EFFECTS OF INCORPORATING CLASSROOM PERFORMANCE SYSTEMS WITH METACOGNITIVE AND CONCEPTUAL STRATEGIES ON THE UNDERSTANDING OF PHYSICAL SCIENCE CONCEPTS

by

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ABSTRACT

The use of Classroom Performance Systems (CPS) in classrooms has been studied extensively at the postsecondary level. However, there has been little research done at the secondary level, especially the middle school.

This project investigated the effects of using the CPS with metacognitive and conceptual feedback strategies at a small middle school with one-third of the students qualifying for free and reduced lunch. Student's conceptual understanding was assessed by comparing the CPS unit to the traditional taught unit using pre and postunit assessment data, and interview data, which included concept mapping and conceptual questions.

Other forms of data collection were employed in both units to determine the effects on long-term memory retention, ability to answer questions of varying levels of Bloom's Taxonomy, student attitudes, student engagement, and teacher attitudes. Long-term memory was observed using delayed assessments and delayed interview techniques. Student motivation and engagement were assessed through student surveys, observations, and cooperative group grading, and engagement checks. Effects on my own teaching, attitude, and motivation were determined through the use of journaling, self-evaluation, and peer observations.

Using the CPS in conjunction with metacognitive and conceptual feedback strategies showed an increase in student understanding, especially on higher-levels of Bloom's Taxonomy. The CPS also showed increase in student attitude towards science. However, data showed mixed results of student engagement, long-term memory, and teacher attitudes.

INTRODUCTION AND BACKGROUND

The topic of my capstone is the effect of incorporating a Classroom Performance System (CPS) with metacognitive and conceptual strategies on students' understanding of the eighth-grade physical science curriculum. The following helps to describe why I selected this topic.

During the 2007-2008, 2008-2009, and the 2009-2010 school years, the East Helena school district has not made Adequate Yearly Progress (AYP). In the 2008-2009 school year, the district was classified as *safe harbor* because our free and reduced lunch students increased their score by a certain percentage. In 2009-2010, the district was not classified as making AYP due to the lack of students tested under special education. Because of this, there has been a major shift in focus to concentrate on test scores throughout all schools and all subjects district wide. While most of the focus has been in math and reading, science is another area of focus because it is also assessed during our Criterion Referenced Test (CRT) for all eighth-grade students. To align my teaching with the focus of the district, I have been trying to increase student understanding of the physical science concepts to increase test scores. Also, I did not feel that students were as engaged in lessons as I would like. This has lead to many students' reduced awareness and understanding of what I was teaching. Because of this, students could not answer questions when called upon or were not able to participate in group discussions.

I use many formative assessment techniques during class but due to the nature of the assessment techniques, I feel that I had not been getting accurate data. I had been asking students to show me finger signals to check their level of understanding. I felt students were not completely truthful and it was hard to get a quick check of how many really understood the topic. Since I did not have accurate data, I was not as successful in closing the feedback loop of understanding as I would have liked. By not closing the feedback loop effectively, my students' questions and misconceptions were sometimes not addressed, which often lead to students not understanding concepts and receiving lower test grades than are acceptable by our school district. The East Helena Public Schools consider a score of 80% to be mastery of a topic and often times my averages were in the 70% to 75% range. I anticipated that the changes I had implemented in my classroom would aid in helping me gain that extra 10% on test scores. I predicted that having better data would help me with my feedback, and the feedback would help students understand the content. If students understood the content, then test scores should increase. I wanted to come up with a method to gather data that would be anonymous to peers in the classroom and allow me to give immediate feedback. It was reasonable to believe that if the students could give me more accurate data and I could give them more immediate feedback, then my students understanding and, thus, test grades would improve to an acceptable range.

My school is lucky enough to have access to four different CPS machines with student devices. These machines are more commonly known as "clickers." In our school, CPS is readily available, but most teachers use it strictly as a summative assessment tool to help with quicker grading. This project served as a project idea for others to incorporate technology more into their classroom and to use a CPS as more than just a summative assessment tool. It will show the versatility of the CPS for formative assessment, hopefully encouraging more of the staff to take advantage of the technology we have in our school, and to use it in a more productive manner.

Physical science concepts are often difficult for students to understand. By incorporating a CPS with conceptual questioning, I hope to give students more feedback on their conceptual understanding. I could also see that the students needed to become more aware of their monitoring of their understanding of concepts by using metacognitive strategies with the CPS. Metacognition, which is getting students thinking about their thinking, can be used to help students gain a deeper understanding of content, to take students thinking to a higher level, and to steer students into adulthood. Incorporating metacognitive strategies is something I had never formally attempted in my classroom; however, from all the conferences and workshops I have attended, I felt it was an area that was important to the use of CPS and that should get more focus. I incorporated metacognitive questioning with the CPS to help students become more aware of their thinking processes and their ability to monitor their learning. This gave students a greater sense of responsibility for their learning.

My project focus question is what are the effects of CPS with metacognitive and conceptual feedback loop strategies on students' understanding of eighth-grade physical science concepts? The project subquestions are as follows: what are the effects of CPS on students' long-term memory of concepts; what are the effects of CPS on students' ability to answer questions at varying cognitive levels; what are the effects of CPS on students' attitudes towards science; what are the effects of CPS on students' engagement in lessons; and what is the effect of the implementation of CPS on my teaching, attitudes, and time management?

I teach at East Valley Middle school, which is located in East Helena, Montana and consists of roughly 400 students in Grades six through eight. I am the only science teacher for the eighth-grade students and I teach physical science. The 8th grade class consists of about 150, 35% of which qualify for free and reduced lunch. Even though the class covers both physics and chemistry, during the period of the capstone project students were only studying physics concepts. The physics concepts for the project were describing motion, forces, and work and machines.

The members of my MSSE cohort offered valuable information throughout the writing process. Members of my validation team, Dan Rispens and Ryan Hazen served as editors and critics, providing thoughtful insight. Todd Samson and Jana Nygaard provided valuable information as critical friends and observers. Jewel Reuter, Ph.D. was my Montana State University Master of Science Education instructor and advisor. Jewel provided guidance and direction. Irene Grimberg, Ph.D., from the Math and Science Resource Center at Montana State University, and Shannon Willoughby, Ph.D., from the Physics Department, served as readers on my graduate committee and provided constructive feedback.

CONCEPTUAL FRAMEWORK

According to Abrahamson (1999), more than 2000 years ago Socrates realized that people understand more by answering a question than by being told an answer.

Scientists created the audience response system technology because they wanted to build a system that would enable teachers to teach interactively in classes of any size (Abrahamson, 1999). Their goal was to make the environment more like the one-to-one or one-to-five ratios that would be ideal for the best instruction. Ward (2003) found that technology-empowered classrooms were over 1000% more interactive than traditional classrooms. They also saw that learning benefits of questions could not be achieved if students don't participate in the processing of questions and formulation of answers to the questions.

A CPS, or an audience response system, allows students to click in their responses to multiple-choice questions using remote devices, the results are instantly collected, summarized, and presented to the class in a visual format (Kay & LeSage, 2009). CPS has been extremely popular and effective in higher education; however, the benefits and research for the benefits in secondary education is sparse (Kay & Knaack, 2009). One use of the CPS that has very little documentation is the incorporation of metacognitive strategies. Metacognition refers to learners' awareness of their own knowledge and their ability to understand, control, and manipulate their own cognitive processes. Veenman, Van Hout-Wolters and Afflerbach (2006) said that metacognitive strategies include activities that involve self-evaluation of learning strengths and weaknesses, and use of self-reflection at the end of the learning process. Penuel, Abrahamson, and Roschelle (2006) and Kay and Knaack (2009) are two of the few studies found to study the use of CPS in the K-12 setting. Both studies claim that the CPS was used primarily for formative assessment or summative assessment and it was rarely used to generate discussion or metacognition.

According to Veenman, Van-Hout Wolters, and Afflerbach (2006) metacognition was often found to be inferred from certain cognitive activities. For instance, doing things step-by-step may be indicative of planned behavior, although self-instructions for planning are not explicitly verbalized. They further summarize that the vast majority of students spontaneously pick up metacognitive knowledge and skills to a certain extent from their parents, their peers, and especially their teachers. Also, metacognition increases learning in a broad range of students. Preszler, Dawe, Shuster, and Shuster (2006) found that traditional lectures and textbooks rely on one-way communication from instructors to students, leaving students unable to apply a meaningful understanding of science to the solution of personal and societal issues. They also found that when the CPS was used to stimulate discussion and cooperative problem solving, it enhanced meaningful learning in courses of any size. Educational research shows that promoting metacognition in the science classroom prompts students to refine their ideas about scientific concepts and improves their problem-solving success (Crowe, Dirks, & Wenderoth, 2008).

Many reports have been published on the use of CPS in various teaching situations. However, results concerning the impact on short- or long-term retention have been contradictory. Crossgrove and Curran (2008) found that learning gains were generally not observed in older studies when CPS was used primarily for stimulus response-type learning, but positive effects on student learning when used in conjunction with active-learning strategies. They concluded that instructional strategies that increase the level of original learning lead to greater retention of knowledge over the long term. Another study conducted by Conoley, Croom, Moore, and Flowers (2007) found that students who received immediate feedback using the CPS retained significantly more information than students who received delayed feedback. They also mention a study by Clariana (1992), which found students who received delayed feedback exhibited more retention for items that were easier, while immediate feedback had more impact on more difficult questions. On the other hand, a study performed on undergraduate students by Doucet, Vrins, and Harvey (2009), found short-term memory retention was greater in a group of undergraduate students using the CPS. However, those same students tested a year later, had scores that dropped more drastically in comparison to students without the CPS, which may indicate a decrease in long-term memory of concepts.

The CPS can be used to gauge students' ability to answer varying levels of cognitive questions. According to Handelsman, Ebert-May, Beichner, Bruns, Chang, DeHaan, & Wood (2004), much research has been done in the last 10 years toward developing students' critical-thinking skills by increasing student engagement in the learning process. Crowe, Dirks, and Wenderoth (2008) cite Bloom (1956) saying that "Bloom's Taxonomy is a well-defined and broadly accepted tool for categorizing types of thinking into six different levels: knowledge, comprehension, application, analysis, synthesis, and evaluation" (p. 369). They further state that a revised version of Bloom's Taxonomy developed by Anderson (2001) subcategorizes the original taxonomy and converts the different category titles to their active verb counterparts: remember, understand, apply, analyze, create, and evaluate. Crowe, Dirks, and Wenderoth (2008) describe how to rank questions addressing varying cognitive levels. The first two levels of Bloom's, which are knowledge and comprehension, represent lower orders of cognitive skills, while the analysis, synthesis, and evaluation levels are true higher-order cognitive skills. They place application in the middle as a transition from the lower order to higher order. Lopez-Herrejon and Schulman (2004) state that traditional instruction addresses knowledge formation and comprehension, the first two levels of Bloom's taxonomy of educational objectives. However, Crouch, and Mazur (2001) believe the higher-order thinking required to form concepts that are addressed by the later objectives in the hierarchy, including application, analysis, synthesis, and evaluation, can be met with interactive engagement, such as CPS, which includes asking questions in class and promoting discussion. Questions can be created in CPS to address higher levels of cognitive thinking. In order to address the higher levels of cognitive thinking, Barnes (2008) made multiple answer multiple-choice questions and sequence- type questions.

Kay and Knaack (2009) cite several sources that have collected extensive data finding student attitudes to be very positive toward CPS (Caldwell, 2007; Fies & Marshall, 2006; Judson & Sawanda, 2002; Simpson & Oliver, (2007). They further cite more sources about students perception that CPS is easy to learn and use (Hinde & Hunt, 2006; Pradhan, Sparano, Ananth, 2005; Sharma, Khachan, Chan, & O'Byrne, 2005; Siau, Sheng, & Nah, 2006). Stowell and Nelson (2007) believe it may not be the experience of any emotion, such as enjoyment, that mediates the benefits of CPS, but the enhanced cognitive processing associated with it. Conoley, Croom, Moore, and Flowers (2007) found that students favored immediate feedback delivery methods and were more enthusiastic in their assessment and believed that it increased learning.

Research by Conoley, Croom, Moore, and Flowers (2007) indicates when a CPS is used in a higher education classroom, students are more engaged in the content presented, participate more, and pay more attention to concepts presented. Keeping students alert and responsive during oral presentation is a challenge even for experienced teachers in small group settings, such as a middle school classroom. Research has shown the importance of student participation and involvement in the learning process. Many ideas and strategies have been proposed to promote these two vital education elements in the secondary education setting. Among these ideas are the use of interactive technology where the instructor asks a question to the class and each student answers individually. The teacher can see who has participated in the answering process and who has not. These answers are tallied and the instructor receives immediate, quantitative, and real-time feedback information that can be used to detect and address comprehension problems and to adapt the lecture plan accordingly (Conoley et al., 2007). Preszler, Dawe, Shuster, and Shuster (2006) found that CPS engages students as the students commit to the answer and has the potential to provide dramatic improvement over the teacher orally posing a question. They found if teachers orally presented a question, many students watched passively as the few who are willing responded. They also found that projecting the histogram of class responses allowed students to gain a better understanding of their class and to help them understand what concepts they need to study further, making students more metacognitively aware of their learning.

Overall, the attitudes of teachers towards CPS are positive. In a survey conducted by Penuel et al. (2007), nearly all teachers had adopted CPS by choice, most often having been offered the opportunity to use it by someone else at no cost to themselves. The survey found that teachers who were broad, frequent users of CPS were much more likely to report benefits in the areas of enhancing feedback on learning; improving the classroom environment; and enhancing student learning and engagement than those who did not use if frequently. In addition, the infrequent users were much more likely to report lower levels of benefits of using the CPS.

The purpose of this study is to evaluate the use of incorporating metacognitive and conceptual strategies with a CPS on eighth-grade students and their understanding of physical science curriculum. Educational research shows that promoting metacognition in the science classroom prompts students to refine their ideas about scientific concepts and improves their problem-solving success (Rickey & Stacy, 2000). Research also indicates that incorporating conceptual feedback and metacognitive strategies using the CPS increases overall student understanding, has the ability to increase long-term memory of concepts and increases students ability to answer questions at all levels of Bloom's Taxonomy. CPS has been shown to increase student engagement in lessons, while student attitudes towards science have improved as well. Teachers who use CPS frequently report more benefits in the areas mentioned above and have a positive attitude toward using the CPS.

