurate model is somewhat more complicated. For example, Beghetto (2004) suggests that competitive goals have two separate categories: competitive-approach or competitive-avoid. A competitive-approach mindset may be effective for certain learners by increasing effort due to a learner's motivation to appear better than others or to demonstrate excellence. On the other hand, competitive-avoid goals involve situations where learners are focused on avoiding embarrassment or the appearance of low ability. A competitive-avoid mindset typically impedes performance and may cause students to disengage with the learning process, avoid effort, and feel excessive levels of anxiety.

Other researchers describe an even more complicated model with respect to how students approach learning situations and how they are motivated. Hidi and Harackiewicz (2000) suggest that most students are adopting certain levels of both mastery and competitive goals and that the importance and dominance of each type of goal within a student's overall motivational level is dynamic. That is, for any given task, most students probably have some level of desire to appear better than others (competitive) while simultaneously having a desire simply to get better at the task or learn (mastery). Furthermore, successful students sometimes set less productive, less challenging competitive-type goals whereas some low achieving students may set more challenging mastery goals. Finally, students may also approach or avoid tasks for reasons that have fundamental differences even within the performance and mastery categories. For example, a student might have a competitive goal-setting tendency based on relative ability. Relative-ability goals motivate students to avoid appearing worse than others or to demonstrate superiority to others. However, an alternative competitive-type goal is an extrinsic goal. Extrinsic goals motivate students to gain rewards or to avoid punishments. Moreover, relative ability goals and extrinsic goals may be beneficial at some times for some students, particularly in the short term. In the short term, Hidi and Harackiewicz suggest that interesting, well-delivered instruction promotes mastery goal-setting, even if the primary motivation for the completion of the task at hand is extrinsic or competitive in nature. The researchers suggest that "a combination of intrinsic rewards inherent in interesting activities and external rewards, particularly those that provide performance feedback, may be required to maintain individuals' engagements across complex and often difficult, perhaps painful periods of learning" (p.159). However, although rewards and feedback that support competitive motivation have some value as a method in individual classes, they should be used within a school culture that conveys a mastery-goal type of message that emphasizes the importance of effort, improvement, and learning for its own sake.

Risks of competitive outlook. Despite the potential for competitive goals to improve learning at times, there is a great deal of evidence to support the promotion of mastery goals when possible. For example, students who set competitive goals not only value effort less than mastery goal-setters; they may actually view the exertion of effort as a sign of low ability (Dweck, 1986). Additionally, goal-setting appears to be a function of students' relative sense of whether ability and intelligence are set quantities or are changeable by practice and effort. As Dweck states, "children who believe intelligence is a fixed trait tend to orient toward gaining favorable judgments of that trait (performance goals), whereas children who believe intelligence is a malleable quality tend to orient toward developing that quality (learning goals)" (p.1041). Therefore, the adoption of a mastery philosophy leads to self-fulfilling mindset that increased effort correlates to increased success.

Additionally, there are some troubling gender-specific trends that indicate that promotion of mastery goals is educationally sound. Specifically, high-achieving girls have been found in a number of studies to adopt competitive goals, select less challenging tasks, be less persistent, and show more anxiety and helplessness than other groups of students. And although these results do not appear to make a difference for achievement at the primary and secondary education levels, Dweck (1986) suggests that there may be serious repercussions over time. A 38-year longitudinal study showed disturbing trends for high-achieving girls. In the study, when groups were crossed by gender versus achievement level, every group showed significant increases in IQ from pre-adult to adult except high-IQ females. This finding suggests that high achieving girls may be particularly likely to set competitive-type goals and to experience detrimental consequences of setting such goals.

Competitive mindsets are especially damaging when learning activities are more challenging (Dweck, 1988). Dweck reported that when tasks are relatively easy and students face no confusion or obstacles, numerous studies show that students with competitive goals show achievement levels equal to those with mastery goals. But when faced with rigorous or difficult learning situations, students with a mastery outlook out-perform their competitive peers. In a study with late grade-school age children, Dweck found that all students achieved at equal levels as long as problems were easy and all students were experiencing success. Moreover, all students reported high levels of self-efficacy as long as they experienced success. But when the researchers offered the students more difficult problems, students with competitive-type goals underperformed, became disenchanted and bored with the task, and failed to attempt problem-solving strategies or other self-regulation methods. Dweck states that these children "viewed their difficulties as failures, as indicative of low ability, and as insurmountable" (p.258). Moreover, Dweck reports that similar results have been shown for other age groups from early primary to adult. Finally, Dweck again notes that the crucial element that determines students' goal-setting tendencies involves their understanding of the nature of intelligence. Students who view intelligence as a changeable quality that can be improved by effort are more likely to adopt mastery goals whereas students who believe that intelligence is a fixed, unchangeable trait are more likely to adopt competitive type goals.

Although a competitive mindset appears detrimental for all students during challenging tasks, low achieving students with competitive goals in challenging situations experience an especially damaging environment. Elliott and Dweck (1988) conducted an experiment with 5th grade students that underscored the particularly harmful condition that occurs when students with low ability have competitive goal-setting tendencies. By artificially manipulating the types of goals that students were likely to set and the perceived abilities of the students, Elliott and Dweck analyzed mastery versus competitive goal-setters in terms of their task choice, performance during difficulty, and affective response. Students with low ability and competitive goals chose easy tasks, performed poorly, showed low levels of persistence, and did not enjoy the learning experience. Furthermore, all of the students "attributed failure to an uncontrollable cause" and "None attributed failure to a lack of effort" (p.10). In other words, not only did these students perform poorly, not one of those students would be likely to do anything differently in the future to improve their performance. Moreover, although high ability students in Elliott and Dweck's study showed more persistence than their low ability counterparts, high ability students with competitive goals avoided choosing challenging tasks whereas mastery groups of both levels of ability consistently chose challenging tasks and showed high levels of persistence.

Even when prior performance is substituted for perceived ability, mastery goals seem to be clearly superior to competitive goals. Bergin (1995) attempted to investigate the effects of mastery versus competitive outlooks in a more realistic classroom environment and by grouping students based on grade point average (GPA). Whereas most research on the effects of goal-setting categorizes students' ability based on self-reported ability, Bergin substituted GPA for perceived ability, and found that low GPA had effects that were analogous to low perceived ability. Students with lower GPA who adopted competitive-type goals showed significantly lower performance than low GPA students who adopted mastery-type goals. On the other hand, high GPA students showed no difference in performance whether they adopted mastery or competitive-type goals. Therefore, although instructional techniques that provide extrinsic rewards and promote competitive outlooks in students may have some value, there are serious risks associated with such a mindset. Specifically, a competitive mindset appears to be particularly harmful for low achieving students and girls, and may be harmful for all students during challenging activities. Moreover, not only does a competitive mindset appear to be less productive, it also can promote a sense of futility and disengagement among those students who underperform, which may lead to repeated failures and lack of success.

Feedback and Student Attitudes

The types of feedback provided to students can have significant impacts on their outlooks and the effectiveness of instruction. Butler (1988) conducted a similar study on

5th grade Israeli students in which she measured the impact of feedback on intrinsic motivation. Intrinsic motivation, in Butler's view, is analogous to mastery goal-setting in that the motivation to perform well on a task is derived from improvement at the skill in question rather than from relative ability or outside judgments of one's ability. Butler was particularly interested in the effects of grades on intrinsic motivation, and compared three methods of feedback in terms of their impact on intrinsic motivation. The three possible types of feedback were grades only, comments only, and grades plus comments. Butler found that both high achieving and low achieving students maintained levels of intrinsic motivation if they received comments only, but that both groups' intrinsic motivation dropped when they were given grades as feedback. Moreover, while high achievers who received grades continued to show good performance, the performance of low achievers was decreased after receiving grades as feedback. Interestingly, when grades were combined with comments, the effects were essentially equivalent to giving grades only. Furthermore, Butler found that when students received grades plus comments as feedback, most students could not remember any of the content of the comments – an indication that when grades are combined with comments, comments receive little attention from the learner. On the other hand, when students received comments only, "all but two recalled at least one component [of the feedback]" (p.10).

Other research supports the notion that the relationship between feedback, motivation, goal-setting, and learning is both crucial and complex. Hattie and Jaeger (1998) combined and synthesized many of the important principles of goal-setting, self-regulation, feedback research, and classroom practice. They note that increased student achievement is clearly dependent upon effective feedback. They further state that feedback is “the most powerful single moderator that enhances achievement” (p.114). Hattie and Jaeger also acknowledge that effective feedback can promote a mastery outlook in students, and that improved mindset promotes motivation and self-regulation which in turn tends to increase achievement. Hattie and Jaeger state that “goals motivate individuals to persist” (p.112) and “feedback allows them to set reasonable goals” (p.112). Hattie and Jaeger (1998) note that reducing class size, using computer-assisted instruction, or giving more homework can increase the amount or quality of feedback. However, they caution that such measures only create the potential for more feedback, they do not “guarantee that they will occur” (p.114).

