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The effects of self-examination to peers on student learning in physical science

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THE EFFECTS OF SELF-EXPLANATION TO PEERS ON
STUDENT LEARNING IN PHYSICAL SCIENCE

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ABSTRACT

This study was undertaken to test if the use of self-explanation to a peer would affect learning outcomes in the classroom. The outcomes of classes taught using the self-explanation technique were compared to outcomes from traditional lecture courses in lessons of comparable content. Great Scholars and traditional students in a sixth grade physical science classroom setting were given pre-and post-tests in two units of study, matter and waves. In the matter unit, students participated in a lesson on density using traditional lecture and a lesson on changes in matter using self-explanation. In the waves unit, students utilized lecture instruction for a lesson on electromagnetic waves and self-explanation instruction for a lesson on sound waves. Pre-test scores, post-test scores, and learning gains were analyzed for each lesson across instructional treatments and class types. After the unit on waves students were given an opinion survey to determine which instructional method they preferred using.

Self-explanation had a significantly positive impact on learning gains for the Great Scholars students in the first unit of study. No detectible differences in gains for the second unit of study were found in either group of students. However, the opinion survey given after the second unit of study suggests that students experience greater enjoyment when using the self-explanation instructional technique. Larger sample sizes and experiments in other science disciplines may lead to a better understanding of how self-explanation to a peer impacts student learning.

INTRODUCTION

A Need for Change in Instructional Techniques

The 1983 report *A Nation at Risk* described a failing education system in the United States (National Commission on Excellence in Education, 1983). The report called for reform and shortly afterward national educational standards were drafted. These national standards were used in many cases to write state standards in mathematics and science in hopes of creating a shared experience of rigor and relevance in all classrooms (U.S. Department of Education, 2008). Now the state of Louisiana, 30 years later finds itself in much the same position described in the 1983 report. Of Louisiana public schools, 44.1% received a grade of D or F in the 2010-2011 school year based on state performance scores (Louisiana Department of Education, 2012). State performance scores are based on student scores on the LEAP, *i*LEAP and Graduation Exit exams, drop-out rates, attendance of students, and graduation outcomes. In the 2009-2010 school year 19,224 students dropped out of school in Louisiana and did not return to an educational setting (Louisiana Department of Education, 2012). Most signs indicate that what the Louisiana public educational system has been doing on a broad scale is not working for students.

We are in the midst of change once again with national Common Core standards aiming to drive our students toward achievement (Mathis, 2010). In order to support the rigor of Common Core standards teachers, administrators, and superintendents need to increase availability, training, and usage of research-based strategies in our classrooms on a daily basis (National Research Council, 2011). Since *A Nation at Risk* was published educational research has focused on experimenting with cognitive ability, engagement, and the physical changes of the brain when learning takes place (Zull, 2002). By implementing educational research in our classes and our schools daily, perhaps we, as teachers, can embrace the coming change, make the

most of it, and most importantly serve justice to our students by changing the statistics for Louisiana.

Traditional versus Active Learning Classrooms

Lecture-based classes, or classes with whole-group instruction have several benefits for teachers. These types of lessons require less time and fewer resources to prepare (Chism, 1989), they allow the teacher to cover the maximum amount of material in a limited amount of time (Felder, 1993; Mulryan-Kyne, 2010), and they afford the teacher the ability to supervise the entire class (Nicol & Boyle, 2003). Lecture-based courses have also been used frequently in the university setting to accommodate large numbers of students, limited time by faculty researchers (Chism, 1989), and have often been defaulted to as an effective teaching style (Felder, 1993; Mulryan-Kyne, 2010).

One limitation of lecture-based instruction is that students are viewed as a *tabula rasa* upon which knowledge can be inscribed. Students often play a passive role in this environment and are required to interact with the material at a minimal level (Mulryan-Kyne 2010; Dufresne, Gerace, Leonard, Mestre, & Wenk, 1996). Students in lecture-based courses are less confident about their ability to do and explain science and overall they score lower on self-efficacy tests than students taught with active learning strategies (Ebert-May, Brewer, & Allred, 1997). Another limitation of lecture-based instruction is that this cover-all approach of whole class instruction does not account for culture, personal experience, prior knowledge, learning style, and other facets which makes learners unique (Felder,1993).

Studies in a post-secondary setting have indicated that active-learning strategies can significantly improve student understanding and learning (Hake, 1998; Costin, 1972). Classes that incorporate interactive-engagement activities have been found to have twice the gains as

traditional lecture-based courses (Hake, 1998). In a survey of 6,578 students which examined pre- and post-test scores for introductory mechanics courses, classes using "heads on" and hands on strategies to promote discussion between peers and instructors had twice the normalized learning gains compared to traditional lecture-based courses (Hake, 1998). Studies comparing cooperative learning (Anderson, Mitchell, & Osgood, 2005), discussion (Lake, 2001; Costin, 1972), peer instruction (Crouch & Mazur, 2001), frequent quizzing (Fitch, Drucker, & Norton, 1951), and projects (Costin, 1972) to traditional lecture-based courses have consistently found higher learner gains in the active "student centered" classrooms.