METHODOLOGY

Project Treatment

My capstone project contained one nontreatment unit and two treatment units. The units were comparable in difficulty and the same group of students were used to administer all three units. The nontreatment unit was titled “Describing Motion.” It introduced the concepts of motion, speed, velocity, and acceleration. The first treatment unit was “Forces.” This chapter includes concepts such as force, friction, gravity, Newton’s Laws of Motion, momentum, free fall, and circular motion. The second treatment unit was titled “Work and Machines.” This chapter covered work and power, understanding machines, inclined planes and levers, and putting machines together. During the nontreatment unit students were exposed to a more traditional method of teaching. At the beginning of the unit, students took a pretest. The pretest can be found in Appendix A. Throughout the unit, students participated in several oral discussions where they were asked to take notes, work in their books, and participate in small group discussions, which I call table talk. They also completed lab assignments and homework when necessary. Periodically in the oral discussions, students were asked a multiple-choice question where they were asked to raise their hand for which answer they thought was correct. Based on the responses given, I either explained the correct answer and moved on if it appeared most students answered correctly, or, if many students answered incorrectly, I reviewed the material again and then repeated the question. Also, during the discussion, I asked students to confer with their table to answer a particular short answer question. During table talk, all members of the group were responsible for their table's answer, because any one of them could be called on. The method used for calling on students was to pull a stick from a jar with a student's name on it. The name on the stick was responsible for answering. The labs in this unit related directly to the material covered in class. For example, students completed an activity titled Speed Challenge, which can be found in Appendix B. In this lab activity, students were asked to calculate their own speed for hopping, walking, and walking backwards. Based on the data collected, they figured out how long it would take to go varying distances if they maintained their speed. At the end of the unit, students were given a summative assessment. The assessment, which was the same as the pretest, consisted of one question from each of the levels of Bloom's Taxonomy. Fourteen days later, students were given the same test to assess their long-term memory retention.

The treatment units, or intervention units, started with a pretest. The pretest for treatment unit one can be found in Appendix C and the pretest for treatment unit two can be found in Appendix D. The rubric used to grade the students on the concept level questions can be found in Appendix E. Prior to the start of the first treatment unit, students also took an initial survey about their attitudes toward science, engagement in lessons, perceived benefits of CPS, and metacognitive awareness. This same survey was also given after the second intervention unit. This survey can be found in Appendix F. At the beginning of each class where an oral discussion took place in the intervention units, students received a "clicker" which I assigned to them. Students took notes during the discussion and periodically were asked a series of multiple-choice questions using the

CPS. Students clicked in their answers, but were also required to write justifications for their answers on a sheet of paper. Students turned in their justifications at the end of the class. After each question, students were shown a histogram of the answers selected by the entire class and the reasoning behind each question was discussed. An example from each treatment unit is found in Appendix G and Appendix H. Also during these discussions, students were asked to click in their answer to two attention check questions. The first question dealt with the level of engagement in the lesson. The second question dealt with how aware they were of their understanding. The attention check questions were given at the beginning, middle and end of class. They can be found in Appendix I. In the intervention, students participated in lab activities as well. However, in these lab activities the questions they were asked related not only to the concept material, but also had metacognitive questions as well. For example, students had to answer how the lab related to other material we have covered previously, and they also had to rate their group members on participation. For example, the second treatment unit contained a lab titled "I Want to Pump You Up," which can be found in Appendix J.

An example of a lesson taught during the first intervention unit was a class discussion on Newton's three laws of motion. As we went through the lesson, students were introduced to each of the laws and given examples of each. After this, students were given their clickers and were given several real-world examples where they were asked to tell me which one of Newton's laws described the scenario the best. While more than one law may have applied, I was more concerned about their reasoning behind the law, therefore, students were asked to justify their answer on a sheet of paper and then turn it in. The examples of the Newton's Laws discussion questions can be found in Appendix G. After this, I gave students a paragraph describing several events in which Newton's three laws of motion can be applied. As a group, students decided which laws were represented for the various situations. They were asked to write them down and be able to explain them. The paragraph can be found in Appendix K. As students were working, I scanned through their justifications, and looked at their answers to the CPS questions. After reviewing the answers, I asked students to put down their pencils so I could go over the information I found from their responses. Then, I gave students a couple minutes to make any changes or any modifications to their paper. Upon completion, students graded each other on participation within the group. The cooperative group grading form can be found in Appendix L. Following the activity, a series of questions going from low-cognitive levels to middle-cognitive levels were asked and students needed to justify their answers on a separate sheet of paper. These wrap-up questions can be found in Appendix M. I received their answers for each level, closed the feedback loop as needed, and moved on.

Using the CPS as a tool to implement metacognitive and conceptual strategies helped students be more aware of the reasoning behind their answers and increased feedback to help expand their understanding. There were several strategies used to increase their metacognitive awareness. First, students were asked whether or not they were paying attention in lessons and how comfortable they were with the material. If students were not paying attention or did not understand it would help them track and adjust their learning. Also, students were asked several conceptual questions during the lessons where they would have to click in their responses and write a justification. Students were made more aware of their learning, were able to visually see how they were doing compared to other students, and were encouraged to participate in their learning to help them better understand concepts. While this might intimidate some students because of the immediate feedback and the feeling that other students always know what they were answering, I carefully explained that they can never be identified by their peers, and this eased some of the tension. Each student was tracked by their number and I saw how well individual students or groups of students were doing. Based on this indicator, I decided who I need to close the feedback loop with more effectively in a one-on-one situation, and who I could ask higher-level questions to in order to enrich their understanding.

Data Collection Instruments

The students in this project were eighth-grade students from East Helena, Montana. Many residents of East Helena are not very wealthy, leading to roughly 35% of the students qualifying for free and reduced lunch. My second period science class, which is my first class of the day but only one of my five physical science classes consisting of about 30 students, participated with my capstone project. I see all class periods on a daily basis for forty-seven minutes, unless we have a special schedule. I chose this class because of the broad range of learning styles and abilities. I was able to sample students who were low, middle, and high-ability and was able to get perspectives for how my intervention affected all abilities. Included in this class is a paraprofessional who is there to help read text to low-level students and assist in classroom management. In order to determine which class I used, I looked at CRT scores from the seventh grade and science test scores from the eighth grade.

During the project I collected various forms of data for each of my project questions to allow for triangulation. Table 1 shows the triangulation matrix.

Table 1
Data Triangulation Matrix for Capstone Project

Project question	Data source 1	Data source 2	Data source 3
Student understanding	Preunit and postunit assessments	Preunit and postunit concept map	Preunit and postunit perception of understanding concepts interview questions
Long-term memory	Postunit and delayed unit assessments for each unit	Postunit and delayed unit interview concept questions	Postunit and delayed unit concept map
Varying levels of cognitive questions	Preunit and postunit assessments	Random questions during lessons with observations	Classroom observer with prompts
Student attitudes	Preunit and postunit student surveys	Classroom observer with prompts	Cooperative group grading
Student engagement	Preunit and postunit student surveys	Engagement check question with CPS	Cooperative group grading
My attitudes	Journal with prompts	Self- survey	Critical friend observations with a guide

My capstone project focused on the incorporation of a CPS with metacognitive and conceptual strategies to improve student understanding of the eighth-grade science curriculum. In order to measure this, I gave all students a pretest and posttest using one question from each of the cognitive levels according to Bloom's Taxonomy. The pretest questions for treatment unit 1 can be found in Appendix C and treatment unit 2 in Appendix D. The rubric I used for concept level questions can be found in Appendix E. At the end of the unit, students were given a posttest where they were asked the same questions as in the pretest. After each of the preunit and postunit tests, students were interviewed. The interview questions for the nontreatment unit can be found in Appendix N. The interview questions for treatment unit 1 can be found in Appendix O, and treatment unit 2 can be found in Appendix P. The students were selected by separating students by ability as measured by the CRT and randomly selecting two students each from low-, high-, and medium-ability. Students were asked to spend some time before or after school or a lunch period with me to do a formal interview. Once the group of interviewees were selected, the same students were interviewed for each session to maintain consistency and integrity of data. During the interview, students were asked a series of open-ended questions and were encouraged to answer honestly. The interview questions consisted of a concept map, a content knowledge question, and perception of knowledge questions. The rubric for the concept map can be found in Appendix Q.

The first subquestion in my capstone project relates to long-term memory retention. I used three data techniques to determine the effect of incorporating a CPS with metacognitive and conceptual strategies. The first technique is using a delayed assessment for each unit, which was given 14 days after the posttest and consisted of the same questions from the pretest and posttest. The results were then compared using the percent of information retained. The same students were interviewed as before and asked the same questions. Also, an interview was conducted 14 days later to ask similar questions about the concepts. The answers helped give me a clearer understanding of whether or not students remembered the concepts.

The next subquestion of my project was gauging students' ability to answer varying cognitive level questions using a CPS with metacognitive and conceptual strategies. In order to gauge their ability, I focused on the preunit and postunit assessments. The preunit assessment helped me see where students' ability started, while the postunit allowed me to verify if students were increasing their ability to answer varying cognitive-level questions. Also, students were asked questions of varying levels during lecture to see if they were able to answer them. These questions ranged from knowledge to analysis. The final piece I used was a classroom observer's observations on how using the CPS affected my ability to ask questions of varying levels. The classroom observer prompts can be found in Appendix R.

The third subquestion of my project dealt with student attitudes in lessons. The data collection techniques I relied on for this question were as follows: student surveys, classroom observations, and cooperative group grading. All students completed the student survey before the first treatment unit and after the second treatment unit. It contained several questions using a Likert Scale and a few open-ended questions. The Likert scale questions were answered using the CPS, while the open-ended questions were completed using a pen and paper. Students were also required to explain all the Likert Scale rankings. The survey gave students an opportunity to share their feelings and attitudes so I could see trends throughout the entire class. The survey can be found in Appendix F. The classroom observations occurred every Thursday to give the observer a wide range of activities being conducted. The final technique used to collect data of student attitudes was having students rank others in their group for their attitude and the overall attitude of the group during lab exercises. The cooperative group grading can be found in Appendix L.

Student engagement was another question for my project. I relied on preunit and postunit surveys, engagement checks and cooperative group grading. The surveys and cooperative group grading are both techniques that have been used in other areas. The other technique I used for engagement was engagement checks. Periodically during oral discussions, students were asked to use their CPS remotes to rate their level of awareness or engagement in the lesson. They were asked to rate their level of engagement and understanding at the beginning, middle, and end of the class period. These questions were incorporated into the class discussions in which the CPS was being used, and was the second question of the attention checks. The attention check questions can be found in Appendix I.

My final question addressed my attitudes, motivation, and time management. I used journaling, personal observations and critical friend observations. I maintained a journal everyday during the project to determine my feelings throughout the project. The journal prompts can be found in Appendix S. I also included any observations on how my attitudes, motivation, and time management changed. Included in my observations is a personal survey that I took every day. The teacher survey can be found in Appendix T.

The final thing I did was to consult with my critical friend on a weekly basis. I would meet with him every Friday, and based on our conversation, he would fill out the critical friend prompts, which can be found in Appendix U. I asked him to track my attitudes, motivation, and time management based on his impressions meeting with me. He also kept a journal of what he found.

My capstone project occurred from January, 2011 to March, 2011. A detailed project timeline can be found in Appendix V.

DATA AND ANALYSIS

During the project, I collected data during nontreatment and treatment units to verify the usefulness of incorporating metacognition and conceptual feedback strategies with the CPS on student understanding of the eighth-grade physical science concepts. The data were collected using various methods in order to allow for triangulation and the results will be discussed in detail.

Data from the pre and postassessments enabled me to calculate the percent change in understanding of unit concepts, and then compare growth between nontreatment and treatment units. These assessments consisted of six short answer questions, with one question from each of the levels of Bloom’s Taxonomy. Question one was the lowest level, knowledge, while question six was the highest level, evaluation. Table 2, on the following page, shows the percent change in student scores from preassessment to postassessment for the nontreatment unit as well as the two treatment units.

In both treatment units, all groups improved their percent increase in comparison to the nontreatment unit, except for the low-achieving students who showed lower percent increase than the nontreatment unit. However, I observed that students gained a better ability to explain their thinking. For example, a low-achieving student on the nontreatment postassessment said, “An object is in motion when it is accelerating.” Contrastingly, in the postassesment for the treatment unit he stated, “To increase frictional force you can increase the mass of the two objects, and the second way is to apply more force on the objects.” While the student was only partially correct, he was able to put his thinking into clearer and more detailed descriptions. In the second treatment unit, students overall scores improved. Once again, an increase in students’ ability to explain their thinking was noticed.

Table 2
Average Scores and Percent Increase from Preassessment to Postassessment for All Units Split into Low-Achieving (n=8) Mid-achieving (n=10) and High-Achieving and (n=9) and All Students N=27 Groups

Group Description	Nontreatment			Treatment 1			Treatment 2		
	Preunit	Postunit	% Change	Preunit	Postunit	% Change	Preunit	Postunit	% Change
Low	9.25	14.5	57	7.5	11.8	52	7.38	10.13	37
Mid	11.9	18.5	55	7.7	16.8	118	9.4	15.2	62
High	13.22	20.56	56	8.22	18.22	122	9.11	16.78	84
All	11.56	18	56	7.81	15.67	101	8.70	14.2	63

The other measurements of student understanding that supported my pre and postassessments were based on interviews conducted with six students, which allowed further insight into students understanding. The interview data showed that during the nontreatment unit, students showed a wide range of growth. One low-achieving student showed a negative growth from the preassessment to the postassessment. These numbers, however, were in direct correlation with the amount of participation in class. The students, regardless of achievement level, who were involved in class discussion and debates, did far better on concept map construction than those students who were less involved in discussion. This was seen during the engagement checks using the CPS and an overall observation by the teacher and the classroom observer. Figure 1 shows a comparison of percent change for individual students on the concept map during the preinterview and the postinterview for all three units. The average of the low-achieving students' growth was the highest, while the high-achieving students showed a growth the lowest growth. Table 3 shows the averages for each group of students for all three units.