The student-teacher ratio also places obvious limitations on the amount and quality of feedback provided to students. Hattie and Jaeger (1998) describe the typical amount of feedback that is possible in a forty minute class with twenty students and one teacher. Clearly, in such a scenario, the maximum amount of time that a teacher could spend giving feedback to any one student would be two minutes. In practice, given the other activities that teachers must accomplish during a class period, one may conclude that the amount of feedback per student per class period is actually much lower. Due to this mathematical reality, Hattie and Jaeger see critical implications for differentiating instruction in the classroom. Specifically, Hattie and Jaeger state that “individualization in regular classes must fail and does fail” (p.115). However, the researchers suggest that if individualization of instruction could be “coupled or complemented with feedback, achievement effects would dramatically increase” (p.116). Finally, Hattie and Jaeger suggest that effective presentation techniques tend to augment the effects of effective feedback whereas poor instruction may neutralize any potential benefits.

Engagement

Engagement involves student motivation, attention, participation, reflection, and processing and has been defined as "the active, enthusiastic, effortful, participation in learning activities" (Skinner, Kindermann, & Furrer, 2008, p. 495). Intrinsic motivation is closely linked to engagement (Ryan & Deci, 2000) and has been defined as "motivation to engage" (Hidi & Harackiewicz, 2000, p. 158), while Skinner et al. state that engagement predicts achievement, school completion, and may be thought of as "the quality of students' participation with learning activities" (p. 494). Engagement affects persistence, resilience (Riggs & Gholar, 2009), and cognitive functioning (Hidi & Harackiewicz, 2000), and deeply engaged students typically raise their hands, answer orally, participate in discussion, "go beyond the requirements, exhibit preferences for risk-taking, and show greater commitment" (Paris & Paris, 2001, p. 93). Furthermore, while engaged learners exhibit high levels of motivation, attention, participation, and processing, they also experience positive emotions about school and learning (Jensen, 2003; Riggs & Gholar, 2009; Skinner, et al., 2008). Specifically, engagement is associated with adaptive motivational beliefs, self-confidence, optimism, higher goals, and feelings of involvement with the learning process, whereas beliefs that results are uncontrollable, avoidance behaviors, and negative feelings toward school and teachers decrease engagement (Bandura, 1989; Beghetto, 2004; Skinner, Kindermann, & Furrer, 2008).

Although student characteristics affect their engagement levels, the nature of classroom activities and methods is also important because students who are interested in a task have better attention, persistence, and enjoyment of the learning process (Hidi &

Harackiewicz, 2000). Moreover, student interest or enjoyment in a particular task can be promoted by instructional methods like giving students a choice in their assignments (Skinner, Pappas, & Davis, 2005) or providing external rewards (Hidi & Harackiewicz, 2000). Hidi and Harackiewicz' suggest that external rewards can be particularly effective in maintaining engagement during difficult or extended academic tasks, whereas Skinner, Pappas, and Davis state that engagement can be undermined when tasks require too much effort, reinforcement is too infrequent, or reinforcement is low quality, and suggest that solutions include breaking tasks down into smaller segments, allowing assignment choices, increasing rates of reinforcement, promoting increased response rates, and modifying existing reinforcement methods. Moreover, tangible rewards like prizes and food are often the most powerful, but less powerful reinforcers like feedback and task completion can be effective "when they are delivered at higher rates and more immediately" (p. 398). Interestingly, even when the task itself is not changed and rewards are not offered, manipulating the classroom environment toward a mastery situation that emphasizes developing skills instead of public competition improved interest, enjoyment, and achievement among college education students (Bergin, 2004). Bergin manipulated the classroom environment simply by telling students that the purpose of a task was either "to use it in your own teaching" or "to rank you in terms of your ability" (p. 306) and found that the former condition gave superior results, particularly for students with lower GPA's.

Group rewards are another method of increasing student interest in a task, and Popkin and Skinner (2003) found that randomizing group rewards so that students were unsure which reward would be attached to a particular task increased performance in math and English for middle level students with emotional disturbance. The researchers suggest that this method is effective because “at least some consequences are high quality reinforcers for each student” (p. 284), and that the dramatic improvements shown during the intervention indicate that previous poor performance was caused by students “choosing not to engage” (p. 292) rather than inability to complete tasks.

The discrete task completion hypothesis describes an interesting way of making the task itself a reward, and suggests that breaking assignments into smaller tasks promotes engagement because “each completed task acts as a reinforcer” (Skinner, 2002, p. 349). Getting students more opportunities to participate and become actively involved in learning activities has numerous learning benefits and may also “reduce the probability of students engaging in disruptive behaviors” (Skinner,2002, p. 348), and Sencibaugh (2008) suggests that combining “an interactive instructional sequence with a teaching device” (p. 88) can increase learning and engagement by making students more active participants. Other methods that may promote engagement through greater student involvement include requiring students to read aloud as though in a performance, having students record and listen to their own readings, using a whisper phone to reduce distractions, and using phrase boundaries to draw attention to important pauses in reading (Hudson, Lane, & Pullen, 2005). Other researchers found that breaking math assignments into smaller activities improved the amount of work completed and decreased teacher re-directs for a student with a learning disability (Wallace, Cox, & Skinner, 2003). Wallace, Cox, and Skinner note that learning interventions cannot be successful unless students choose to “engage in learning activities” (p.132), that making tasks briefer may increase the likelihood of engagement, and that students with learning problems may be particularly susceptible to fail to engage during typical tasks.

Other facets of engagement that can be affected by increasing response rates and instructional methods include participation, attention, and on-task behavior. Turner and Patrick (2004) state that "participation facilitates learning" (p. 1760) by enabling students to apply and reflect on new knowledge, and providing teachers a way to diagnose learning problems. These researchers also found that calling patterns that limit opportunities for responses reduced participation and involvement in two middle level math students. In a review of methods that increase response rates, Skinner, Fletcher, and Henington (1996) reported that increasing the number of learning trials during a class improved on-task behavior, participation, and accuracy. This was accomplished by reducing the inter-trial interval, which is the time after feedback is given from one learning task until the next task is begun. If tasks include an assignment, response, and feedback, reducing the inter-trial period can increase the number of tasks completed while also improving attention. Furthermore, the researchers also increased the amount of wait time, which is the time after the assignment has been completed during which students are able to think and respond. Other effective methods described by Skinner, Fletcher, and Henington included choral responding, use of response cards, and reducing allocated time for tasks, whereas Evans-Hampton et al. (2002) used a stopwatch to increase student response rates and increased 8^{th} grade students' accuracy levels in mathematics. Similarly, a majority of 3^{rd} grade general education students improved math fluency after being asked to respond to math problems before the correct answer was given via audiotape (McCallum, Skinner, Turner, & Saecker, 2006). The researchers suggested that the requirement to answer problems more quickly may promote automaticity and the ability to provide the intervention on a class-wide basis allows the intervention to affect more students. And although increasing response rates has been shown to promote engagement, altering response topography for elementary students by requiring verbal responses also resulted in more learning trials and greater learning rates (Skinner, Belfiore, Mace, Williams-Wilson, Johns, 1997). Finally, using a color-wheel to draw 2nd grade students' attention to new instructions resulted in sustained and immediate increases in on-task behavior and reductions in out of seat behavior (Fudge et al., 2008). The color-wheel was designed to re-direct students to salient instructions during transitions, a particularly challenging part of lessons especially for younger students and students with attention problems. Fudge et al. stated that the color wheel system showed high external and contextual validity in that the system appeared to be effective for all students and had high acceptability for both teachers and students.

Requiring students to become more active learners can take a variety of forms, and in a review of 51 studies that focused on teaching students study skills, Hattie, Biggs, and Purdie (1996) found that reflection strategies often promote engagement by improving motivation and self-concept in students. Interestingly, the study skills interventions had more of an effect on student attitudes and engagement than on actual use of the skills themselves. These kinds of self-regulated learning have been described as "inherent in goal-directed engagement" (Winne, 1997, p. 397), and application of metacognitive strategies also raised achievement scores for 1st graders (Eilers & Pinkley, 2006). In addition to reflection, requiring students to actively process content within lessons has also been shown to increase engagement. Middle and junior high students using a summarization strategy increased comprehension (Gajria & Salvia, 1992), while participating in story-mapping raised scores on comprehension questions for four out of five elementary students with mild learning handicaps (Idol & Croll, 1987). Finally, technology can be used to encourage engagement and enhance student attention by giving periodic prompts, fostering self-regulatory behavior, requiring students to apply learnt content frequently, and to actively verify their learning (Azevedo, 2005). In a review of a number of experiments that used technology to promote engagement, Azevedo found that technology can help students become more active learners by scaffolding self-regulatory skills.

Not surprisingly, although methods that increase participation rates and enjoyment can increase engagement and learning, other factors can decrease levels of engagement and lead to avoidance behaviors in which students' primary motivation is to escape potentially embarrassing situations (Dweck, 1986). Avoidance behaviors are associated with classroom anxiety (Dweck; Turner & Patrick, 2004; Zimmerman, 1989), and harm learning by leading to lower effort and resilience, greater likelihood of withdrawal, and impedance of metacognitive processes (Dweck & Leggett, 1988; Zimmerman, 1989). Therefore, methods that can to create anxiety such as public praise, rankings, and feedback that threatens self-esteem are often ineffective and harmful to engagement (Criswell, 2005; Kluger & DeNisi, 1986; Dweck, 1986). Moreover, threats to engagement can be exacerbated among certain groups of students including low achieving and low socioeconomic status students (Elliott & Dweck, 1988), girls (Dweck, 1986), and adolescents (Brown & Knowles, 2007).

In numerous studies involving teaching students self-regulatory and study skills, low ability students consistently failed to show improvements in learning (Hattie, Biggs, & Purdie, 1996), and Bandura (1989) noted that students who “doubt their capabilities” (p.730) are prone to stress and disaffection. Low achieving students are likely to attribute failure to ability and become disaffected Elliott and Dweck (1988), and students who developed a helpless affect toward school were likely to avoid challenges and give up quickly during tasks (Dweck & Leggett, 1988). Moreover, rankings like grades were particularly ineffective feedback for students with lower achievement levels (Butler, 1988). Finally, avoidance behavior may be particularly common in girls (Dweck, 1986) and therefore classroom methods that emphasize public competition may be especially damaging.

In addition to the vulnerability of these groups, numerous researchers have reported on the need for adolescents and middle level learners to have classroom environments that are safe and non-threatening. Many adolescents are going through a period in which their academic motivation is declining and their “interests and attitudes toward school is deteriorating” (Hidi & Harackiewicz, 2000, p.151). Brown and Knowles (2007) add that embarrassing kids in front of peers causes stress and that such “threatening situations can cause helplessness” (p.93). Pedrotty Bryant et al. (2006) note that middle level students often struggle with maintaining attention and self-regulation, and that limitations in their working memory can make it difficult to apply new knowledge or complete complex tasks, and Montague (2006) adds that middle level students with learning disabilities often are unable to abandon ineffective learning strategies.

To reduce stress and accommodate their unique needs, adolescents need to be active learners, receive continual feedback, and get “multiple opportunities to make their learning visible” (Beamon, 2001, p.106). Boston (2002) suggests that feedback that focuses on corrective measures is particularly helpful to lower achieving students because it indicates that effort can lead to improvement and Sencibaugh (2008) suggests that students with learning difficulties may benefit when lessons are made more interactive. Researchers have also suggested that adolescents need a safe environment in which “emotions such as fear of punishment and embarrassment are minimized” (Beamon, 2001, p.6), stress is reduced, and feedback is systematic (Kinder & Stein, 2006), immediate, and non-threatening (Montague, 2006).

Classroom Response Systems

Classroom Response Systems and Engagement

Engagement involves not only a student’s levels of participation and concentration, but their enjoyment of the learning process. Teaching methods that increase engagement typically offer increased opportunities to participate, increased accountability, and frequent, prompt feedback, whereas, factors that increase the risk of embarrassment and anxiety tend to decrease engagement. CRSs inherently increase the immediacy and frequency of certain kinds of feedback and enable much greater participation rates than traditional NCRS and verbal responding. CRSs also promote student accountability by providing immediate evidence of student responses to teachers and can reduce anxiety because each student’s response is anonymous and known only to the teacher (Nightingale, 2008). Due to these factors, many studies using CRSs have reported positive results for engagement, components of engagement, and learning. (see Table 1).

Table 1
Classroom Response Systems' Effects on Learning

Instructional Goal Achieved	Supporting Study
Learning Gains	Conoley, 2005; Hill, Smith, & Horn, 2004; Freeman, Blayney, & Ginns, 2006; Greer & Heaney, 2004; Guthrie & Carlin, 2004; Horowitz, 1988; Sharma, et al., 2005.
Increased Participation	Burnstein & Lederman, 2001; Conoley, 2005; Draper & Brown, 2004; Fies, 2005; Freeman, Blayney, & Ginns, 2006; Guthrie & Carlin, 2004; Hill, Smith, & Horn, 2004; Roselli & Brophy, 2006; Swan et al., 2004; Ward, Reeves, & Heath, 2003.
Enjoyability	Conoley, 2005; d'Inverno, Davis, & White, 2003; Draper & Brown, 2004; Fies, 2005; Hatch, Jensen, & Moore; Hill, Smith, & Horn, 2004; Horowitz, 1988; Roselli & Brophy, 2006; Sharma, et al., 2005; Swan et al.
Increased Attentiveness	Horowitz, 1988; Roselli & Brophy, 2006; Sharma, et al., 2005.
Increased Processing	Draper & Brown, 2004.
Increased Self-Assessment	Brewer, 2004; Draper & Brown, 2004; Greer & Heaney, 2004; Roselli & Brophy, 2006.
Reduced Anxiety	Draper & Brown, 2004; Freeman, et al., 2006; Greer & Heaney, 2004; Guthrie & Carlin, 2004; Sharma, et al., 2005.

Classroom Response Systems and learning. Although there is some evidence that CRSs promotes learning, other studies have not found significant learning gains

(Fies, 2005; Swan et al., 2004). The two most rigorous studies that support the claim that CRS promote learning gains are Horowitz' (1988) study of corporate training at IBM and Conoley's (2005) dissertation with high school students in agri-science courses. Horowitz consistently found that students were more attentive and had increased recall of course content when they participated in interactive learning, and that this benefit was amplified by a CRS-supported classroom. In two separate experiments, Horowitz found a 19% increase in retention when students interacted by answering questions during class compared to a pure lecture methodology. In a follow-up study, Horowitz found that this increased to a 27% improvement when the interactive method was enhanced by CRS technology. Conoley separated a convenience sample of high school agri-science students into a CRS group and a comparison group and found that the CRS group scored 89.98 on a locally created test compared to 84.41 for the comparison group, and Sharma et al. (2005) found that college physics students learned more in a CRS-supported classroom than in a traditional one, but noted that the results were based on locally created tests that had been used in previous years' courses. Finally, Fies found a positive, but not statistically significant effect on learning by CRS-supported classrooms in teacher education classes. Additionally, these results are supported by a number of studies that base claims of increased learning on surveys of student perceptions (Freeman, et al, 2006; Greer & Heaney, 2004; Guthrie & Carlin, 2004; Hill, et al., 2004).

Classroom Response Systems and participation rates. Studies that indicate increased participation rates due to CRS usage cover a wide range of content areas, levels of education, and means of assessment. For example, Ward, Reeves, and Heath (2003) claim nearly 100% participation rates in chemistry classes at the University of North

Carolina at Wilmington. Roselli and Brophy (2006) similarly suggest that response rates reach 100% in their college engineering courses. Both of these claims seem to be based mainly on anecdotal evidence, however. Somewhat more well-documented claims, if not as striking, are based on surveys, interviews, and other qualitative methods of exploring student perceptions at the completion of courses of study. Conoley (2005) found that students strongly associated increased participation with CRS through a combination of interviews and word-frequency analysis on focus groups of high school agri-science students. Fies (2005) used surveys and video analysis to discover similar perceptions among pre-service teachers in a physical science course. Other results also indicate that CRS may increase participation rates in college physics courses (Burnstein & Lederman, 2001), college psychology classes (Hill, et al., 2004), college accounting classes (Freeman, et al, 2006), and in many different content areas during an institution-wide integration of CRS technology at the University of Glasgow (Draper & Brown, 2004). Finally, perhaps the most accurate and striking indication of CRS affect on student participation can be found in Guthrie and Carlin's (2004) use of actual log files of student responses in a college business course. This direct measurement of participation indicated that students participated at a 95% rate when using CRS. These results indicate that students using CRS technology participate at very high rates, and that students self-report a strong preference for CRS-based participation relative to traditional methods of participation, particularly verbal responses to instructor questions.

Classroom Response Systems and anonymity. Especially given the potentially damaging consequences that public embarrassment holds for lower achieving students and adolescents, a number of studies indicate that the anonymity afforded by CRSs may also provide an important benefit. In one college level, institution-wide study, the value of anonymity was a recurring theme, even in classes that were relatively small and included students who had known each other for some time (Draper & Brown, 2004). Students reported that anonymity enables them to avoid embarrassment, and instructors suggested that "anonymity seems to function to induce people to pick a definite answer even when they are quite uncertain" (p.89). Therefore, although the researchers found that the most common benefit of CRSs was cognitive in that they caused students to think about instructor questions, the anonymity was found to be the mechanism which caused many students to choose to engage. Similarly, Sharma et al. (2005) found that the anonymity of CRSs decreased embarrassment and among college physic students, and college level business students reported that anonymity was a critical factor affecting student willingness to participate (Freeman et al., 2006). In the latter study, 63% of the students in class stated that they valued anonymity when they were uncertain of their response and 62% said that they generally value anonymity from their peers. Moreover, when a variety of methods of responding were offered, CRSs had the highest level of anonymity and also ranked highest in preference among students. Other studies in college geosciences classes (Greer & Heaney, 2004) and college business classes (Guthrie & Carlin, 2004) support the value of anonymity for student participation, with Guthrie and Carlin reporting that nearly half of the students in class thought anonymity was very important for them to be willing to participate.