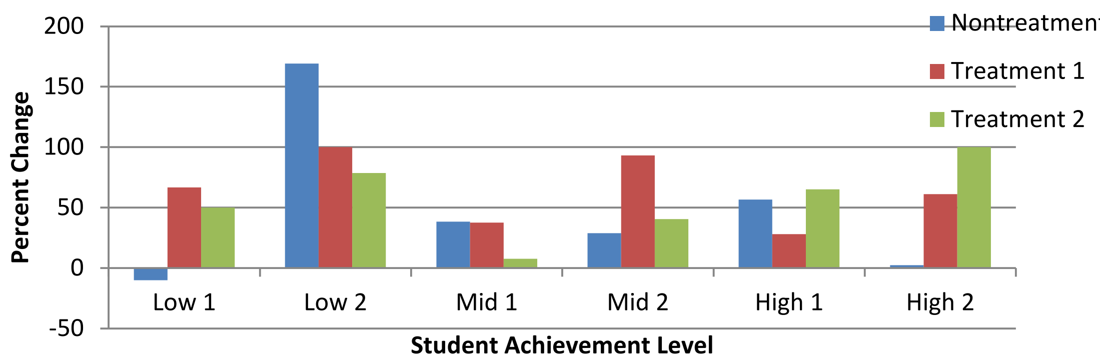


Figure 1. Percent Increase on Concept Map from the Preinterview and Postinterview by Student for Each Unit
Note. Low 1 = low-achieving student number one, Low 2 = low-achieving student number one, Mid 1 = mid-achieving student number two, Mid 2 = mid-achieving student number two, High 1 = high-achieving student number one, High 2 = high-achieving student number two.

Table 3
Scores and Percent Increase from Preinterview Concept Map to Postinterview Concept Map for All Units by Achievement Groups (n=2 for each group)

Achievement Level	Nontreatment			Treatment 1			Treatment 2		
	Preunit	Postunit	% Change	Preunit	Postunit	% Change	Preunit	Postunit	% Change
Low	16.5	26.5	61	13	24	85	15	24.5	63
Mid	29	38	31	15.5	25.5	65	31.5	40	27
High	36	45	25	25	35	40	31.5	55.5	79

During the first treatment unit, students showed more growth than the nontreatment unit on average. Each group improved their overall average from the nontreatment unit. The data indicate that the low-achieving group showed the most growth and the high-achieving group showed the lowest growth. Of the six students interviewed, two of them did not have a higher percent increase than the percent increase in the nontreatment unit. The individual student's percent change can be found in Figure 1, while the group averages can be found in Table 3.

During the second treatment unit, each group increased their average compared to the nontreatment but the mid-achieving students had the least improvement. The mid-achieving showed little growth, and the high-achieving showed a large growth. One low-achieving student and one mid-achieving student did not increase their percent growth from the nontreatment unit.

After completing the concept map, students were asked a conceptual level question about their understanding of the unit. The data support the findings in both the concept map and the pre and postassessments. In the nontreatment unit, students were asked to describe the motion of an object. During the pretest, all students had a difficult time describing motion. Most of them said motion is moving. They could not give specifics of how to determine if an object is in motion or any formulas you might use for motion. During the postassessment, students had a much clearer grasp of the concept. A low-achieving student said, “Motion covers a distance and takes time.” They were not able to give an equation, but they knew what to do. A mid-achieving student said, “It could have acceleration which is final speed minus initial speed divided by time.” A high-achieving student said “motion is relative to a reference point and can have speed, which is distance divided by time. If there is a direction with the speed then it has velocity.” Each group of students had the correct idea, however, the high-achieving student was better able to put their thoughts into words and answer the question more completely. A similar pattern was noticed in both the treatment units.

In Treatment Unit 1 on motion, students were asked to describe how objects reacted to forces. In the preinterviews, students were unable to explain their ideas and basically read their concept map because they had nothing else to rely on. During the postinterview a low-achieving student said, “pushing an object can make it move.” The mid-achieving student said, “If there is a net force on the object it will move.” The high-achieving student said, “Any object reacts by moving or not moving depending on if it has enough force to overcome friction.” The low-achieving student developed a basic understanding, which was greater than the understanding in the nontreatment unit. The greatest gains were made by the high-achieving students who were able to pull information from previous chapters to complete their answers.

In Treatment Unit 2 on work and machines, students were asked to describe how machines make work easier. During the preinterview, it was difficult to get information out of the students because they were unfamiliar with the topic. During the postinterview, the high-achieving students were better able to describe how machines make work easier and were able to draw from information in the previous units with more convincing statements and detailed descriptions which were better than the nontreatment unit. The low-achieving and mid-achieving students were able to state information without having to refer to their concept maps. The low-achieving students had short concise answers, while the mid-achieving students had a more complete description including some relationship to words in previous units. All groups were able to give a correct answer.

Also during the postinterview, students were asked several questions about their perception of their own knowledge. In other words, how well they felt they understood the material. Students were asked what material they found easy, what concepts they found difficult and how confident they were in the material overall. While the examples they gave were similar to the nontreatment, their ability to describe why they felt the material was confusing increased in the treatment units. The low-achieving students often times admitted to finding certain terms confusing. For example, in the treatment unit, one of the low-achieving students said they had a tough time with the term inertia. They rarely talked about the relationship between terms being difficult. The mid-achieving students talked about how Newton's laws of motion were confusing because they couldn't keep them straight. One said, "I felt like I knew the laws, but I would confuse them and mix them up." The high-achieving students rarely felt they had trouble with any of the concepts. One even stated, “I’ve had this information during fifth-grade, and I still remember pieces.” The low-achieving students would also only use terms to describe what they found easy to understand. I noticed they would refer to their concept maps and pick words that they felt were easy to put links to. The low-achieving students had difficulty explaining why they felt the concept was easy or difficult, which was very similar to the nontreatment unit. For example, one student said, “I just didn’t study inertia, so I don’t know what it is.” The mid-achieving students were able to explain why they felt concepts were easy with more convincing arguments than they did in the nontreatment unit. They were able to give examples of why it was easy. For example, one said, “I remember seeing the picture in the book and that showed the two dogs pushing on a box. The dog that had the larger force on the side made it so the box moved.” The high-achieving students found the math concepts easy. If it involved formulas, they felt confident in it and were able to repeat the formulas when asked. One high-achieving student even stated, “I really like math, and I know it is something I want to pursue in the future to get into a good college.” This was similar to the information gained in the nontreatment interview, as similar answers were given from the same students.

The results from these three different forms of assessment suggest using the CPS with metacognitive and conceptual feedback strategies was more effective in assisting students in understanding physical science concepts than those employed during the nontreatment unit. The greatest change observed in the treatment units was formation of strong connections within the material and prior knowledge. Discussion with students during the interviews revealed students realized the impact of forces on motion as well as the benefit of machines. While all groups of students increased their understanding of physical science concepts, the most gain was made by high-achieving students.

In addition to determining if this method increased overall conceptual knowledge, I was interested in knowing if it promoted long-term memory retention. Fourteen days after each postassessment, students were given a delayed assessment to test for long-term memory. Table 4 shows a comparison of the percent of information lost from the posttest for each group. During the nontreatment unit, the low-achieving students showed the most percent loss, however, during the first treatment unit, they showed the least percent of information lost. The mid-achieving group showed the lowest percent loss during the nontreatment, but the most during the first treatment unit. The high-achieving students showed the lowest percent lost in the last treatment unit. All groups of students showed more change, meaning more loss of information, during the treatment units compared to the nontreatment unit. The only group of students to lower their loss of information was the low-achieving group during the first treatment unit, and the high-achieving group during the second treatment unit. Overall, the average assessment data show that all groups of students had more loss of knowledge during the treatment units.

Table 4
Scores and Percent Change from Postassessment to Delayed Assessment for All Units by Achievement Groups Low-Achieving (n=8) Mid-Achieving (n=10) and High-Achieving and (n=9) and All Students (N=27)

Achievement Level	Nontreatment			Treatment 1			Treatment 2		
	Postunit	Delayed	% Change	Postunit	Delayed	% Change	Postunit	Delayed	% Change
Low	14.5	13.0	-10	11.4	10.5	-8	10.1	9.0	-11
Mid	18.5	17.9	-3	16.8	13.7	-18	15.2	12.6	-17
High	20.6	19.3	-6	18.2	15.6	-15	16.8	16.7	-1
All	18	16.9	-6	15.7	13.4	-15	14.2	12.9	-9

A postinterview was also given 14 days later. During this interview students were asked to create a concept map using the same terms as in the preinterviews and postinterviews. Table 5 shows a comparison of how the individual groups of students compared. These data better support the effectiveness of the intervention strategies. All groups of students showed less percent change of relating concepts during both the treatment units compared to the nontreatment unit, which indicates the students retained more information during the treatment units. The low-achieving group had two of the three highest percent changes, while the mid-achieving group had two of the lowest percent changes. The high-achieving group showed the lowest percent change in the nontreatment unit, but the highest in one of the treatment units.

Table 5
Scores and Percent Lost from Postconcept Map to Delayed Concept Map for All Units by Groups of Students Interviewed. (n=2 for each group)

Achievement	Nontreatment			Treatment 1			Treatment 2		
Level	Postunit	Delayed	% Change	Posunit	Delayed	% Change	Postunit	Delayed	% Change
Low	26.5	15.5	-61	24	14.5	-40	24.5	20.5	-16
Mid	38	25	-31	25.5	23	-10	40	33.5	-16
High	45	28	-25	35	29	-17	55.5	45	-19

During the postinterview, students were also asked the same concept question as in the preinterview and postinterview. They were able to describe the work machines do with little accuracy. They were able to describe their thinking, but it was difficult to get the reasoning of why machines make work easier. For example, a mid-achieving student said, “Work is made easier with machines because machines put out a large force when you only put in a small force.” He was only partially correct, but I could understand his thinking behind what he was saying. This was the trend throughout the groups. Most students had difficulty stating the correct answer, but were able to explain their thinking using terms from previous units. This data corresponds with the information found in the concept map and postassessment.

The data resulting from using the concept maps as well as pre and postassessments shows that while the CPS may have had a negative impact on long-term memory of concepts, it does have a positive effect on the relationship between concepts. Students are better able to form strong connections between what they have learned in the past to the material they are currently studying and apply that to their concept map. They may not be able to answer the question with 100% accuracy, but they are better able to describe their answer and pull information from past units to help with their answers.

As part of this project, I was also interested in students' ability to answer varying levels of questions from Bloom's Taxonomy. During the nontreatment unit, students were asked questions that required a finger signal or a show of hands to indicate the correct answer. This technique showed little information, as it was difficult to get all students to respond, and if they did respond, it was difficult to tell if they were just copying the students who responded first. Throughout the treatment units, however, students were asked to answer several multiple-choice questions and were asked to respond using the CPS. The purpose of asking questions, was to check student understanding and to be able to increase communication in order to prepare students for their postassessment. Assessment questions at successive levels of cognition were developed based on Bloom's Taxonomy. Level 1 represented the simplest form of cognition: knowledge and comprehension. Level 2 was analysis and application. Level 3 signified the most complex form of cognition, synthesis and evaluation. In general, all groups of students had a larger percent change during the treatment units than they did during the nontreatment unit. The low-achieving students were the only group of students that showed lower percent change during the treatment units than the nontreatment unit. Their percent change was lower in all three levels during the treatment units. For all students, they had one lower percent change on the level 1 questions for the first treatment unit, but all other scores increased. The percent change of scores on the preassessment to the postassesesment for each group of students for all units can be found in Table 6 on the following page. These findings suggest students are better able to construct higher-order understanding employing strategies using the CPS with metacognitve and conceptual feedback strategies.

The cognitive questions during instruction during the treatment unit showed expected results and further showed the high-achieving students are better able to answer questions correctly. This trend was also observed during the nontreatment unit, however, only qualitative data were used during the nontreatment unit, therefore numbers could not be compared. A graph of the results from the treatment units can be found in Figure 2 on the following page. Overall, the higher the student scored on their state CRT, which is how students' achievement-levels were sorted, the better able they were able to answer multiple-choice questions relating to the material covered in class, regardless if the CPS was used during the discussion or not.

Table 6

Average Percent Change in Understanding from Preassessment to Postassessment by Question Level in the Class (N=27) and Split into Low-Achieving (n=8), Mid-Achieving (n=10) and High-Achieving (n= 9) Groups.

Note. Level 1 = Knowledge and Comprehension Level 2 = Application and Analysis Level 3: Synthesis and Evaluation

Achievement Level and Question Level	Nontreatment			Treatment 1			Treatment 2		
	Preunit	Postunit	% Change	Preunit	Postunit	% Change	Preunit	Postunit	% Change
Low Level 1	1.4	2.3	64	1.4	1.7	21	1.1	1.7	55
Low Level 2	1.9	2.8	47	1.2	1.8	50	1.5	1.9	27
Low Level 3	1.4	2.2	57	1.1	1.6	45	1.1	1.4	27
Mid Level 1	1.8	3.2	78	1.4	3	114	1.6	2.7	69
Mid Level 2	1.4	3.1	121	1.3	2.7	108	1.9	2.8	47
Mid Level 3	1.9	2.6	37	1.2	2.3	92	1.2	2.2	83
High Level 1	1.7	3.5	106	1.4	2.9	107	1.4	3.3	136
High Level 2	2.7	3.7	37	1.5	3.4	127	1.9	2.7	42
High Level 3	2.2	2.7	23	1.2	2.8	133	1.2	2.4	100
All Level 1	1.6	3.1	94	1.4	2.6	86	1.4	2.9	107
All Level 2	2.3	3.2	39	1.3	2.6	100	1.8	2.7	50
All Level 3	1.8	2.4	33	1.2	2.6	117	1.2	2.4	100

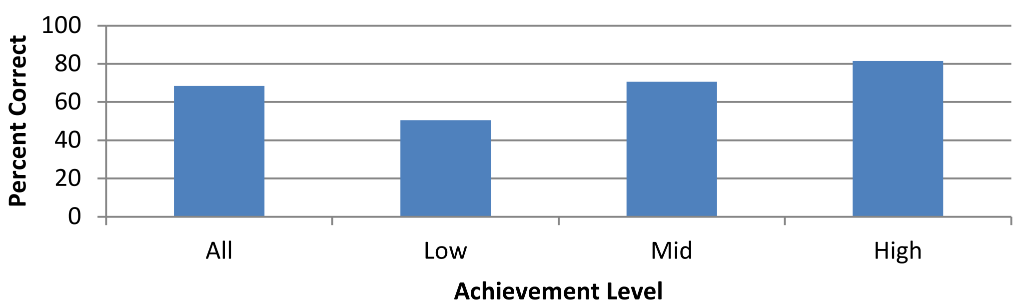


Figure 2. Percent of all cognitive questions answered correctly in the class during the treatment units (*n*=27) and split into low-achieving (*n*=8), mid-achieving (*n*=10) and high-achieving (*n*= 9) groups.