Other benefits of Classroom Response Systems. Part of CRSs ability to increase participation stems from their capability to enable every student to respond simultaneously to a single question. Since typical scenarios limit response rates to one at a time, participation in a CRS-supported classroom can theoretically increase at a rate of class size: 1. In other words, if there are 30 students in a class, there can be thirty times more participation in a CRS-supported classroom than in a traditional classroom. Of course, alternatives like hand-raising, wide calling, and thumbs-up / thumbs-down are available in the traditional classroom, but several studies indicate that students prefer CRSs to these methods (Draper & Brown, 2004; Fies, 2005; Freeman, et.al., 2006; Hill, et.al., 2004). Furthermore, Swan et al. (2004) reported that although a pilot study in middle school classes comparing a control condition, use of document cameras, and use of wireless writing pads all had essentially equal levels of engagement, using CRSs resulted in engagement levels that were a full level higher than the others.

In addition to the strong evidence that CRSs promote participation, most studies also found that students seem to prefer CRS-supported classrooms to the typical environment. For example, Conoley (2005) found that students associated “fun” with using the CRS as the fourth most common response in a word frequency tabulation. Other researchers who surveyed student perceptions of the technology similarly received a positive reaction to the CRS-supported classroom (d’Inverno, et al., 2003; Draper & Brown, 2004; Fies, 2005; Hatch, Jensen, & Moore, 2005; Hill, et al., 2004; Horowitz, 1988; Roselli & Brophy, 2006; Sharma, et al., 2005). Although the stated causes of such preferences vary from student to student and across studies, some researchers attribute CRS advantages to the increased interactivity (Hill, et.al., 2004), increased ability to pay attention (Roselli & Brophy), and anonymity (Draper & Brown, 2004) that the devices afford. Interestingly, even when CRS technology was used to increase student accountability through evaluating student participation, students still responded favorably to using the CRS (Roselli & Brophy, 2006). Several studies did report negative student perceptions regarding CRSs due to cost of the devices (Greer & Heaney, 2004; Guthrie & Carlin, 2004) and technical difficulties associated with using the technology (Draper & Brown, 2004; Guthrie & Carlin, 2004). However, despite significant technical problems that occurred in the latter two studies and other legitimate student complaints, every researcher found that most students enjoyed or preferred a CRS-supported classroom.

In addition to promoting student enjoyment, studies indicate that CRSs can improve attention, processing of information, and self-regulation. Numerous studies suggest that students improve their frequencies and levels of attention in CRS supported classrooms (Horowitz, 1988; Roselli & Brophy, 2006; Sharma, et al., 2005). Using a body language analysis system, Horowitz found that attentiveness increased from a 47 rating in a traditional classroom environment using strictly lecture to a 68 in one that increased interactivity through traditional question and answer methodology. Horowitz further found that the attentiveness gain due to interactivity was increased to an 83 in a classroom enhanced by CRS technology. In two other studies, students reported similar increases in attentiveness among college engineering students (Roselli & Brophy, 2005) and physics and life science students (Sharma, et al., 2005).

Although attentiveness is important, long-term learning is most likely when information is "understood, organized, and integrated" (Ormrod, 1990, p. 218) with existing knowledge. Several studies indicate that CRS technology can promote self-regulation among students. Draper and Brown (2004) found that students rated the capability of CRS to check "whether you are understanding it as well as you think you are" (p.86) as the greatest advantage that the technology affords the learner. Greer and

Heaney (2004) concluded that students felt that CRS helped students track their own progress and check their understanding of lecture material. Finally, Roselli and Brophy (2006) found that student survey results generally supported the claim that CRS technology fosters increased self-assessment.

Draper and Brown (2004) specifically refer to increased processing as an outcome of using CRSs, stating that CRSs get “students to think about the question and decide on an answer whereas the alternatives do not” (p.90). Sharma et al. (2005) and Greer and Heaney (2004) imply that increased engagement was occurring stating that there was more deep thinking and more higher order learning, respectively. Additionally, Nightingale (2008) found that students with lower GPA’s increased engagement when CRS were used, and a survey of 585 K-12 teachers found that increased engagement was a common outcome of using CRS technology, particularly when instructors focused on instructional rather than assessment goals (Penuel, et.al., 2005).

Although increasing student rates of attentiveness, processing information, and self-assessment may not fully solve every problem in education, it certainly addresses three areas of need that have proven connections to learning. Moreover, it seems clear that these three processes are interwoven and synergistic. That is, one cannot possibly process information without first paying attention, and one cannot reflect very well about one’s learning if one has not thought carefully about the content. Therefore, an increase in attentiveness enables more processing which should make self-assessment more possible and more rewarding for the learner. Therefore, CRS technology appears to have the potential to be a very powerful tool for learning in this regard.

Summary of CRS Research

The research base on CRSs can be generally described as heavily skewed toward higher education and highly qualitative in nature. Despite these limitations however, the near unanimity of the qualitative results across many studies lends credence to the claim that CRS benefit learning. The strongest evidence for the value of CRS involves their effect on rates of participation and student enjoyment levels, but there is also reason to believe that CRS may improve student attentiveness, engagement, self-assessment, and learning gains. Furthermore, one study goes to some length to attempt to measure formative assessment behaviors by instructors, and these researchers do find some evidence that such behaviors are augmented by the use of CRS.

The vast majority of classroom response system research consists of survey studies in higher education that make a variety of claims about the efficacy of these devices. For example, Brewer's (2004) survey results found that CRS corresponded with increased formative assessment and self-assessment by students in college biology classes. Burnstein and Lederman (2001) used surveys as the primary method to indicate increased participation and student enjoyment of the learning environment in college physics classes. Draper and Brown (2004) studied an institution-wide rollout of CRS at a university in the United Kingdom, and although they found that learning may have increased, this study also mainly based its claims on survey data of student and teacher perceptions.

The best supported claims about CRS involve the device's effect on student participation. This is partially because the classroom response system itself can be the mechanism for measuring participation rates and for enforcing lack of attendance or participation. At least nine studies make specific claims about CRS affect on participation (Burnstein & Lederman, 2001; Conoley, 2005; Draper & Brown, 2004; Fies, 2005; Freeman, et al., 2006; Guthrie & Carlin, 2004; Hill, et al., 2004; Roselli & Brophy, 2006; Ward, Reeves, & Heath, 2003). Two of these studies (Roselli & Brophy; Ward, et al., 2003) claim that participation rates reach 100%, but both of these base their claims on anecdotal evidence or survey data. Guthrie and Carlin (2004) appear to have the most reliable evidence of increased participation, using actual log files of student responses on the classroom response system as evidence of this gain. But again, the strength of the research base generally relies more upon the consensus of the studies than the rigor of the experimental methods.

This trend continues across the rest of the breadth of learning related constructs and claims of actual learning gains that are found in the research base on CRSs. Although there are studies that suggest that CRSs improve important variables like student engagement, attentiveness, or self-assessment, none use any quantitative means of measuring these variables. Essentially, all of these claims are based on student or teacher perceptions. One study (Roselli & Brophy, 2006) uses an interesting system involving trained observers coding instructor behaviors in order to study levels of formative assessment, but this is the only example of a rigorous attempt to measure a construct of this type.

Finally, the research base does include some direct support for claims regarding CRS effect on student learning. Horowitz (1988), Sharma, et al. (2005), and Conoley (2005) all achieve results that indicate an augmentation of student learning by CRS, but each study has limitations. Horowitz' study involves a relatively small group in a nontypical setting. Sharma's study uses two-year old class results as a control group on which to base his claims of learning gains, and all of the studies use locally created tests and convenience samples, which limits their external validity. Furthermore, none of these studies indicate rigorous control of instructional procedures across lessons. On the other hand, these results are bolstered by a number of qualitative studies (Hill, et al., 2004; Freeman, et al., 2006; Greer & Heaney, 2004; Guthrie & Carlin, 2004) in which students and teachers seem to agree on a perception that CRS did improve learning.

CHAPTER III

Method

Numerous studies have suggested that students find CRSs enjoyable and believe they learn more when using the technology. Data also suggests that CRSs increase student attention and therefore, engagement, but little evidence is present to confirm actual learning gains. This investigation is believed to be the first to use an alternating treatments design to augment experimental control in CRS study. Of these two alternative conditions, we will refer to the condition in which students respond by raising their hands and do not use CRSs as the NCRS condition. We will refer to the other condition as the CRS condition. In the CRS condition, students used CRSs to respond during questioning. The purpose of the investigation was to study the effect of CRSs on student recall of information from readings of passages on topics in science. An additional goal of the study was to assess student acceptability of the technology.

Participants

The participants were 67 students attending a middle school near Pittsburgh. The school is a small, suburban public school with a socioeconomically diverse, predominantly Caucasian population. The school serves 1168 students in grades K-12. Of this population, 31% receive free or reduced lunch. Additionally, 92% of the students are White, 6% are Black, with less than 2% Hispanic or Asian students. The students participating in the study were selected from a convenience sample of 7th grade students enrolled in full inclusion, science classrooms, with class sizes that typically range between 20 - 30 students. There were four sections of this course included in the experiment, all of which were taught by the same instructor. Parent consent was obtained to gather data on student achievement levels and demographic information. Student assent to use the data was also obtained. The study was conducted in the February, 2012.

Materials

The CRSs used in this experiment were Smart Response Systems produced by Smart Technologies, Inc. These response systems use remote controls to communicate with a central computer. The devices enable teachers to track, compile, and manage student results. These CRSs include a variety of questions and activities that can support instruction and the results may be available to the instructor as soon as all students have responded to a question or when the instructor ends a particular question. Typically, all students in a class will respond to every question, and the results that an instructor receives can quickly be used for summative or formative evaluation. Furthermore, the CRSs are usually formatted so as to allow students to see their results immediately, as well as seeing their overall percent correct. The CRSs used in this experiment are capable of being used for true/false, yes/no, multiple choice, numeric response, and multiple answer formatted questions. These questions are most commonly created prior to the session and displayed on some sort of projector, but it is also possible to create questions on the fly and insert them into a presentation. Additionally, instructors may set up CRSs so that it is possible to know and record results for each student. In order to record individual results and know which scores belong to each student, it is necessary to enter each student's name and an identifying number in the CRS database before beginning the first session. In this mode, students must log in to the system using the CRS devices and enter their unique login ID. The system will recognize the student's login ID and show their name on the CRS screen. However, it is also possible to set up the devices in an anonymous mode wherein overall results are recorded, but the teacher does not know how individual students responded. In anonymous mode, the devices may be used immediately without any need to enter the names or ID numbers of students into the system. The students may be able to know the percent of question they answer correctly and the teacher can detect levels of participation and assess overall understanding, but the teacher would not see the individual scores of the student in the anonymous mode.

Questions taken from Timed Readings Plus in Science (Glencoe/McGraw-Hill, 2003) series were used to measure student learning in this experiment. The Timed Readings series has been used in a number of other studies to measure student learning (Gajria & Salvia, 1992; Neddenriep, Hale, Skinner, Hawkins & Winn, 2007; Winn, Skinner, Oliver, Hale, & Ziegler, 2006). The series contains 10 books, and each book is comprised of 25 passages controlled for readability using Fry's Readability Index (Fry, 1968). Each passage contains a 400 word narrative with ten multiple choice questions assessing recall and comprehension of the passage. Examples might include, "the part of the electromagnetic spectrum that is responsible for skin cancer is: a. infra-red; b. ultra-violet; c. gamma." or, "one can infer from reading the passage that: a. Albert Einstein wasn't good at math; b. Albert Einstein's theory of relativity was incorrect; c. Albert Einstein's ideas led to other important discoveries." In addition to the assessment of student learning, a questionnaire was used to measure student acceptability of the intervention and attitudes toward the use of CRSs specifically.

Dependent Variables

There were two dependent variables assessing student learning. After reading a science passage, students were quizzed on the content of the passage. Out of a total of ten quiz questions, five were unknown to the students until the quiz was taken whereas the other five were reviewed by the teacher before the quiz. We will refer to the questions that were reviewed before the quiz as *review questions*. In the CRS condition, students responded to each review question using CRSs whereas the NCRS condition required students to respond by raising their hands. The average number of class-wide quiz questions answered correctly out of the five review questions per probe constituted one of the primary variables in this study. The average number of class-wide quiz questions answered correctly out of the five questions not reviewed constituted a second dependent variable. The data was graphed with sessions on the X-axis and total number of questions answered correctly on the Y-axis. Visual analysis was used to analyze the data. The effect size of application of the CRS compared to the NCRS condition was computed using Cohen's *d* (Cohen, 1988).

In addition to the comprehension measure, this study used a questionnaire to measure student and teacher acceptability of the technology. After the completion of the intervention, students rated acceptability of CRSs based on a Likert scale of 1-4, from strongly disagree to strongly agree. Students were asked to rate their levels of engagement, learning, anxiety during participation, and relative enjoyment levels during the CRS condition versus the NCRS condition.

Research Design

An alternating treatments design was used to assess the relative effects of two treatment conditions. The first treatment condition utilized hand-raising to review questions after a reading activity. This treatment condition will be referred to as the NCRS condition. The second condition added the use of CRSs during the questioning portion of each lesson. This condition will be referred to as the CRS condition. Alternating treatments addressed the threat of order effects, in which performance in one condition is affected by participation in a previous condition. In this study, the condition for each session was randomly selected with no more than two consecutive sessions having the same condition. By randomly determining the conditions on each consecutive day throughout the experiment, the treatments were counterbalanced. This design addressed the possibility that performance will be improved or undermined by repeated use of the same treatment. For this study, students the students were asked to listen to passages for ten consecutive days. Potential threats could have included student performance improving due to extra practice or decreasing due to boredom due to experiencing the same activity repeatedly. Counterbalancing the treatments minimized the influence of such factors (Richards, S., Taylor, Ramasamy, & Richards, R, 1999). Additionally, out of ten total quiz questions, five questions were selected as review questions whereas the remaining five questions were not reviewed before the quiz.

Procedures

This study investigated the effects of CRSs on immediate student learning of science content. In the study, we compared two alternative teaching methods that involved different ways of conducting a question and answer activity. To introduce the experiment, students were read the following statement at the beginning of the first session, "In the upcoming days, you will be read passages corresponding to national and state standards for science, and each passage contains material that may be interesting, surprising, or relevant to middle school students. While the questions you will be asked about these passages are not a test and will not count for a grade, they do contain important science information, and we ask you to do your best to listen to each passage and try to remember as much of the information as possible. Additionally, we are interested in student preferences regarding alternative ways of questioning students. One of those methods will involve a technology called a Classroom Response System, and you should know that technology often has benefits and drawbacks, and we are interested in your honest reaction to the effectiveness of the technology, and we urge you not to alter any responses based on what you may think we hope the results will be. In the end, any educational tool should only be used if it is truly beneficial, and wrongly concluding that a technique is effective can be just as harmful as failing to discover the potential of something that would have been helpful."

In this experiment, we compared a NCRS condition in which the teacher utilized the most common questioning technique, calling on students whose hands are raised, to review quiz questions following a listening activity. Conversely, in the CRS condition Classroom Response Systems were used to gather responses during the questioning portion of the lesson. In both conditions, the teacher began each lesson by reading aloud a passage that described a concept in science while the students listened. Each passage took approximately three minutes to read. The students were asked to listen only, and were not provided a copy of the passage to read. The read-aloud option was preferable for this study because it eliminated reading ability as a confounding factor for the dependent variable. It also eliminated the possibility of students using their written copies of the reading passages to help answer the quiz questions. This too would have presented a threat to the reliability of any findings.

In both conditions, the reading of the science passage was followed by displaying a series of five questions that assessed student comprehension of the passage. Each question was displayed on a Smartboard using presentation software and a projector. In the NCRS condition, to reflect the most realistic and effective employment of the traditional questioning methodology, the teacher made an effort to garner at least two responses for each question. Once all differing opinions were voiced, the teacher revealed the true answer. The teacher then repeated the process until all five questions were answered. After the five review questions were answered, the students completed a multiple choice quiz on all ten questions for the passage. While the students completed the quiz, assistance was limited to helping students decode the language of the questions and strictly avoided helping students with vocabulary or the content of the questions.

The total amount of time allotted for instructional activities was 10 minutes. This allowed 2 minutes for taking roll and starting the lesson, 3 minutes to read the passage, and 5 minutes for questioning. Students then had five minutes to complete their written responses to the ten quiz questions. As students completed their quizzes, response sheets were collected. After the last session, an acceptability questionnaire was administered to the students to determine student perceptions of the experiment.

CHAPTER IV

Results

This chapter presents empirical data regarding the impact of classroom response systems (CRS) on the comprehension of science-related passages. The independent variable of this study was use of the CRS for discussion of the science passages. In one condition, students used CRSs during the review process, and this will be referred to as the CRS condition. The alternative condition did not use CRSs during the review process, and this condition will be referred to as the Non-CRS condition (NCRS). All of the passages contained 10 comprehension questions gauging the students' factual knowledge and ability to make inferences regarding the passage. In each condition, half of the 10 comprehension questions were the subject of discussion and the other half were not the subject of discussion prior to answering the comprehension questions.

Content Comprehension

Table 2 presents descriptive data regarding aggregated student performance by condition and question type. With respect to the five comprehension questions reviewed during class discussion, the mean performance was higher in the NCRS condition compared to the CRS condition. The effect size for this difference, 0.15, was small. Similarly, for questions not previously reviewed during class discussion, the mean performance of the students was also higher for the NCRS condition than in the CRS condition. However, again, the effect size was small (0.14).