Every Thursday, while conducting this research, a classroom observer made observations. Part of her job was to see how students were able to answer varying levels of Bloom's Taxonomy questions. When asked to summarize her findings on students' ability to answer questions during the treatment units compare to the nontreatment units she said, "I saw a wide variety of cognitive questioning being used by the teacher. During discussion there were countless questions that involved students to apply what they learned from the text and apply it to a more common example. These questions allowed students to think outside the box and come up with creative examples that fit the criteria." The classroom observer noted that no particular group stood out in their ability to answer higher-level questions, but the students that were choosing to not participate had a more challenging time answering these questions. She stated, "students were able to answer higher-level questions after they had time to first work through their thoughts with a small group. They not only were able to answer correctly but they also had a deep understanding with which they could explain and give examples or details when answering. Their understanding of higher-level questions was also apparent when all students answered the CPS questions individually. Then, when the scores were revealed, it was clear that two choices were the favorites, students were able to explain why each were chosen and why one was wrong." This data supports what was seen in the assessments.

The data collected show that using the CPS with metacognitve and conceptual feedback strategies is a benefit to all levels of students, except for the low-achieving, when answering questions, especially questions that require high-levels of understanding.

This is especially true in the Level 3 questions where students showed the largest percent change for all groups. The low-achieving group did not benefit as much as the mid-achieving and high-achieving groups, but a significant change in their ability to explain their thinking was observed.

Data were obtained and analyzed through use of student surveys, cooperative group grading and a classroom observer to help answer my subquestion regarding how the CPS affects student motivation and attitude. Students were asked to take a pretreatment and postreatment survey in order to judge their attitudes and motivation in class. Although no statistical analysis was done on the data, it appeared students felt they participated more frequently, gained confidence on tests, learned more in general, gained confidence in answering questions and gained ability to explain their answers. In general, they felt that homework completion, grade importance, as well as enjoyment of class decreased. Figure 3 shows a comparison of scores on the pretreatment and posttreatment student survey.

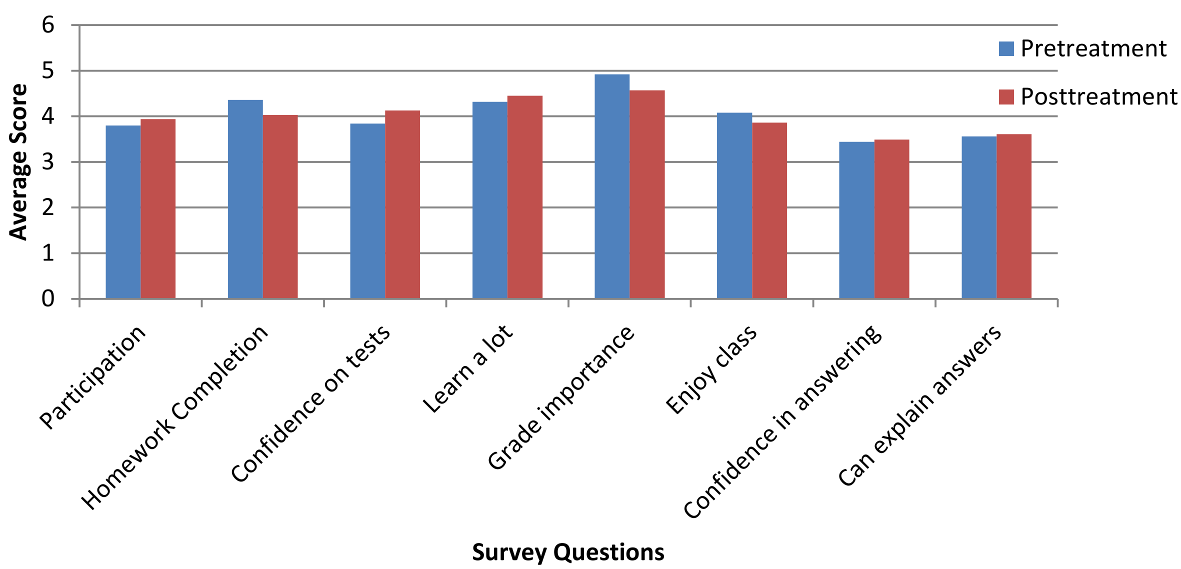


Figure 3. Comparison of average scores on pretreatment and posttreatment student surveys (*n*=27). *Note.* Likert scale 5=strongly agree to 1=strongly disagree.

On the survey, students had a few questions that asked about how the CPS changed their attitudes and understanding of science. Over half the students said, “I feel the CPS made it fun to see how I did and see how I compare to my peers.” They also commented on how the CPS made them feel more involved in class. One student noticed that it “made the group stay on a topic longer instead of moving on.” Most of the students commented on the fact that “CPS helps me understand science better because if I didn’t know the answer we discussed why.” However, two students did not like the CPS and did not feel they benefited from it. For example, one student said, “The CPS was boring and it was aggravating that we used it so much.”

The classroom observer was also asked to track students’ attitudes and motivation in class. Overall, she had similar findings as the student. She felt students had a very positive attitudes towards CPS. She stated “students can get the answer wrong but not be exposed publicly. It also leads to students coming to a consensus on an answer making for great discussion.”

A piece of data that supported the evidence of student attitudes was found in the cooperative group grading. Student attitudes were mixed regarding the CPS. Students noted that it was beneficial to see how they were doing in comparison to their peers, but also stated that the CPS could be boring and repetitive. The CPS had little effect on their motivation in science class, but a decrease in the excitement of using the CPS as the use continued was noticed.

Student attitudes were overall positive to the CPS. Many students could see the benefit of keeping them on track, being more metacognitvely aware of what they understood, and their increased discussion abilities. Students also noticed an increased confidence in answering questions, their level of learning, and their ability to explain their answers. However, the CPS had a negative impact on their level of enjoyment in class, their homework completion and the importance of their grades.

The cooperative group grading was done during labs and activities. Students were asked to rank themselves and their groups in different areas, such as behavior, engagement, and attitudes. Figure 4 shows a chart comparing student behavior to the group as well as personal attitudes to the group attitudes. Overall, students felt they behaved themselves better than the group as a whole but felt they shared similar slightly positive attitudes about the activities completed. During the nontreatment unit, students were not asked to grade themselves or their group members, but students often complained of doing more work than their peers or having group members that did not participate at all.

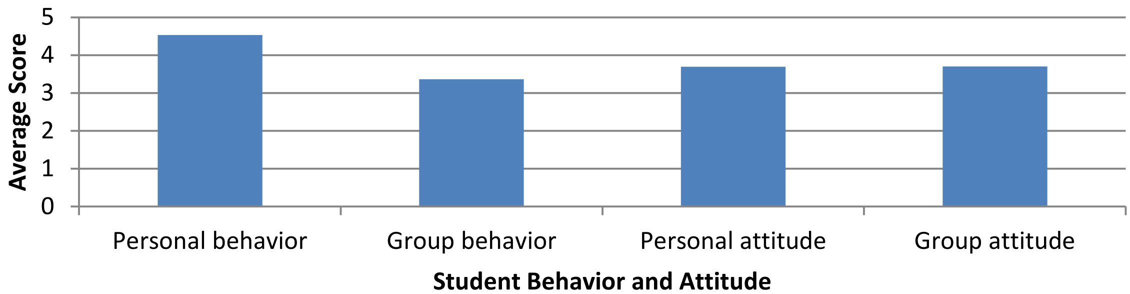


Figure 4. Comparison of student attitudes and behavior to the perception of whole group attitudes and behavior during the treatment units using Likert Scale.

Note. Likert Scale 5= strongly agree to 1=strongly disagree.

The impact of the CPS on student engagement was reaffirmed by triangulating data from cooperative group grading, engagement checks and student surveys. Using the cooperative group grading, it was found that students on task behavior ranked much higher than their group behavior. This can be seen using Figure 4. So, while students felt they were on task, they felt that their group members were slightly less on task and engaged in the lab activity. The cooperative group grading also showed that all groups felt they contributed a great deal to discussion. Figure 5 shows the level of engagement of each group of students. The low-achieving students felt they contributed less to the discussion than their classmates, while all other groups felt they contributed more than their classmates. The low-achieving and mid-achieving students felt they were less on task, therefore less engaged, than their classmates.

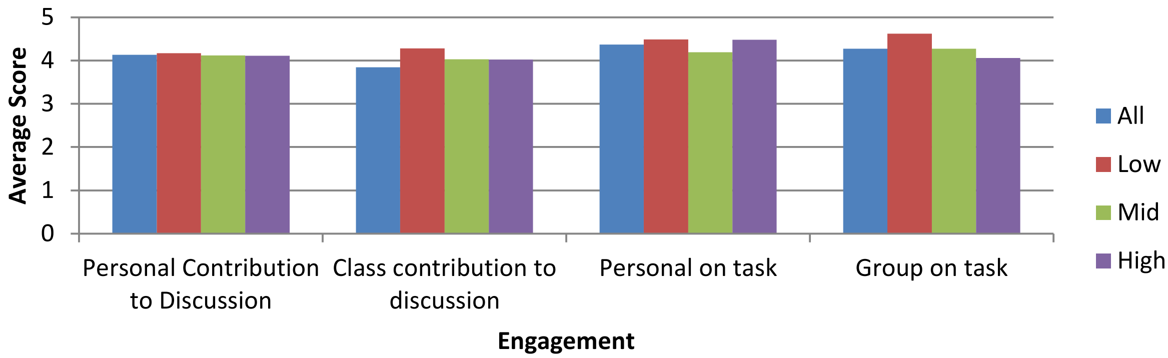


Figure 5. Comparison of engagement all students (*N*=27) split into low-achieving (*n*=8) mid-achieving (*n*=10) and high-achieving (*n*=9) groups from cooperative group grading using Likert Scale.
Note. Likert Scale 5= strongly agree to 1=strongly disagree.

Another source of data that supported the cooperative group grading was the student survey. The student surveys showed that students increased their own engagement, the class engagement, and their own participation in class. The survey also showed that students felt that the CPS slightly increased their engagement in lessons. Figure 6 shows a comparison of engagement and participation scores from the presurvey and postsurvey.

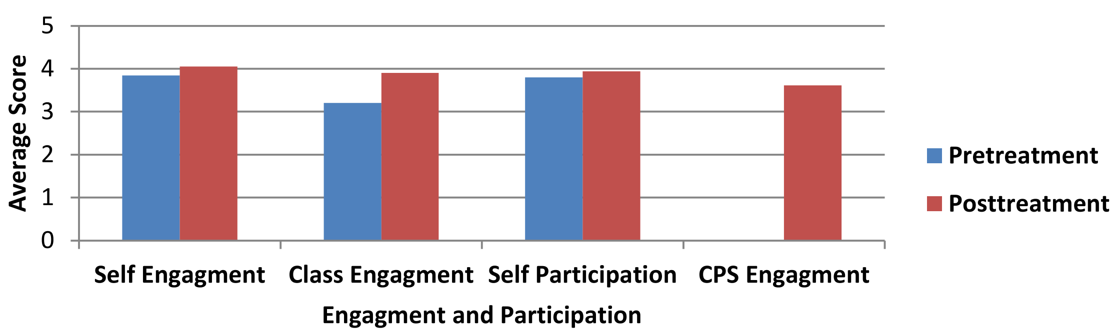


Figure 6. Comparison of engagement and participation of all students (*N*=27) from the pretreatment and postreatment surveys using Likert Scale
Note. Likert Scale 5= strongly agree to 1=strongly disagree.

During the nontreatment unit, observations were made of when the students appeared to be the most engaged. Students appeared to be the most engaged in the middle of class. When the class started, it was often times hard to get students to settle in and be prepared to learn, but once they settled down they were engaged in the class. However, this level of engagement decreased towards the end of the class as students became restless. Students were given attention checks to show their level of paying attention during lessons during the treatment units. These attention checks showed students' engagement in lessons and followed the previous trends seen. Table 7 shows a comparison of low-, mid- and high-achieving students compared to the entire class on level of engagement from the beginning, middle and end of the class period during the treatment unit. In general, all groups were least engaged at the beginning and end of the class period, and most engaged in the middle of the class. This data corresponds with the nontreatment unit observations. The low-achieving students were by far the least engaged at the end of the class. The mid-achieving students were the most engaged of any group during the middle of the class. Also, low-achieving students noticed that even though they felt they contributed a lot to discussions, they realized they were not contributing as much as their peers. Students noticed that the CPS held them accountable for answering questions and not being allowed to just sit in class. It was also shown that students paid the most attention during the middle of class and that their engagement at the beginning and end of class was lower.

Table 7
Average of Attention Check Scores from Treatment Units by Low-Achieving (N=8) Mid-Achieving (N=10) and High-Achieving (N=9) Groups as well as All Students (N=27) Using Likert Scale
Note. Likert Scale 5= strongly agree to 1=strongly disagree.