Table 2. *Student Comprehension Performance by Condition and Question Type*

	NCRS		CRS		
Question Type	M	SD	M	SD	Effect Size
Reviewed	4.46	.95	4.30	1.05	0.15: NCRS > CRS
Non-Reviewed	3.61	1.19	3.45	1.16	0.14: NCRS > CRS

Figure 1 displays the mean number of correctly answered comprehension questions regarding previously reviewed content by condition. Visual analysis of this figure suggests that mean performance across sessions is somewhat higher in the NCRS condition than in the CRS condition. The highest mean performance took place during an NCRS session and the lowest mean performance occurred under the CRS condition. Furthermore, four out of the five highest mean performances took place during NCRS sessions.

Figure 1: Mean Performance, Reviewed Questions

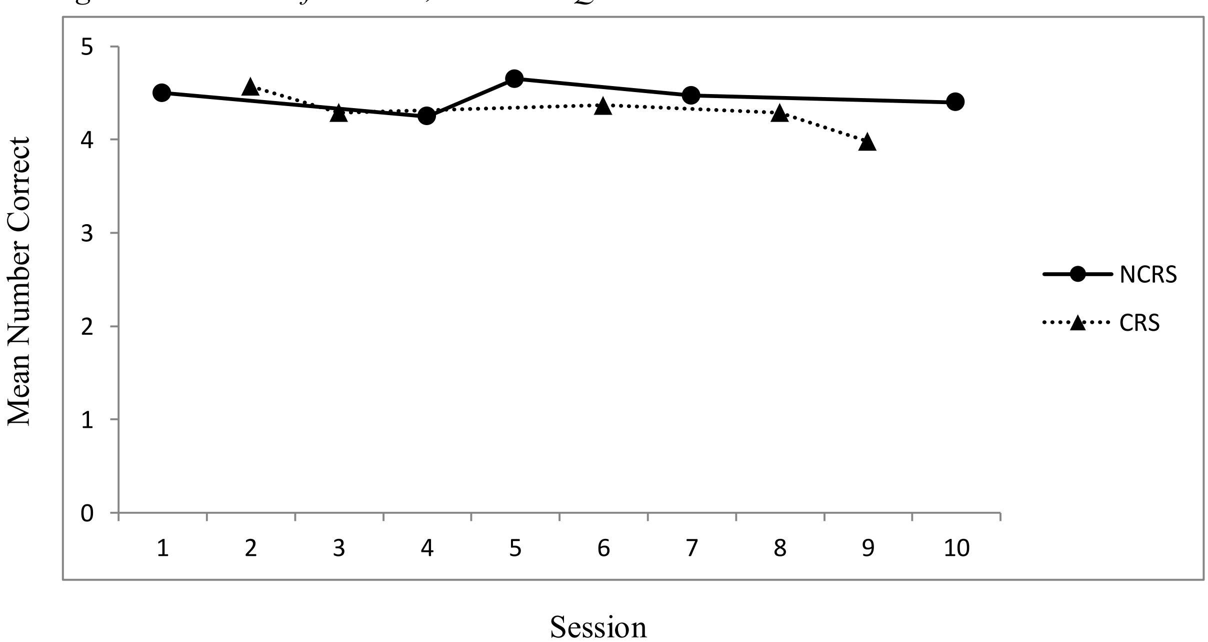
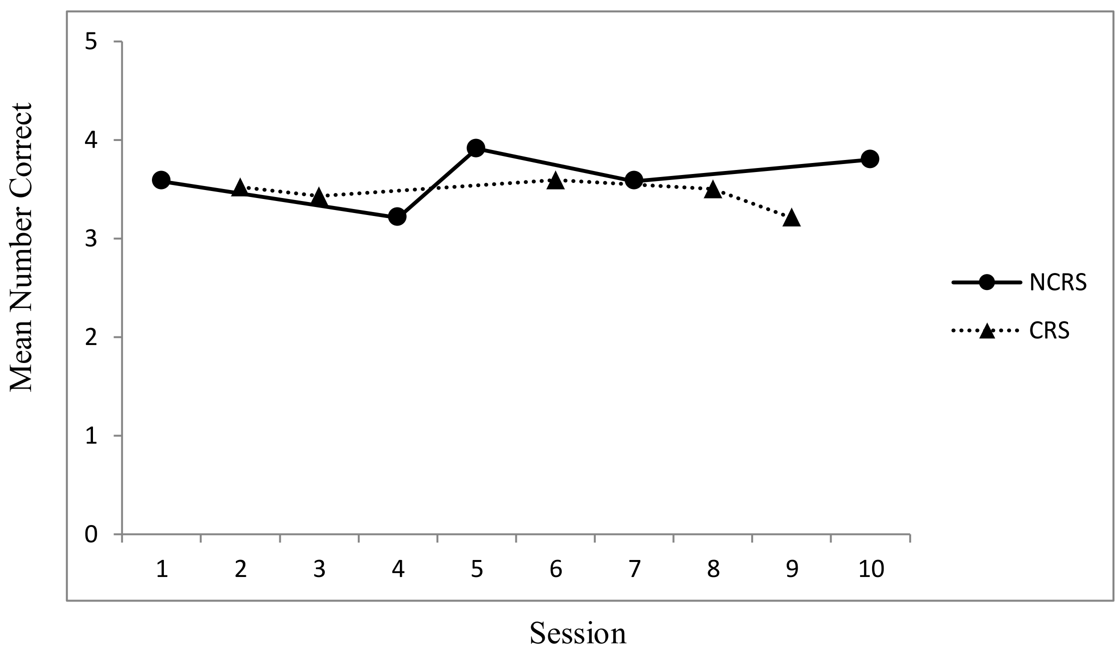


Figure 2 displays the mean number of correctly answered comprehension questions regarding content that was not previously reviewed by condition. Overall, visual analysis suggests that comprehension of non-reviewed questions was greatest during the NCRS condition. Again, the highest mean performance occurred during an NCRS session and the lowest mean performance occurred during a CRS session. Similar to the data regarding reviewed comprehension questions, four out of five NCRS sessions resulted in mean performances that were essentially equal to or better than the best CRS mean performance. Figure 2 also shows somewhat greater variability in the mean performances during NCRS conditions; however, this variation was on average within less than one comprehension question correct.

Figure 2: Mean Performance, Non-Reviewed Questions



The pattern of mean performance was very similar for the CRS condition between questions previously reviewed and questions not previously reviewed. To illustrate, for each question type, the second CRS session reflected a decrease relative to the first CRS session, followed by a slight increase in the third session, then a slight decrease in the fourth session, followed by a relative decline in the fifth and final CRS session. The pattern of mean performance between reviewed and non-previously reviewed questions was also similar across NCRS sessions.

Student Acceptability

A student acceptability questionnaire asked students to report on their perceptions and reactions to the CRS technology relative to raising their hands and being called on during a class discussion. The questionnaire required students to respond to statements on a 1 to 4 Likert scale. A response of 1 indicated strong disagreement with the statement and a response of 4 indicated strong agreement with the statement. Table 3 shows the results of the questionnaire.

Table 3. *Student Acceptability Data*

Question	M
1. I would rather answer questions by raising my hand than by using clickers.	1.98
2. I am more likely to answer questions when we use clickers in class.	3.13
3. I pay attention better when we use clickers in class.	2.65
4. One thing I like about using clickers is that no one else knows my answer.	3.15
5. When we use clickers, I like getting to see the graph that shows how the rest of the class answered.	3.03
6. Class is more fun when we use clickers.	2.91
7. I think I remember better when we use clickers.	2.73
8. It is stressful to answer questions by raising my hand and being called on.	2.14
9. It is stressful to answer questions using clickers.	1.62
10. I enjoy answering questions by raising my hand and being called on.	2.35
11. I enjoy answering questions using clickers.	3.20

The questionnaire had two questions relating to the question of involvement. Question number two, which referred to a student's relative likelihood to respond in the CRS condition versus the NCRS condition, indicated that many students agreed that they were more likely to respond in the CRS condition (M = 3.13). Question number three, which referred to students' perceptions that they paid better attention in the CRS condition, indicated that students were neutral with respect to the question of whether their attentiveness was increased when using CRSs (M = 2.65). These results appear paradoxical in that the former indicates students were more likely to respond using CRSs, but the latter indicates that they did not feel that their attentiveness levels were improved. Furthermore, only one item addressed the question of whether students felt that they learned more when using the CRS versus the NCRS condition. Students agreed that the CRS condition improved student learning (M = 2.73).

Several questions addressed student perceptions of stress and anxiety in the two alternate conditions. Students agreed that it was important that the CRSs kept their answers private. (M = 3.15). The students did not report feelings of anxiety in the NCRS condition (M = 2.14), but neither did they report feelings of anxiety in the CRS condition. (M = 1.62).