Group Description	Time In Class Period		
	Beginning	Middle	End
Low	4.20	4.22	4.10
Mid	4.50	4.55	4.53
High	4.23	4.40	4.29
All	4.33	4.4	4.33

The final project question I wanted to address in this project was the effect of the CPS on teacher attitude, motivation, and time management. Data were collected using a teacher survey, teacher journal and critical friend observations. Throughout the unit, I took a survey on a daily basis. I also completed a journal entry after each lesson. Figure 7 shows a nontreatment versus treatment unit comparison of the teacher survey. Overall, the use of CPS has the largest effect on the time spent in my preparation period to get ready. I found myself using most, if not all, of the allotted time to get ready for the day. Writing questions that would allow for discussion seemed to be the biggest difficulty. At one point I explained, “The questions are difficult to come up with in order to allow a progression of topics and it is taking a lot of unexpected time.” The CPS also made me feel less prepared, which lead to me being less excited to start the day and less motivated to teach the lesson.

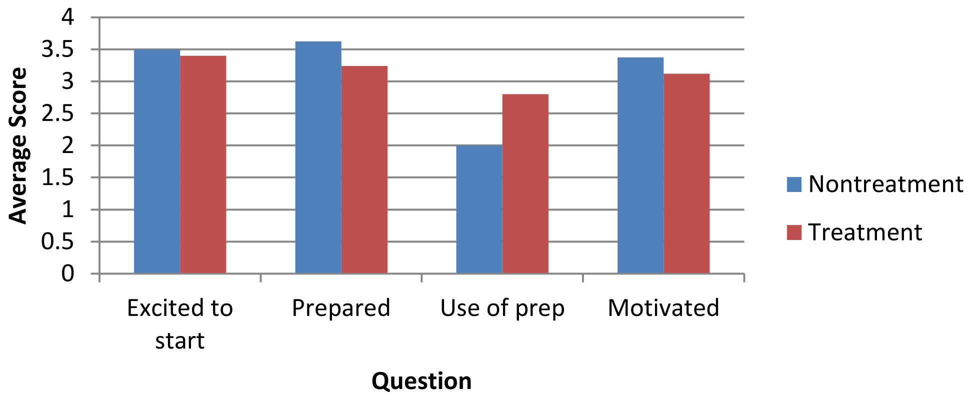


Figure 7. Comparison of nontreatment and treatment units on teacher attitudes, time management and motivation using Likert Scale.
Note. Likert Scale 5= strongly agree to 1=strongly disagree.

The journal showed positive changes on my perception of how the lesson was conducted and the impact on the students. Figure 8 shows a comparison for the journal prompts. The use of CPS had a general increase on my motivation behind the lesson, encouraging critical thinking of students, helping and empowering students to learn, positive student-teacher interaction and positive feeling about the lesson. One of the biggest attributes of the CPS was the ability to get students talking, discussing and debating responses. While students may not have fully understood the concept, they could talk about it and justify their answers. As students worked collaboratively in the treatment units, they were more willing to ask questions within their group and debate why answers were correct or incorrect. This provided me opportunities to ask higher-level questions. Not only did I see this, but my classroom observer also noted this behavior saying, “During instructional times with the CPS, I witnessed on countless occasions students beginning with an initial answer and through discussion and debate students could create a well-developed answer and that clearly expressed their understanding." This lead to me feeling more positive about the lesson and giving me a sense that students were being empowered to learn and think critically.

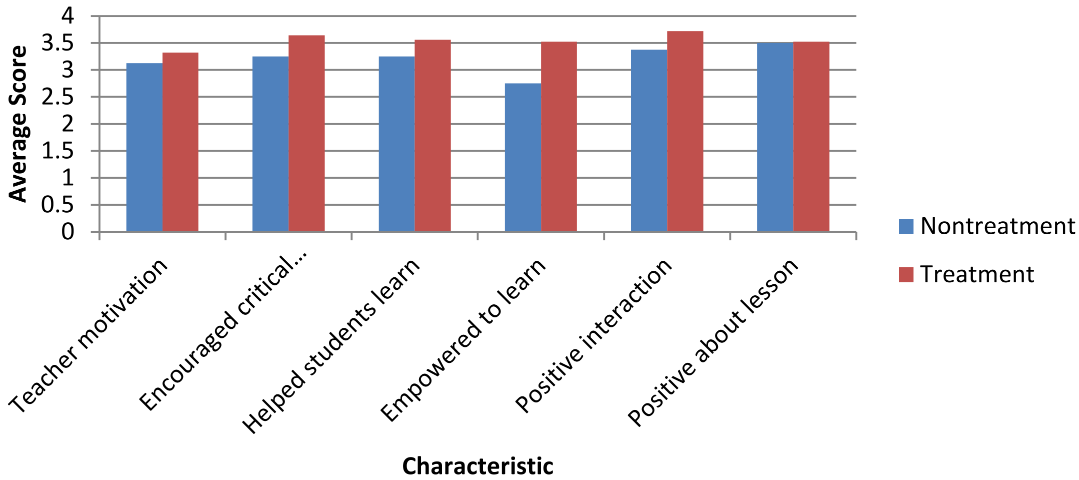


Figure 8. Comparison of treatment and nontreatment unit on teacher motivation and perception of lesson, as well as perceived Effects on students using Likert Scale.
Note. Likert Scale 5= strongly agree to 1=strongly disagree.

At the end of every week during the research period, I consulted with a critical friend who helped track my attitudes and motivation towards the CPS. As seen in Figure 9, there was an obvious decline in teacher attitude, engagement and motivation. This was mostly due to interruptions from the schedule for school-scheduled events. The critical friend made note of this in one of the meetings and was sure to explain why he saw a decrease in motivation. The critical friend summed up teacher attitude by saying, "The teacher's attitude remained positive and her motivation towards doing the activities seemed genuine and productive. She adhered to her scheduled treatments in a timely manner. I experienced a complete lack of any form of procrastination."

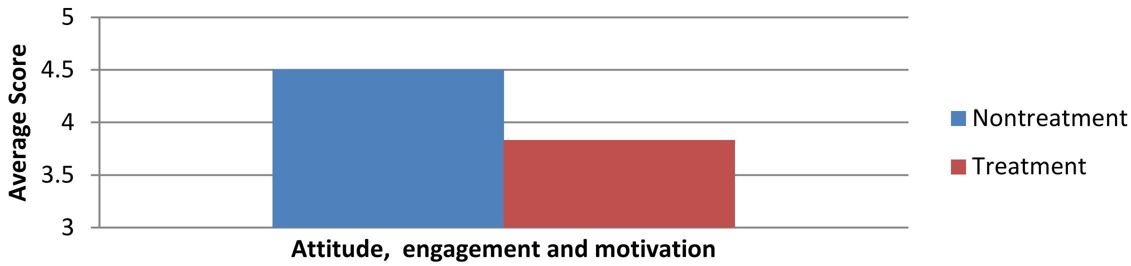


Figure 9. Comparison of treatment and nontreatment unit on teacher attitude, engagement and motivation as perceived by critical friend using Likert Scale
Note. Likert Scale 5= strongly agree to 1=strongly disagree.

Although the critical friend noticed little change, I personally noticed a change in my attitude. I felt my attitude, motivation and time management decreasing. There were several other factors contributing to this lack of time management. This change in motivation and attitude were likely due to personal obligations outside of this project. My feelings toward the CPS however, remained positive. I felt that it increased my ability to ask questions of varying levels, to check student understanding and give proper feedback, and to get students thinking about why they chose answers and not just guessing. All of these improvements in my teaching, led students to understand the material better and to increase their test scores. One of the highlights of the CPS was the impact it had on classroom discussion. It increased the quality discussion in my classroom and made students feel safe to answer questions without ridicule from their classmates.

INTERPRETATION AND CONCLUSION

Data were analyzed to answer my focus question on the effects of incorporating metacognitive and conceptual feedback strategies with a CPS on student understanding of physical science concepts. Evaluation of the data collected from all units suggests use of CPS assisted students in developing a more complex, cognitive understanding of the concepts than traditional methods. Most notably, triangulation of the data suggests the metacognition incorporated with CPS enabled all students to clearly state their reasoning behind answers which lead to high-quality class discussion and debate.

Developing a deeper understanding of concepts was also seen in students' ability to relate concepts to each other and use prior knowledge to support connections. This was especially true in the mid-achieving and high-achieving students. Data collected in the pretreatment unit showed students had little background knowledge and had a difficult time relating information to previous concepts. In the treatment units, students were able to think about the concepts learned previously, and draw connections based off of their prior knowledge.

Data for long-term memory were found to be contradictory. It was effective in helping students organizing and connecting concepts, which was shown on the increase of concept map scores during the interviews. However, assessment scores decreased during the delayed assessment, which suggests a negative effect on the ability to answer questions from levels of Bloom's Taxonomy. On the assessments, students were able to explain the reasoning for their answers, but their answers were often times incorrect.

The CPS with metacognitive and conceptual feedback strategies increased students' ability to answer higher-level questions from Bloom's Taxonomy. This was due to the quality class discussion generated by using the CPS. Students were able to defend their thinking which lead to students debating answers, applying previous knowledge and asking more questions to further increase their understanding. Students were able to share their answers without criticism and “click-in” answers anonymously. Group cohesion and mutual trust appears to be due to the establishment of positive interdependence and personal accountability.

Students appeared to be more motivated to learn and were actively engaged in developing concepts when CPS was used with metacognitive and conceptual feedback strategies were used. Students noticed that it encouraged all students to participate more in class discussions. It was interesting to note that students were more actively engaged in the middle of class and not at the beginning. Most students found the CPS increased their involvement in class and made them more engaged, however, a few students found the CPS to be boring and ineffective at changing their personal participation in class.

Attitudes appeared to be positive towards the CPS. Most students found a great deal of benefit in being able to see how they were doing in comparison with their peers and to hear why their answers were either correct or incorrect. As a teacher, I found a great deal of joy in finding student confidence increase. Students gained confidence not only in answering questions, but also in taking tests.

As an educator, this project has been beneficial to my own teaching, attitude, and motivation by enabling me to explore how to create questions and use questioning techniques that allow for greater class discussion. It proves the benefit of metacognition and getting students more involved in their learning. When students are able to explain their thinking, they can defend answers and generate examples in support.

There were some issues with the data collection for this project that could be improved upon in the future. First, I would include more qualitative data during the nontreatment unit in order to better compare information on attention checks and cooperative group grading. Because I had limited qualitative data, I felt that it was difficult to see the full impact of my treatment interventions. Also, concept questions in the interviews were confusing to the students. Students often times just read their map to me, instead of using their map as a reference to answer the concept question. Asking more questions regarding the concept, or at different levels of Bloom's Taxonomy, might help to better assess student understanding. Also, during the interviews, getting students to explain further why they felt a concept was confusing would be helpful. Giving students the interview questions prior to the interview and asking them to write notes and to think of examples, might help to get more information from students regarding their perception of understanding.

Student surveys, cooperative group grading, and classroom observer prompts would be modified to focus attention on the question trying to be addressed for the project. I found that many questions did not add any pertinent data to my project, therefore, they were simply left out of my data collection. I would be sure to narrow questions down to create less data and get at the heart of the subject matter. Focusing attention to questions asked, formatting questions to gain a clearer understanding, and giving students the interview questions before hand will improve the quality of data collected and allow for easier sorting of important information to ease the tension of data analysis.

VALUE

The implication of the study for me personally is that it gave me an opportunity to explore new teaching strategies, while also developing professionally. Designing and implementing this project has allowed me to reflect on my own teaching, ways to provide a more valuable learning experience for students, and the importance of metacognition.

Incorporating the CPS with megatacognitive and conceptual feedback strategies gave me a chance to align my teaching practice with what I feel is an important aspect of science class: engagement. Students who are engaged in science, usually enjoy science more. I want to engage all students, whether they enjoy science or not, in class. Also, if they are more engaged in a discussion, they may realize that they enjoy science, and that it is something they can take home and demonstrate to their parents. If I can get students thinking about the subject matter, and realize that even if they are not going to be a scientist, the information can be used in their future, they will become better prepared for their future.

The CPS benefits my students by providing a meaningful learning experience. It forces all students to have an opinion and voice their opinion, even if they are doing it anonymously. The CPS gives them a chance to take control of their own learning. They have the opportunity to develop higher-level thinking skills by debating and discussing with their peers and creating examples to fit their thinking. Being able to use these higher-order thinking skills in real life helps steer students into adulthood, and helps prepare them for future careers in the field they choose.

One of the most impactful findings of this study was the value of metacognition. When students can explain their answers, they can also defend their answers. This leads to higher quality class discussion and classroom debate of answers. As their teacher, I need to guide them to help them become more aware of thinking about their thinking and help them be able to explain their thinking. I need to express how important it is for them to be aware of their thinking, to be able to explain their thinking, and to help them gain confidence in sharing their responses.

This study has given me reason to share my findings with my colleagues and administrators. Not only for the value of metacognitive awareness, but also to show them how valuable the CPS is as a formative assessment technique, and not just a tool for quick grading of a summative assessment. Metacognitive awareness is something that all teachers can teach to their students. It is relatable among all grades and can be incorporated into lessons fairly simply. If all students become more metacognitively aware, I believe that the quality of discussion will increase in all classes because students will be able to ask more thoughtful questions. If they can ask more thoughtful questions, they can get a deeper understanding of the material.

This study leads me to wonder about the low-achieving student’s ability to process information and if there is a correlation between how much they enjoy science and their study habits. If they enjoy a subject more, do they study more? Does the amount of time they study vary by level of student? Also, what strategies can I implement to help the low–achieving students more effectively. Finally, it makes me wonder other ways the CPS can be used as a tool in the classroom.

My capstone project has lead to me reevaluate my traditional style of teaching and use of the CPS. Exploration of the CPS with metacognition and conceptual feedback has shown me that having all students respond to questions and defending their answers can be a valuable learning experience for my students. This project has helped me develop professionally by focusing on strategies and content which better engage my students, make my students more metacognitive, and allow me to give my students better feedback. I intend to continue exploration of CPS with metacognitive and conceptual strategies to better suit the needs and learning of my students.

REFERENCES CITED

Abrahamson, A. L. (1999).*Teaching with a classroom communication system-what it invovles and why it works* . Retrieved October 25, 2010, from http://www.bedu.com/Publications/PueblaFinal2.pdf

Anderson, L. W., Krathwohl, D. R., & Bloom B. S. (2001). *A taxonomy for learning, teaching, and assessing a revision of Bloom's taxonomy of educational objectives.* New York, NY: Longman.