Several questions related to the relative preference for the CRS condition versus the NCRS condition. Students disagreed with the statement that they preferred the NCRS condition (M = 1.98), but agreed that class was more fun in the CRS condition (M = 2.91). Students disagreed with the statement that they enjoyed the NCRS condition (M = 2.35) and agreed with the statement that they enjoyed the CRS condition (M = 3.2). In this case, the data is unique in that all four sets of responses indicated student preference for the CRS condition.

Students were also asked to respond to open-ended prompts regarding what they liked best or did not like about the CRS technology. There were a total of 109 open-ended responses of which 64 referred to things that students liked about CRSs while 45 responses referred to things that students did not like about CRSs.

A number of open-ended responses seemed to relate to the question of student involvement. There were a total of 20 open-ended responses that suggested that students may be more involved in the CRS condition. These included nine students who indicated that they liked the fact that CRSs allowed full participation for all students. Eight other students indicated that they liked the individual feedback that CRSs provided, and three students indicated that they liked the group feedback. On the other hand, a total of 11 students gave responses that indicated that they may have felt less involved in the CRS condition. Specifically, four students indicated that they disliked the forced accountability of the CRSs and seven students indicated that they disliked the forced participation that CRSs enable. In sum, the most common theme in the open-ended responses involved the anonymity of the CRS condition. Seventeen students responded that they appreciated anonymity in the CRSs.

CHAPTER V

Discussion

CRSs have shown promise as a tool to increase student engagement by enabling full participation and providing immediate and anonymous feedback (Conoley, 2005; Hill, Smith, & Horn, 2004; Freeman, Blayney, & Ginns, 2006; Greer & Heaney, 2004; Guthrie & Carlin, 2004; Horowitz, 1988; Sharma, Khachan, Chan, & O'Byrne, 2005). The primary purpose of the present study was to contribute to the scientific literature by using an alternating treatments design that includes an experimental control while assessing whether use of CRSs improved content comprehension in middle level science students. Additionally, and unlike previous studies, this study assessed the acceptability of the technology.

Content Comprehension

There were two research questions addressed by this study. The first research question explored whether the use of CRSs would increase the content comprehension for middle school students in science class. The second research question addressed the acceptability of the CRS technology. As to the first research question assessing whether students learned more when using CRSs, this question was analyzed separately for questions that were reviewed earlier in the class period versus questions that were not reviewed earlier in the class period. Results of data analysis suggested that use of CRSs did not increase the content comprehension of students participating in a middle level science class, either for questions reviewed earlier in the same class period or for questions not previously reviewed. This finding was unexpected as other studies have found learning gains associated with the use of CRSs (Conoley, 2005; Hill, Smith, &

Horn, 2004; Freeman, Blayney, & Ginns, 2006; Greer & Heaney, 2004; Guthrie & Carlin, 2004; Horowitz, 1988; Sharma, et al., 2005). However, there are a number of possible explanations for this finding. It is possible that the five questions that were reviewed each day may have had a spill-over effect on the results of the questions that were not reviewed. That is, since five questions from the science passage were reviewed prior to the quiz, the content of some of those questions might have contained clues that could help a student answer the questions that were not to be reviewed. Since all students were told the correct answers to the five questions that were reviewed, students could have improved their chances of answering correctly on the questions not reviewed through a process other than listening to the passage and remembering. This could have affected the results of the scores on the questions not reviewed.

Despite a detailed review of the students' science curriculum in an attempt to avoid content that students had studied previously, there could have been differences in levels of exposure to content across the various passages. If students had more knowledge about certain concepts than others prior to reading the science content passages and participating in the related discussion, this too could have impacted the results of the study. Additionally, the mere presence of the CRS on a student's desk during the CRS condition and the act of using the CRS may have distracted some students and limited their full attention to the science content.

Research suggests that a significant number of students often fail to maintain optimal levels of engagement (Beamon, 2001; Brown & Knowles, 2007; Montague, 2006). Therefore, one of the primary means by which CRSs might be expected to promote learning in middle level students is through its impact on engagement. CRSs might be expected to improve engagement because they require every student to respond and because they provide each student with immediate feedback regarding the correctness of their response. In this particular study however, students were also quizzed in every session after listening to a science passage and then reviewing five questions based on the passage. Although students were instructed that the quiz would not count toward their regular class grade, daily quizzes were a departure from the typical class routine. Furthermore, after several days of being quizzed after each review session, it is likely that most, if not all, students began to expect the quiz at the end of the session and to recognize that the five reviewed questions were identical to five of the questions that would be on the quiz. It seems likely that this anticipation could serve to increase student engagement and mask any potential effect of the CRS. Additionally, the foreknowledge that five of the quiz questions would be identical to the reviewed questions combined with the fact that the quiz took place immediately after the review process could have caused students to pay attention more than they normally might have. This may have convoluted the results for both the CRS and NCRS condition.

Finally, the potential impact of anticipating daily quizzes can be characterized in terms of a Hawthorne effect. The Hawthorne effect refers to situations in which participants being studied change their behavior simply because they know they are part of an experiment (McMillan & Schumacher, 2001). Despite admonitions to the students in this study that they should treat each session no differently from other classes, the significant change from typical classroom routines highlighted to the students that they were in fact participating in an experiment. Furthermore, the fact that quizzes are a variable that has a strong significance in the minds of most students could have exacerbated this effect in a way that could have interfered with the variables being studied. Again, although students were instructed that the quizzes did not count for a grade, it seems likely that many students would treat a quiz as something important and might therefore be more likely to remain cognizant of the fact that their results would be assessed. Such considerations could have changed student behavior accordingly.

Student Acceptability

The second research question addressed the acceptability of the CRS technology, and assessed student perceptions of involvement, learning, anxiety, and overall preference of the CRSs versus traditional question and answer review format. This study did not support the hypothesis that students were more involved in the CRS condition versus the NCRS condition. Although there were a number of students who indicated that they were more likely to respond using CRSs, other students indicated that there was little difference in attention levels during questioning in either condition. This result may have been affected by the same set of issues that may have affected the performance data. That is, the experimental procedures were such that student attention and involvement levels were greater than normal whether using the CRS or not. If students were more engaged due to the nature of being part of an experiment, or because the students anticipated an assessment each day, it may be that such a heightened engagement level during the NCRS condition would have masked the potential impact of the CRS.

There was some indication that students perceived that their learning increased. Despite the fact that students did not necessarily feel that they were more involved when using the CRS, there are a number of possible explanations as to why most students felt that they learned more. Many students' ratings and open-ended responses indicated that anonymity, group and individual feedback, and the ability to participate in every question was valued when using the CRS. Although students appeared to feel equal involvement during the CRS and NCRS conditions, the additional attributes of the CRS technology may have led the students to believe that their overall learning was greater when using CRSs.

Questionnaire data seemed to support the hypothesis that students felt less anxiety during the CRS condition, but one relatively surprising result was that most students did not feel much anxiety during the NCRS condition. This is surprising because research suggests that many students, and particularly middle level students, experience stress during traditional questioning activities when they may be shown to be incorrect in front of their peers (Brown & Knowles, 2007; Freeman, Blayney, & Ginns, 2006; Ryan & Deci, 2000; Zimmerman, 1989). This relative lack of anxiety could be attributable to the effects of this particular classroom teacher or to a general climate of acceptance in the school or classroom. Alternatively, students may simply not have wished to indicate that they felt anxiety, or they may not have reflected accurately on their feelings when completing the questionnaire. On the other hand, despite the fact that students did not indicate high levels of anxiety in either condition, many students indicated that they valued the anonymity of the CRSs. It therefore seems likely that CRSs were beneficial with respect to reducing student anxiety.

Finally, students did indicate a preference for the CRS condition compared to the NCRS condition. On three separate questions related to relative preference, students consistently indicated that they preferred using the CRSs. This is important for future research, because although the CRS condition did not result in greater content comprehension than the NCRS condition, the CRS devices did appear to have certain advantages including increasing levels of participation and reducing anxiety. These advantages, when coupled with the result that students appeared to prefer the CRS condition, suggest that future studies should continue to explore whether CRSs are likely to improve student learning, particularly in conditions that more closely reflect a typical classroom situation.

Limitations of the Study

There are several limitations regarding the current study. One limitation was that quizzing took place very soon after the presentation and review process. This is a limitation because it is both a departure from typical classroom situations and it only suggests results as to short-term recall of content. Educators are interested in tools that will help student learning in real classroom conditions, and future researchers should endeavor to test in ways that are most likely to generalize to everyday classrooms. Additionally, short-term recall is of limited value. Educators are more concerned with long-term learning and ability to apply, analyze, or evaluate recalled information. On the other hand, it is also true that short-term remembering is necessary for long-term recall to take place. However, future researchers might consider adding a component measuring longer-term recall or even application of such recall, particularly if it can be established with some level of confidence that CRSs support increases in short-term recall in the first place.

Other limitations included the length of the study, the restriction to content in science, the multiple-choice format of the questions, the, the grade level of the students, and the small number of class sections as well as having a single teacher. Multiple choice questions assess student recognition of a correct response, and are a limited assessment of learning versus completion or essay questions. Additionally, middle level students have unique sets of attributes relative to other age groups, and these attributes may make the various qualities of the CRS technology more or less effective. Also, the fact that there were only four separate class sections limits the ability to generalize these results to the rest of the middle level population of students, while the single teacher involved may have had an ability to engage students or create a classroom environment that is atypical in terms of student anxiety. These factors also affect our ability to generalize these findings.

Implications for Future Research

The results of this study have several implications for future research. First, this study demonstrated that despite some beneficial aspects of CRS technology, those benefits do not appear to be sufficient to cause reviewing using CRSs to improve students' short-term ability to remember orally presented content relative to traditional reviewing procedures, especially when students expect follow-up quizzing to take place immediately following the review. Although, in retrospect this result may appear intuitive, it was important to establish this in the research base. This result sets the stage for several lines of research.

While this study assessed students' relatively immediate recall of presented content (within 5 minutes of presentation), future studies should assess recall after some lapse of time has passed. One possible modification of the current experimental procedures would be to give the quiz for a particular passage on the day following the reading of the passage. As opposed to an experimental procedure that used a single posttest type assessment, such a setup would eliminate the problem of having differences in the delays between presentation and assessment for sessions nearer the end of the experiment versus initial sessions. An alternative experimental procedure might be to have the review process take place as in the current study, but delay the quizzing for a week. The ordering of the sessions and the remainder of the current experimental procedure could remain essentially intact, but could assess whether the apparent short term learning that took place in the current study would be repeated for either the CRS or NCRS condition or both.

Other potential confounding factors included students remaining conscious of the fact that they were part of a study and an atypical level of attention due to the expectation of daily quizzing. Future research could address this by having some variable frequency of assessment. For example, out of ten total sessions, quizzes might only take place on 4 or 6 days. Future researchers my also consider whether to place CRS devices on student desks during both CRS and NCRS conditions to reduce the potential for distraction during CRS sessions. Although it may be suggested that distractibility may be an inherent trait attributable to CRSs, particularly for middle level students, the counter-argument is that in a typical classroom that might use CRSs in the future, the most advisable procedure would be to have CRSs available on a daily basis.

Another possible confounding factor in this study was likely differences in prior knowledge among the participants. If students had prior exposure to the content and vocabulary contained in specific passages, the impact of the discussion session and use of the CRS would be minimized. Future researchers might try to better control for the background knowledge of the participants..

The hypothesis that the possible effect of anticipated accountability through quizzing impacted the results of this study is worth addressing in future research. Some research has suggested that the literal feedback provided to students is more important for learning than student awareness that they will be held accountable for their learning (Black & Wiliam, 1998). However, the apparent impact of the daily quizzing in this study may suggest that the effect of perceived accountability, and immediate accountability in particular, motivated the students to learn the material, regardless of experimental condition. Specifically, the students were quizzed after all instruction was complete, and they understood that they would not receive feedback about the correctness of their results after the quizzing. Therefore, any importance attached to the quizzing by the students must have been solely based on some perceived importance of the quiz itself. If true, this would have some obvious implications for education research and CRS research in particular. Educational research should continue to critically examine the relative importance of mastery and competitive goal-setting and determine best practices to harness the full potential of each. As Hidi and Harackiewicz (2000) suggest, this is an incredibly complicated and nuanced question, and best practices will necessarily take into account the effects of gender, age, content area, and other crucial instructional variables. For CRS research, to the extent that accountability, and immediate accountability, have a positive impact on learning, the potential of this technology is very likely to be related to these variables. Specifically, while the effects of CRSs may have been masked by the anticipated accountability of quizzes in this study, daily quizzing of this type is simply not practical under normal circumstances in the absence of something like a CRS.

However, it should be noted that the most significant results in this study with respect to anticipated quizzing involved a very clear and unambiguous connection between the instruction and the learning. On the questions that were reviewed before the quiz, overall performance was very impressive in both the CRS *(M=4.30)* and *NCRS (M=4.46)* condition. Furthermore, performance on the reviewed questions than the questions that were not reviewed in both the CRS *(M=3.45)* and NCRS *(M=3.61)* condition. Based on those results, it appears that students were confident that their attention to the reviewed questions would be likely to increase their success on the quiz to follow. Therefore, future research exploring the use of quizzes or CRSs to harness the power of accountability must also take into account the importance of the facts that students must be aware of the connection between a particular item of instruction and the accountability to follow and they must also have high levels of confidence that their attention to the initial instruction is likely to result in success on the coming assessment. This argument should inform procedures for research as described above that might delay assessment for some period of time after quizzing. If raised engagement levels are dependent on a combination of expectation of accountability, confidence that raised engagement levels will result in success, and awareness of the moments when it is most critical to raise engagement levels, then variations of methods affecting all of these variables should be carefully considered if building upon the current study.

Although academic engagement is ultimately an internal mental function, there are a number of observable behaviors typically associated with increased engagement. These behaviors can be expressed in both individual and classwide terms. Individually, we expect that students who sit forward, look intently, respond, and discuss taught materials with peers are likely to be engaged. When observing a class, we would typically classify an active, on-task group of students as engaged. Anecdotally in this study, students in the CRS sessions demonstrated extremely high levels of these sorts of behaviors, while students in the NCRS sessions appeared less engaged. Specifically, during the review process in the CRS sessions, student attention to the reviewed questions appeared to be almost universal. Students were attentive, discussion of the questions was animated, and anticipation of the correct answer was evident. Upon announcement of the correct answers, the class would erupt with discussion and enthusiastic responses in a way that both the instructor and the researcher associated with high levels of learning. The NCRS sessions, on the other hand, while appearing to be educationally sound, were much more subdued. It was not nearly as apparent whether the majority of students were actually absorbing the material during the review process. Once again, based on experience, the instructor and the researcher both agreed that the latter condition would be likely to include an unacceptably high number of students who were not engaged, but about whom it would be virtually impossible to know for sure. They are the silent plurality of the student body. However, this group was clearly paying attention at the crucial times in this study, and performed better during the quieter, more subdued, less responsive NCRS sessions than during the more active CRS sessions.

This result raises several questions. First, it is possible that the types of behavior typically associated with high levels of engagement and consequently increased learning may not be accurate indicators of such engagement. It is possible that apparent attention, responsiveness, and on-task behavior are not really reliable predictors of cognitive engagement. On the other hand, we find it more likely that these behaviors do in fact typically relate closely to improved engagement, but that other factors were in play. As previously discussed, perhaps other immediate accountability measures would have a similar impact on learning. However, it is noteworthy that the apparently less active NCRS sessions actually out-performed the apparently more engaging CRS sessions, albeit with small effect sizes. In other words, if we conclude that anticipated accountability resultant from daily quizzing raised student engagement levels and masked potential effects of the CRSs, we still might expect the combined effects of the CRS and the anticipated accountability to result in better performance if in fact the CRSs provide a benefit for learning. In fact, the NCRS condition had better results than the CRS condition, but with small effect sizes. Perhaps the high levels of apparent engagement during the CRS sessions inhibited students' ability to store the corrective feedback they received during the review process. A possible interaction between a heightened level of anxiety due to anticipated accountability and these high levels of responsiveness and enthusiasm that also decreased students' ability to recall may also have been present. Both of these possibilities should be considered separately. If the latter issue were true and some sort of interaction was taking place, then perhaps the kinds of high levels of engagement that were observed would generally be desirable because daily quizzing would not be typical.

This study used a methodology on which future research involving CRS technology may be designed. By using an alternative treatments design, this research suggests a vehicle by which the effectiveness of CRSs may be studied in an environment that is as close to a natural classroom experience as possible. Although reading of science passages is somewhat different from a typical lesson, it represents a situation that is likely to be analogous to any other lecture or oral presentation in class. In combination with the controlled difficulty levels of the readings and questions, these procedures suggest a direction for research that could provide important information about whether CRSs can actually improve student learning.

Summary

This was the first known study that used an alternating treatments design to improve experimental control. The present investigation expanded the existing research base by using immediate learning as a dependent variable and studying the use of CRSs with middle school students. The study provides a model and suggests several possible lines of research using the model including varying the method of assessment, the frequency of the assessment, and addressing experimental threats to more closely resemble a natural classroom lesson and reduce a potential Hawthorne Effect. The study found that there was no difference in content comprehension for middle level students on orally presented readings of science passages in a CRS reviewing condition versus an NCRS condition in which reviewing was conducted using traditional hand-raising. On the other hand, the study suggested that students did feel less anxiety in the CRS condition and that they preferred the CRS condition to the NCRS condition. One surprising result was that these middle level students did not seem to feel much anxiety during reviewing in either condition, even if it was possible that they might be called upon to answer orally in front of their peers. Future research should be conducted to further explore whether CRSs may support student learning for middle level students and should address the limitations of the current study.

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