Barnes, L. J. (2008). Lecture-free high school biology using an audience response system. *The American Biology Teacher , 70*(9), 531-536.

Caldwell, J. E. (2007). Clickers in the large classroom: Current research and best-practice tips. *Life Sciences Education, 6*(1), 9-20.

Conoley, J. W., Croom, D. B., Moore, G., & Flowers, J. L. (2007). Using electronic audience response systems in high school agriscience courses. *Journal of Agricultural Education , 48*(3), 67-77.

Crossgrove, K., & Curran, K. L. (2008). Using clickers in nonmajors- and majors-level biology courses: Student opinion, learning, and long-term retention of course material. *CBE-Life Sciences Education , 7,* 146-154.

Crouch, C., & Mazur, E. (2001). Peer instruction: Ten years of experience and results. *American Journal of Physics, 69*(9), 970-977.

Crowe, A., Dirks, C., & Wenderoth, M. P. (2008). Biology in bloom: Implementing Bloom's taxonomy to enhance student learning in biology. *CBE - Life Sciences Education*. *7*(4), 368-381.

Doucet, M., Vrins, A., & Harvey, D. (2009). Effects of using an audience response system on learning environment, motivation and long-term retention, during case-discussions in a large group of undergraduate veterinary clinical pharmacology students. *Medical Teacher , 31*(12), 570-579.

Fies, C., & Marshall, J. (2006). Classroom response systems: A review of the literature. *Journal of Science Education and Technology*, *15*(1), 101-109.

Handelsman, J., Ebert-May, D., Beichner, R., Bruns, P., Chang, A., DeHaan, R., & Wood, W.B. (2004). Education: Scientific teaching. *Science , 304* (5670), 521-522.

Hinde, K., & Hunt, A. (2006). Using the personal response system to enhance student learning: Some evidence from teaching economics. In D.A. Banks (Ed.), *Audience response systems in higher education: Applications and cases*. Hershey, PA: Information Science Publishing.

Judson, E., & Sawada, D. (2002). Learning from past and present: Electronic response systems in college lecture halls. *Journal of Computers in Mathematics and Science Teaching*, *21*(2), 167-181.

Kay, R. H., & LeSage, A. (2009). Examining the benefits and challenges of using audience response systems. *Computers & Education*, *53*(3), 819-827.

Kay, R., & Knaack, L. (2009). Exploring the use of audience response systems in secondary school science classrooms. *Journal of Science Education and Technology*, *18*(5), 382-392.

Lopez-Herrejon, R., & Schulman, M. (2004). *Using interactive technology in a short java course: An experience report.* Retrieved February 22, 2010, from The University of Texas at Austin: http://microlib.cc.utexas.edu/academic/diia/crs/bestpractices/Iticse17.pdf

Penuel, W., Abrahamson, L., & Roschelle, J. (2006). Theorizing the networked classroom: Sociocultural interpretation of the effects of audience response systems in higher education. In D. Banks, *Audience response systems in higher education* (pp. 187-208). Hershey, PA: Information Science Publishing.

Penuel, W.R., Boscardin, C.K., Masyn, K., & Crawford, V (2007). Teaching with student response systems in elementary and secondary education settings: A survey study. *Educational Technology Research and Development*, *55,* 315-346.

Pradhan, A., Sparano, D., Ananth, C. V. (2005). The influence of an audience response system on knowledge retention: An application to resident education. *American Journal of Obstetrics and Gynecology*, *193*(5), 1827-1830.

Preszler, R., Dawe, A., Shuster, C., & Shuster, M. (2007). Assessment of the effects of student response systems on student learning and attitudes over a broad range of biology courses. *CBE-Life Science Education , 6*, 29-41.

Rickey, D., Stacy, A. (2000). The role of metacognition in learning chemistry. *Journal of Chemical Education , 77* (7), 915.

Sharma, M. D., Khachan, J., Chan, B. & O'Byrne, J. (2005). An investigation of the effectiveness of electronic classroom communication systems in large lectures. *Australasian Journal of Educational Technology*, *21*(2), 137-154.

Siau, K., Sheng, H. & Nah, F. (2006). Use of classroom response systems to enhance classroom interactivity. *IEEE Transactions on Education*, *49*(3), 398-403.

Simpson, V., & Oliver, M. (2007). Electronic voting systems for lectures then and now: A comparison of research and practice. *Australasian Journal of Educational Technology*, *123*(2), 187-208.

Stowell, J. R., & Nelson, J. M. (2007). Benefits of electronic audience response systems on student participation, learning, and emotion. *Teaching of Psychology*, *34*(4), 253-258.

Veenman, M., Van-Hout Wolters, B. A. & Afflerbach, P. (2006). Metacognition and learning: conceptual and methodological considerations. *Metacognition and Learning , 1* (1), 3-14.

Ward, D.L. (2003, April 20). The classroom performance system: The overwhelming research results supporting this teacher tool and methodology. Retrieved October 26, 2010 from http://www.einstruction.com/News/index.cfm?fuseaction=News.display&Menu=newsroom&content=FormalPaper&id=209

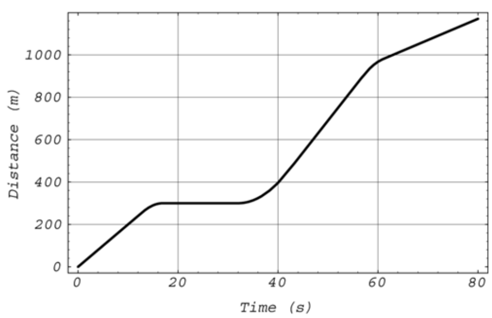
APPENDICES

APPENDIX A

PRE/POST/DELAYED ASSESSMENT NONTREATMENT UNIT: DESCRIBING MOTION

Appendix A
Pre/Post/Delayed Assessment Nontreatment Unit: Describing Motion

1. Describe in detail how we know an object is in motion. Please be specific.
(Knowledge)
2. Compare and contrast speed and velocity.
(Comprehension)
3. Calculate the speed of you walk to school if you walked 750 m and it took you 8 minutes to walk that far. Show your work.
(Application)
4. Based on the graph provided, explain what might have been going on during the time the graph was presented.
(Analysis)



5. Construct a distance vs. time graph to show two different motions experienced during a day.
(Synthesis)

6. Suzie is considering taking a new route to school. Prepare a list of criteria to judge which route would be the best. Indicate priority and ratings.
(Evaluation)

APPENDIX B

SPEED CHALLENGE ACTIVITY

Appendix B
Speed Challenge Activity

Speed Challenge

Get Ready!

Step 1: Gather your materials!
Each team needs 2 timers, 1 meterstick, 1 roll of masking tape, and 1 marker.

Step 2: Create your "race" track!
Find a spot in the hallway or classroom and measure off a 10 meter race track. Use three pieces of yarn to mark the beginning, middle, and end of your track. Mark each distance (0 m, 5 m, and 10 m) on the tape with a marker.

Step 3: Go for it!
Each team member will need to perform the following tasks for each distance: hopping, walking backwards, walking (regular rate), and speed walking. Your team will need people with timers or stopwatches at the 5 meter and 10 meter points. Record the time it takes to perform each task.
NOTE: Speed walking is going as fast as you can without jogging or running!

Collect That Data!
Record your data from the experiment in the chart, then use the information to calculate the speed for each task and distance. Round answers to the nearest hundredth if needed. Label your answers!

Task	**Distance**	**Time**	**Speed**
Hopping	5 m		
	10 m		
Walking Backwards	5 m		
	10 m		
Walking Regular	5 m		
	10 m		
Speed Walking	5 m		
	10 m		

Think About It!
1. Which task and distance resulted in the fastest speed?
Task = _____________ Distance = _____________ Speed = _____________

2. Which task and distance resulted in the slowest speed?
Task = _____________ Distance = _____________ Speed = _____________

3. How far could you speed walk in 10 minutes based on your speed for the 10 meter trial? Show your work!

4. How long would it take you to hop 30 meters based on your speed for the 5 meter trial? Show your work!

5. How far could you travel walking backwards in 15 minutes based on your results for the 5 meter trial?
Show your work!

6. How long would it take you to walk (regular rate) 1 kilometer (or 1,000 m) based on your speed for the 10
meter trial? Show your work!

7. Are your results accurate? Why or why not?

APPENDIX C

PRE/POST/DELAYED ASSESSMENT TREATMENT UNIT 1: FORCES

Appendix C
Pre/Post/Delayed Assessment Treatment Unit 1: Forces

1. Describe two ways you can increase the frictional force between objects. Please be specific.
(Knowledge)

2. Explain why action-reaction forces do not cancel out.
(Comprehension)

3. Draw a picture for each of Newton's three laws of motion.
(Application)

4. Write a commercial to sell a new air bag for cars. Be sure to include why the air bag is needed.
(Analysis)

5. Design an experiment in which you could show that momentum is not conserved in a collision between two marbles when friction is present.
(Synthesis)

6. Suppose you are an astronaut making a space walk outside your space station and your jet pack runs out of fuel. How would you handle this situation in order to get you back to your space station?
(Evaluation)

APPENDIX D

PRE/POST/DELAYED ASSESSMENT TREATMENT UNIT 2: WORK AND

MACHINES

Appendix D
Pre/Post/Delayed Assessment Treatment Unit 2: Work and Machines

1. Describe how we calculate work and power.
(Knowledge)

2. Discuss how each of the different types of machines can be used. Include an example of each type.
(Comprehension)

3. You go rock climbing with a pack that weighs 70 N and you reach a height of 30 m. How much work did you do to lift your pack? If you finished the climb in 10 minutes (600 s), what was your power?
(Application)

4. Categorize the following tools as one of the types of simple machines or a compound machine: tweezers, steering wheel, seesaw, boat propeller, bicycle, scissors, faucet, ramp elevator, flag pole, staple, and rake.
(Analysis)

5. Your friend's parents tell him that he needs to do more work around the house. How can your friend use science to explain to them that he does plenty of work just by going through his daily activities?
(Synthesis)

6. Your friend wants to design a wheelbarrow with an ideal mechanical advantage of 5,000. What problems do your foresee with his design? What possible solutions can you see to make his idea more practical?
(Evaluation)

APPENDIX E

CONCEPT QUESTIONS RUBRIC

Appendix E
Concept Question Rubric

LEVEL ONE: KNOWLEDGE AND COMPREHENSION (understanding the basics)
4 - The work consistently demonstrates clear, accurate, detailed and comprehensive understanding of the relevant facts / data / theories/ terms as well as the ability to organize the information for application, presentation, documentation, and/or further examination.
3 - The work demonstrates an adequate understanding of the relevant facts / data / theories/ terms as well as the ability to organize the information for application, presentation, documentation, and/or further examination
2 - The work demonstrates an uneven and shaky understanding of the relevant facts / data / theories/ terms as well as a limited ability to organize the information for application, presentation, documentation, and/or further examination.
1 - The work demonstrates an inadequate understanding of the relevant facts / data / theories/ terms as well as a limited ability to organize the information for application, presentation, documentation, and/or further examination.
LEVEL TWO: APPLICATION AND ANALYSIS (attaining the concept)
4 - The work demonstrates confident ability to work with the key concepts / information / process / theory - applying or extending them to a wide variety of new problems or contexts, making predictions, recognizing hidden meanings, drawing inferences, analyzing patterns and component parts, communicating insightful contrasts and comparisons.
3 - The work demonstrates adequate ability to work with the key concepts / information / process / theory - applying or extending them to a variety of new problems or contexts, making predictions, recognizing hidden meanings, drawing inferences, analyzing patterns and component parts, communicating insightful contrasts and comparisons.
2 - The work demonstrates uneven and shaky ability to work with the key concepts / information / process / theory - applying or extending them with mixed success to new problems or contexts, making predictions, recognizing hidden meanings, drawing inferences, analyzing patterns and component parts, communicating insightful contrasts and comparisons.
1 - The work demonstrates extremely limited ability to work with the key concepts / information / process / theory - applying or extending them with very limited success to new problems or contexts, making predictions, recognizing hidden meanings, drawing inferences, analyzing patterns and component parts, communicating insightful contrasts and comparisons.

LEVEL THREE: SYNTHESIZING AND EVALUATING (going beyond the given)
4 - The work demonstrates surprising/insightful ability to take ideas / theories / processes / principles further into new territory, broader generalizations, hidden meanings and implications as well – as well as to assess discriminatively the value, credibility and

power of these ideas (etc.) in order to decide on well-considered choices and opinions.

3 - The work demonstrates adequate ability to take ideas / theories / processes / principles further into new territory, broader generalizations, hidden meanings and implications as well – as well as to assess discriminatively the value, credibility and power of these ideas (etc.) in order to decide on well-considered choices and opinions.
2 - The work demonstrates uneven and superficial ability to take ideas / theories / processes / principles further into new territory, broader generalizations, hidden meanings and implications as well – as well as a limited ability to assess discriminatively the value, credibility and power of these ideas (etc.) in order to decide on well-considered choices and opinions.
1 - The work demonstrates little ability to take ideas / theories / processes / principles further into new territory, broader generalizations, hidden meanings and implications as well – as well as a limited and superficial ability to assess discriminatively the value, credibility and power of these ideas (etc.) in order to decide on well-considered choices and opinions.

Based on a draft from Elaina Bleifield and the Paulus CT Group.

References

Peirce, W. (2006). *Designing Rubrics for Assessing Higher Order Thinking*. Available at http://academic.pgcc.edu

APPENDIX F

STUDENT SURVEY

Appendix F
Student Survey

Please rate the following 1 (strongly disagree) to 5 (strongly agree) and give an example or an explanation of why your rated yourself the way you did.

1. I am engaged in oral discussions in class.
2. Most of my classmates are engaged in oral discussions.
3. I participate regularly in oral discussions.
4. I complete my homework when assigned.
5. I am confident when taking science tests.
6. I feel like I learn a lot in class.
7. Getting good grades is important to me.
8. I enjoy coming to science class.
9. I feel confident in answering any question, regardless of the difficulty.
10. I can give explanations for why I answer questions the way I do.
11. If I do not understand something, Mrs. Gillespie explains it differently to me.
12. If I am struggling with a concept, Mrs. Gillespie realizes it and tries to fix it.

Posttreatment Add-Ins:

1. The CPS increased my engagement in lessons.
2. The CPS made me think more about why I was answering questions the way I was.
3. Using the CPS made me more excited to come to class.
4. The CPS helped me understand the content better.

Please answer the following questions:

1. What types of lessons do you feel most engaged in? What are the characteristics of this type of lesson that make you feel engaged?
2. Do you enjoy science? Why or why not?
3. What do you do to study for a test?
4. Do you feel you can justify your answers? Why or why not? Give an example.

Posttreatment Questions:

1. How do you feel the CPS changed your attitudes towards science.Explain.
2. How do you think the CPS changed your conceptual understanding of science? Explain.
3. How do you think the CPS changed Mrs. Gillespie's teaching? Explain.

APPENDIX G

TWO-TIER QUESTIONS NEWTON'S LAWS

Appendix G

Two-Tier Questions During Discussion- Newton's Laws

Directions: Using the CPS, click in your answers to the following questions. Be sure to explain your answer on a separate sheet of paper.

1. A rocket sitting on a launch pad demonstrates which of Newton's laws?
    a. First law of motion
    b. Second law of motion
    c. Third law of motion
    d. Newton's law of celestial optics
    e. Newton's law of angular momentum

    Explain your answer.

2. Rocket propulsion can be explained by Newton's ______ law of motion.
    a. First
    b. Second
    c. Third
    d. All of the above
    e. None of the above

    Explain your answer.
3. If you and your friend are standing on roller skates facing each other as shown below. What will happen if you push off your friend?
    a. You will move backwards, your friend stays in one spot.
    b. You move backwards and your friend moves forward.
    c. You move backwards and your friend moves backward.
    d. Nothing happens.

    Explain your answer.

4. You take a relatively sharp turn to the left. you feel yourself "thrown" towards the right. Which of Newton's Laws best describes what happened to you?
    a. First law of motion
    b. Second law of motion
    c. Third law of motion
    d. Newton's law of celestial optics
    e. Newton's law of angular momentum

    Explain your answer.

5. You are the quarterback of the football team. If the acceleration of the person about to tackle you is 5 m/s/s, which player would you prefer hit you?
    a. A 55 kg person
    b. A 50 kg person

c. A 45kg person
d. A 60 kg person

Explain your answer.

6. Which law explains the effect of a 10 Newton force on a baseball would be much greater than that same force acting on a truck.
   a. First
   b. Second
   c. Third
   d. All of the above
   e. None of the above
   Explain your answer.
7. Which law explains when the cannonball is fired through the air (by the explosion), the cannon is pushed backward.
   a. First
   b. Second
   c. Third
   d. All of the above
   e. None of the above
   Explain your answer.

APPENDIX H

TWO-TIER DISCUSSION QUESTIONS WORK AND POWER

Appendix H
Two-Tier Discussion Questions Work and Power

Directions: Click in your answers using the CPS, then explain your answer on a separate sheet of paper.

1. For work to be done on an object what must occur? Explain your answer.
   a. some force need only be exerted on the object.
   b. the object must move some distance as a result of a force.
   c. the object must move, whether or not a force is exerted on it.
   d. the object must not move.

2. If you exert a force of 20 Newtons to push a desk 10 meters, how much work do you do on the desk? Explain your answer.
   a. a. 200 joules
   b. b. 30 joules
   c. 10 joules
   d. 100 joules

3. Which of these is an example of work being done on an object? Explain your answer.
   a. holding a heavy piece of wood at a construction site
   b. trying to push a car that doesn't move out of deep snow
   c. pushing a child on a swing
   d. holding a door shut on a windy day so it doesn't blow open

4. In order to do work on an object, the force you exert must be ____________. Explain your answer.
   a. the maximum amount of force you are able to exert.
   b. in the same direction as the object's motion.
   c. in a direction opposite to Earth's gravitational force.
   d. quick and deliberate.

5. True or False: If you pull at an angle instead of in the direction in which the object moves, more of your force does work. Explain your answer.

6. True or False: If you lift a box from the floor to a height of 1 m and then carry the box for 10 m, you do work only when you carry the box. Explain your answer.

7. True or False: The more power you use to move an object, the more work you do. Explain your answer.

APPENDIX I

ATTENTION CHECKS

Appendix I
Attention Checks

Use the CPS and rate the following 1 (strongly disagree) to 5 (strongly agree) and explain your answers.
Within the first 10 minutes:
Currently, I am paying attention.
I fully understand the concept we are studying right now.

Half-Way through class:
Since the last check, I have been paying attention.
I fully understand the concept we are studying right now.

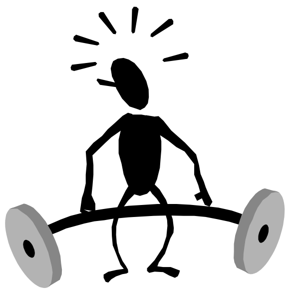
End of Class:
Since the last check, I have been paying attention.
I fully understand the concept we are studying right now.

APPENDIX J

TREATMENT UNIT 2 LAB: I WANT TO PUMP YOU UP!

Appendix J
Treatment Unit 2 Lab: I Want To Pump You Up!

I WANT TO PUMP YOU UP



All machines are typically described by a power rating. The power rating indicates the rate at which that machine can do work upon other objects. To determine the power of a machine, one must be able to calculate the work done by the machine and the time it takes to do this amount of work.

A person is a machine, which also has a power rating. Some people are more power-full than others; that is, they are capable of doing the same amount of work in less time. In this lab, you will measure your own personal power by making measurements as you climb up the steps into the gym. Additionally, you will perform one other activity in which you measure the power of your wrists, arms, etc.

1. Draw a diagram showing all the forces acting upon your body as you climb up the steps at a constant speed. Label as many forces as possible	2. Your upward force applied to your body as you climb the stairs is F = m x 9.8 [your mass is your weight divided by 2.2]
3. Write the two equations – Work = Power =	4. Make a list of all the quantities (variables), which need to be measured in order to determine your personal power as you elevate your body up the steps **Use a ruler to determine the height of the stairs (Note: 12 in = 1 ft and 3.28 ft = 1.0 m). Use a stopwatch to determine the time. 1. 2. 3.

Data Table-use a ruler/make it neat/label units:	Calculate your work and power – show your work [in the mathematical sense ☺]

<u>Part 2:</u>
Now that you have calculated the work and power in your legs, you will calculate the work and power in your arm while lifting weights. <u>Your task</u> – using one of the weights provided, calculate how much work and power your muscles in your arm do to lift the weight ninety degrees.

1. In the space, construct a diagram showing all the forces acting upon your arm as you lift the weight. Label as many forces as possible.	2. Discuss with your group how you will be able to measure the upward force applied to the weight as you lift it with your arm. (HINT: F = m x 9.8)
3. Write the two equations – Work = Power =	4. Make a list of all the quantities (variables), which need to be measured in order to, determine your personal power as you lift the weight. 1. 2. 3.

Data Table-use a ruler/make it neat/label units	Calculate your work and power – show your work [in the mathematical sense ☺]

How Fast Can You Work

Task: You have a variety of different sized dowels. You will need to determine which dowel you have the greatest and least amount of power when lifting up a 0.5 or 1 kg mass.

1. Sketch out what the set up of the experiment looks like from the discussion with Mrs. Gillespie.	2.Discuss with your group how you will be able to measure the force of the mass that you will lift. (HINT: F = m x 9.8)
3. Write the two equations – Work = Power =	4. Make a list of all the quantities (variables), which need to be measured in order to, determine your personal power as you lift the weight. Use a stopwatch to determine the time. 1. 2. 3.
Data Table-use a ruler/make it neat/label units	Calculate your work and power – show your work [in the mathematical sense ☺]

Questions:

a. In what situation did you have the least amount of work and power? The most?

b. How are work and power related?

c. Describe two ways that you could increase work.

d. Describe two ways that you could increase your power.

e. What did you learn by doing this activity? Do you have any questions that remain unanswered about work and power?

f. Be ready to do cooperative group grading.

APPENDIX K

NEWTON’S LAW’S PARAGRAPH

Appendix K
Newton's Laws Paragraph

What Makes a Bug go *Splat*?

Splat! A bug has just flown into the windshield of an oncoming car. The car must have hit the bug much harder than the bug hit the car, right? Let's figure out the whole story to make sense of the situation and answer the questions.

Buzz!

In order for the bug to fly through the air, a force has to push the bug forward. Identify this force. How does the bug produce it and what law allows it to move? (Hint: Think back to how a swimming moves through the water.)

The bug was at rest on a tree when it saw the car and decided to fly toward it. If the bug has a mass of 0.05kg and accelerates at 2 m/s^2 , what's the net force on the bug? What law allows us to calculate this?

Vroom!

The driver hates killing bugs. When she saw one coming toward the windshield, she braked suddenly and hoped it would get out of the way. (Sadly, it did not.) When she hit the brakes, what happened to her? Use one of Newton's laws to explain why.

Splat!

The unfortunate bug hits the windshield with a force of 1N. If you call this the action force, what is the reaction force? Does the car hit the bug any harder that the bug hits the car? Use one of Newton's laws to explain why or why not.

Compare the forces on the bug and the car again. Use another one of Newton's laws to explain why the bug goes splat and the car keeps going, without noticeably slowing down.

APPENDIX L

COOPERATIVE GROUP GRADING USING CPS

Appendix L

Cooperative Group Grading using CPS

1	2	3	4	5
Lowest Ranking		Average Ranking		Highest Ranking

Directions: Use the CPS to click in your ranking for the questions below. On a separate sheet of paper, please justify your rankings.

1. Rank how much you personally contributed to discussion.
2. Rank how much your group members on average contributed to discussion.
3. Rank how you behaved during lab.
4. Rank how your group members behaved during lab.
5. Rank how you contributed to setting up the lab.
6. Rank how your group contributed to setting up the lab.
7. Rank how you stayed on task during the lab.
8. Rank how your group stayed on task during the lab.
9. Rank how much you enjoyed this lab and this lesson.
10. Rank how much you felt your group enjoyed this lab and this lesson.

APPENDIX M

NEWTON’S LAWS WRAP-UP QUESTIONS

Appendix M
Newton's Laws Wrap-Up Questions

Directions: Using the CPS, click in your answers to the following questions. Be sure to explain your answer on a separate sheet of paper.

1. According to Newton's third law of motion, when a hammer strikes and exerts a force on a nail, the nail
   a. Creates friction with the hammer
   b. Disappears into the wood
   c. Exerts and equal and opposite force on the hammer
   d. Moves at a constant speed

   Explain
2. The tendency of an object to resist change in its motion is known as
   a. Mass
   b. Inertia
   c. Force
   d. Balance

   Explain
3. According to Newton's third law of motion, the strength of the reaction force is ___________ to the strength of the reaction force
   a. Less than
   b. Greater than
   c. Equal to
   d. Three times more than

   Explain
4. What force makes it less likely for a person to slip on a dry sidewalk than an icy sidewalk?
   a. Gravity
   b. Friction
   c. Inertia
   d. Momentum

   Explain

5. A 5 kg cat accelerates at a rate of 2 m/s/s. What is the net force acting on the cat?
   a. 10 N
   b. 7 N

c. 3 N
d. 2.5 N

Explain

6. According to Newton’s first law, what will plates on a table cloth do when the tablecloth is pulled out from under them? (Ignore outside forces such as friction)
    a. Fly off the table and hit the ground
    b. Accelerate with the table cloth
    c. Resist the change in motion and stay at rest
    d. Accelerate in the opposite direction of the tablecloth

    Explain

APPENDIX N

PRE/POST/DELAYED INTERVIEW QUESTIONS: NONTREATMENT

Appendix N
Nontreatment: Interview Questions

Pre/Post/Delayed Interview
Concept Map:

I would like you to construct a concept map. This is similar to what your English professor calls a web. It is a visual conceptualization of how the concepts are interrelated.

I have provided you with a set of post-it notes with the following terms: motion, reference point, distance, time, speed, velocity, acceleration, direction. The term motion will be the start of your map at the top. There are also several blank post-its and you may add in extra words to make your map.

Create a concept map by rearrange the post-it notes on the poster provided. Once you are comfortable with how you have arranged the post-its, you may choose to add new post-its to your map. Last, you need to add linking words or phrases (write on the poster) to show how concepts are related.

You may find it useful to think out loud while you do this. When you are done you will explain your concept map to me.

Concept Question: Using your concept map, explain how you describe the motion of an object.

Pre Interview Questions:
What teaching strategies help you understand material better? Explain (or why).
Did you feel that you were motivated to do the work? Explain (or why).
Are you engaged in class? Why or why not?
Do you think you understand the material?
Do you usually understand how to read a graph—why or why not?
What helps you to learn best? Why?
Are you interested in the science topics we discuss in class? Why?

Post Interview Questions
What concept(s) did you find easy to understand? Explain (or why).
What concept(s) did you find confusing? Explain (or why).
In this unit of motion, did you feel that you were motivated to do the work? Explain (or why).
Were you engaged in during this unit on motion class? Why or why not?
Do you think you understood the material covered on motion?

APPENDIX O

PRE/POST/DELAYED INTERVIEW QUESTIONS: TREATMENT UNIT 1

Appendix O
Pre/Post/Delayed Interview Questions: Treatment Unit 1

Pre/Post/Delayed Interview:
Concept Map:

I would like you to construct a concept map. This is similar to what your English professor calls a web. It is a visual conceptualization of how the concepts are interrelated.

I have provided you with a set of post-it notes with the following terms: forces, Newton, net force, friction, gravity, mass, weight, inertia, momentum, free fall, centripetal force. The term forces will be the start of your map at the top. There are also several blank post-its and you may add in extra words to make your map.

Create a concept map by rearrange the post-it notes on the poster provided. Once you are comfortable with how you have arranged the post-its, you may choose to add new post-its to your map. Last, you need to add linking words or phrases (write on the poster) to show how concepts are related.

You may find it useful to think out loud while you do this. When you are done you will explain your concept map to me.

Concept Question: Using your concept map, explain how objects react to forces.

Pre Treatment Interview Questions:
What teaching strategies help you understand material better? Explain (or why).
Do you usually understand how to read a graph—why or why not?
What helps you to learn best? Why?
Are you interested in the science topics we discuss in class? Why?

Posttreatment Questions:
What concept(s) did you find easy to understand? Explain (or why).
What concept(s) did you find confusing? Explain (or why).
Did you feel that you were motivated to do the work? Explain (or why).
Were you engaged in class? Why or why not?
Do you think you understood the material?
How did the CPS affect your understanding of the concepts? Explain (or why).
What did you see as the benefits to the CPS? Explain (or why).
What did you see as the drawbacks to the CPS? Explain (or why).

APPENDIX P

PRE/POST/DELAYED INTERVIEW QUESTIONS: TREATMENT UNIT 2

Appendix P
Pre/Post/Delayed Interview Questions: Treatment Unit 2

Pre/Post/Delayed Interview:
Concept Map:

I would like you to construct a concept map. This is similar to what your English professor calls a web. It is a visual conceptualization of how the concepts are interrelated.

I have provided you with a set of post-it notes with the following terms: work, joule, power, watt, machine, efficiency, simple machine, compound machine, mechanical advantage, input force, output force. The term work will be the start of your map at the top. There are also several blank post-its and you may add in extra words to make your map.

Create a concept map by rearrange the post-it notes on the poster provided. Once you are comfortable with how you have arranged the post-its, you may choose to add new post-its to your map. Last, you need to add linking words or phrases (write on the poster) to show how concepts are related.

You may find it useful to think out loud while you do this. When you are done you will explain your concept map to me.

Concept Question: Using your concept map, explain how machines make it easier to do work.

Posttreatment Questions:
What concept(s) did you find easy to understand? Explain (or why).
What concept(s) did you find confusing? Explain (or why).
Did you feel that you were motivated to do the work? Explain (or why).
Were you engaged in class? Why or why not?
Do you think you understood the material?
How did the CPS affect your understanding of the concepts? Explain (or why).
What did you see as the benefits to the CPS? Explain (or why).
What did you see as the drawbacks to the CPS? Explain (or why).

APPENDIX Q

CONCEPT MAP RUBRIC

Appendix Q
Concept Map Rubric

Map Component	Possible points	Awarded points	Special things noticed about map
Proposition			
Clear and meaningful to the central topic	2 each		
Beyond given set of terms	3 each		
Not properly linked	1 each		
Vague	1 each		
Branch			
Top	1		
Valid successive branches	3 each		
Valid Levels of hierarchy (general to specific)	5 each level		
Valid and Significant Cross Links	10 each		
Valid Cross Links – No synthesis between sets of related concepts	2 each		
Examples	1 each		
Total			
Overall reaction to map and special things noticed.			

References: Novak, J. D. & Gowin, D. B. (1984). *Learning how to learn*. New York, NY: Cambridge University Press.

APPENDIX R

CLASSROOM OBSERVER PROMPTS

Appendix R
Classroom Observer Prompts

Description of Lesson: Date:

Examples of use of metacognitive and/or conceptual feedback:

Student use of CPS: 1 2 3 4 5

Observations/comments:

Student attitude toward CPS: 1 2 3 4 5

Observations/comments:

Student attitude toward lesson: 1 2 3 4 5

Observations/comments:

Student desire to learn: 1 2 3 4 5

Observations/comments:

Students were engaged with the material 1 2 3 4 5
Comments:

Students aware of their own learning: 1 2 3 4 5

Observations/comments:

Class activities empowered the students to learn 1 2 3 4 5
Observations/comments:

Student/teacher interaction was positive 1 2 3 4 5
Observations/comments:

Classroom atmosphere was 'safe' and conducive to learning 1 2 3 4 5
Observations/comments:

Teacher's questioning was covered varying cognitive levels 1 2 3 4 5
Observations/comments:

APPENDIX S

TEACHER JOURNAL PROMPTS

Appendix S
Teacher Journal Prompts

My motivation regarding today's activities 1 2 3 4 5
Comments:

Today's activities were successful in encouraged critical thinking 1 2 3 4 5
Comments:

Today's activities helped students to learn 1 2 3 4 5
Comments:

Today's activities empowered the students to learn 1 2 3 4 5
Comments:

Student/teacher interaction was positive 1 2 3 4 5
Comments:

I feel positive about today's lesson 1 2 3 4 5
Comments:

APPENDIX T

TEACHER SURVEY

Appendix T
Teacher Survey

Please rate the following 1 (strongly disagree) to 5 (strongly agree) and explain your answers.

1. I am excited to start the day.

2. I am prepared for the day.

3. I needed to use my first period prep to finish preparing the lesson.

4. I feel motivated today.

APPENDIX U

CRITICAL FRIEND LUNCH MEETING PROMPTS

Appendix U
Critical Friend Lunch Meeting Prompts

Teacher's attitude/engagement/motivation toward class activities	1 2 3 4 5

Comments:

Class activities described encouraged students to think critically	1 2 3 4 5

Comments:

Class activities described encouraged students to be metacognitive	1 2 3 4 5

Class activities described encouraged closing the feedback loop	1 2 3 4 5

General comments:

APPENDIX V

PROJECT TIMELINE

Appendix V
Project Timeline

January 3, 2010- Nontreatment preunit assessment.
Preunit student survey
Started nontreatment preunit concept interviews
January 4- Nontreatment Unit: Describing Motion Introduction
January 5- Speed and Velocity Calculations
Speed Challenge/Domino Dash Activity
January 6- Finish activities
Classroom observation by colleague
January 7- Graphing Speed and Velocity Activity
Speed and Velocity Calculations
Critical friend meeting at lunch
January 10- Acceleration Activity on Computer
January 11- Finish Acceleration and Test Review
January 12- Nontreatment unit postunit assessment.
Postunit student survey
Treatment unit 1 preunit assessment
Started nontreatment postunit and treatment 1 preunit concept interviews.
January 13- Pretreatment student survey
What's a Newton? Cooperative Group Grading
Classroom observation by colleague.
January 14: Introduce Treatment Unit 1: Forces
Attention checks at beginning, middle and end of class
Cognitive level questions with observations
Critical friend meeting at lunch.
January 18- Friction and Gravity Introduction
Cognitive level questions with observations during lesson.
January 19- Sticky Sneakers Activity – Cooperative Group Grading
January 20- Calculating Newton's Activity
Classroom observation by colleague
January 21- Newton's Laws of Motion Demonstrations
January 24 – Newton's Laws Lecture
Attention checks at beginning, middle and end of class
Cognitive level questions with observations
January 25- What Changes Motion? Activity – Cooperative Group Grading
January 26- Finish activities
Nontreatment Unit Delayed Assessment
Started nontreatment unit delayed concept interviews
January 27- Wrap up Newton's Laws Discussion
Attention checks at beginning, middle and end of class
Cognitive level questions with observations during lesson

Classroom observation by colleague
January 28 – Introduce Momentum
Attention checks at beginning, middle and end of class
Cognitive level questions with observations during lesson
Critical friend meeting at lunch
January 31- Library Day – No Class
February 1- Review Momentum, Newton's Laws
February 2- Mythbusters Videos Promoting Newton's Laws and Scientific Method
February 3- Test Review
Classroom observation by colleague
February 4- Forces Treatment Unit 1 postunit assessment
Started Treatment Unit 1 postunit and treatment unit 2 concept interviews
Critical friend meeting at lunch
February 7- Work and machines treatment unit 2 preunit assessment
Introduce work and power
Attention checks at beginning, middle and end of class
Cognitive level questions with observations during lesson
February 8 – Finish Work and Power Introduction
February 9 – Introduce Understanding Machines
Attention checks at beginning, middle and end of class
Cognitive level questions with observations during lesson
February 10- I Want to Pump You Up! Activity- Cooperative group grading
Classroom observation by colleague
February 11- Mechanical Advantage and Efficiency
Attention checks at beginning, middle and end of class
Cognitive level questions with observations during lesson
Critical friend meeting at lunch.
February 14- Inclined Planes and Levers
Attention checks at beginning, middle and end of class
Cognitive level questions with observations during lesson
February 15- Putting Machines Together
Attention checks at beginning, middle and end of class
Cognitive level questions with observations during lesson
February 16- EdHeads Machines Activity in Computer Lab
February 17- Test Review
Classroom observation by colleague
February 18- Treatment Unit 2 postunit assessment
Delayed assessment treatment unit 1
Posttreatment student surveys
Started treatment unit 2 postunit and delayed treatment unit 1concept interviews
Critical friend meeting at lunch
March 4- Delayed Assessment treatment unit 2
Started delayed assessment treatment unit 2 interviews

APPENDIX W

PROJECT OUTLINE

Appendix W
Project Outline

EFFECTS OF INCORPORATING CLASSROOM PERFORMANCE SYSTEMS WITH METACOGNITIVE AND CONCEPTUAL STRATEGIES ON THE UNDERSTANDING OF PHYSICAL SCIENCE CONCEPTS

I. Introduction and Background
  a. Project Focus
  b. Reason why needed
    i. AYP results from last 3 years
    ii. Not getting accurate data
    iii. Immediate feedback
  c. CPS in schools
    i. Using for summative
    ii. Many other uses not aware of
  d. Metacognitve Strategies
    i. Definition
    ii. Benefits
    iii. How incorporating with CPS
  e. East Valley Middle School
    i. 400 students
    ii. 35% free and reduced lunch
    iii. 150 8^{th} graders
  f. Focus Questions and Subquestions
    i. Focus Question: Student Understanding
    ii. Subquestion 1: Long-term memory
    iii. Subqeustion 2: Varying levels of questions
    iv. Subquestion 3: Student attitudes
    v. Subquestion 4: Student engagement
    vi. Subquestion 5: Teacher attitude
  g. MSSE Support Group
    i. Dr. Jewel Reuter, Ph.D. – Advisor
    ii. Dr. Irene Grimberg and Dr. Shannon Willoughby- Readers
    iii. Dan Rispens, Ryan Hazen- editors
    iv. Todd Samson, Jana Nygaard – critical friends

II. Conceptual Framework
  a. Why CPS Created
    i. Learn more by answering than being told

ii. More interactive
iii. More like 1 to 1 ratio

b. What is CPS
    i. Popular in higher education
    ii. Not much research done in secondary education
c. Metacognitive strategies
    i. Not much research with CPS
    ii. Pick up metacognitive strategies from other places
        1. Teachers (especially!)
        2. Peers
        3. Parents
    iii. Increases learning
        1. Especially when used to generate discussion
        2. Improves problem solving skills
d. Long Term Memory
    i. Results controversial
        1. Older studies show little improvement
        2. Newer studies who marked improvement
    ii. Immediate Feedback
        1. Harder questions retained more
        2. Easier questions retained less
e. Varying Levels of Cognitive Questions
    i. Bloom's Taxonomy Levels
    ii. CPS used for lower levels
        1. Multiple choice questions
        2. Generate discussion
    iii. CPS for higher levels
        1. Multiple answer questions
        2. Sequence type questions
f. Student Attitude in Class
    i. Overall positive
    ii. Favor immediate feedback
    iii. Believe it increased learning
g. Student engagement
    i. CPS Increase engagement
    ii. Keeps students participating
    iii. Keeps students from watching passively
    iv. Must commit to an answer
h. Teacher attitude

i. Overall positive
ii. Use it more find more benefit in it

i. Purpose of Study
   i. Student understanding
   ii. Long term memory
   iii. Bloom's taxonomy
   iv. Student attitude
   v. Student engagement
   vi. Teacher attitude

III. Methodology
   a. Project Treatment
      i. Treatment vs. Nontreatment
         1. Nontreatment – "Describing Motion"
         2. Treatment 1 – "Forces"
         3. Treatment 2 – "Work and Machines"
      ii. Describing Motion
         1. Traditional teaching
         2. Pretest
         3. Table talk
         4. Lab assignment
         5. Hand raising
         6. Fingers for level of understanding
         7. Inaccurate data
         8. Posttest
         9. Delayed
      iii. Forces
         1. Treatment unit
         2. Pretest
         3. Metacognitive Survey
         4. Multiple choice clickers with justification
         5. Histogram = immediate feedback
         6. Attention checks – beginning, middle, end
         7. Interview
         8. Discussion questions – reasoning
         9. Newton's Paragraph
         10. Cooperative Group Grading
      iv. Metacognition
         1. Aware of reasoning
         2. Attention checks

3. Being able to justify answers
4. Compare themselves to others

b. Data Collection Instruments
   i. EVMS
      1. 8th grade
      2. Poor community
      3. 47 minute classes
      4. 30 students
   ii. Triangulation Matrix
   iii. Student Understanding
      1. Pre/Post unit assessments
      2. Pre/Post unit concept map
      3. Pre/Post unit perception of understanding interview questions
   iv. Long-Term Memory
      1. Post unit delayed assessment
      2. Postunit delayed interview
      3. Postunit delayed concept map
   v. Cognitive Levels
      1. Pre/Post unit assessment
      2. Random questions with observations
      3. Pre/Post unit Interview Questions
   vi. Attitudes and Engagement
      1. Pre/Post unit student surveys
      2. Engagement check and observations with guide
      3. Cooperative group grading
   vii. Teacher Attitudes
      1. Journal with prompts
      2. Personal observations with guide and Self Survey
      3. Critical friend observations

IV. Data Analysis and Results
   a. Student Understanding
      i. Pre/Post unit assessments
      ii. Pre/Post unit concept map
      iii. Pre/Post unit perception of understanding interview questions
   b. Long-Term Memory
      i. Post unit delayed assessment
      ii. Postunit delayed interview
      iii. Postunit delayed concept map

c. Cognitive Levels
    i. Pre/Post unit assessment
    ii. Random questions with observations
    iii. Pre/Post unit Interview Questions
d. Attitudes and Engagement
    i. Pre/Post unit student surveys
    ii. Engagement check and observations with guide
    iii. Cooperative group grading
e. Teacher Attitudes
    i. Journal with prompts
    ii. Personal observations with guide and Self Survey
    iii. Critical friend observations

V. Interpretation and Conclusion

VI. Value