Like other interactive engagement activities, the act of self-explanation occurs at a pause in the direct instruction and stimulates a thought process in the learner that requires the student to integrate prior knowledge with new information that is being presented in order to create a functional generalization for their learning process (DeJong, 2001). According to Chi and VanLehn (1991), "A self-explanation is a comment about an example statement that contains domain relevant information over and above what was stated in the example line itself" (Chi & VanLehn, 1991). Ainsworth and Burcham (2007) went farther by grouping self-explanation statements made by learners into seven distinct categories:

1) **Principle-based explanation**: the learner makes a reference to the underlying domain principle in an elaborated way (e.g., this is due to diffusion as molecules are spreading from a greater concentration to a lesser concentration).

2) **Goal-driven explanation**: the learner makes an explanation that inferred a goal to a particular structure or action. (e.g., valves of the heart come together to prevent blood flowing in the wrong direction).

3) **Elaborative explanations**: the learner inferred information from the sentence in an elaborated manner. Metaphors, analogies, and elaborations that link prior material to new ideas are classified in this category (e.g., so the skeletal muscles in the blood vessels squeeze the blood in the right direction, a bit like a hand squeezing toothpaste out a tube).

4) **Noticing coherence**: the learner notices an association between a previous concept and the current material without elaborating.

5) **Monitoring- negative/positive:** the learner states that he or she did or did not understand the material presented (e.g., Okay. that makes sense or I didn't really understand that).

6) **Paraphrasing**: the learner reiterates the information presented using their own words.

7) **False self-explanation:** the learner self-explains within one of the previous categories but the explanation itself is incorrect.

Ainsworth and Burcham (2007) noted that while students who self-explain have greater gains than students who do not, those learners who more frequently used principle-based explanations and paraphrasing had greater gains from the pre-test to post-test scores than other types of self-explanation. Ainsworth and Loizu (2003) found a significant correlation between goal-driven explanations and learning outcomes with students using diagrams and accompanying text.

No matter the type, quality, or quantity of self-explanations, students' use self-explanation strategies to plan, monitor, and evaluate their comprehension of diagrams, text, lecture, and animations, showed improvement in student understanding and learning is observed (Bielaczyc, Pirolli, & Brown, 1995). It is believed that self-explanation is useful because it asks learners to identify and elaborate relationships between main ideas, determine the meaning of

examples that are used, and connect concepts that have been presented in different ways, i.e., text and example problems (Bielaczyc et al., 1995).

Review of Self-Explanation Studies

Identifying the value of self-explanation began with a comparison of the habits of good problem-solvers and poor problem-solvers in mechanics (Chi & Bassock, 1989). Good problem-solvers produced an average of 15.9 elaboration ideas for each worked example problem, while poor problem-solvers produced only 4.3 statements per example. The quality of the explanations between good and poor solvers also differed. Poor solvers made more paraphrasing statements while the good solvers made more inferences and extensions of the problem at hand. Good students were also more readily able to identify when they were failing to comprehend a subject (9.3 statements per example) while poor solvers tended to make positive comprehension statements (6.3 per example) when in fact they were not understanding the material correctly. Thus, good problem solvers self-explain with higher frequency and can accurately assess their progress with greater frequency than poor problem solvers.

Extending previous work, Chi, Mei-Hung, and LaVancher (1994) found that students can be prompted to self-explain resulting in significant academic gains. A group of eighth grade biology students were prompted to self-explain the meaning of each sentence in a passage on the circulatory system as they read along. The control group was not prompted to self-explain, but was allowed to read the passage twice to control for time on task. Students were assessed using a pre-test post-test comparison. Overall the prompted group significantly out-performed the unprompted group. More interesting is that for the more difficult, more conceptual based questions on the post-test, students in the prompted group increased their pre-test post-test scores by 32% while the control group increased their scores by 12.5%. Even with time on task as a

consideration, the prompting of students to summarize, clarify, or put in their own words the meaning of what they read increases their ability to perform on higher-order questions. While this study strongly supports the use of self-explanations in the middle school classroom it only investigated one facet of the classroom experience, reading text. In a modern science class students and teachers are often involved in labs, activities, cooperative learning, model making, and the design of experiments. This leads to questions of whether the self-explanation effect is transferable to other common classroom activities, different subject areas, and different age levels.

Teichert (2002) experimented with self-explanation in a college level thermodynamics course. In the traditional course, students attend a lecture from a professor and a study session implemented by a teaching assistant. In a study session students would ask to have problems worked out or explained by the teaching assistant, ask for clarification on lecture points, or simply listen to further lecturing by the teaching assistant. In this traditional setting students understood the quantitative thermodynamics problems, they struggled, however, with the higher level conceptual questions on exams. In seeking an alternative structure for the course that better supported student learning an experimental discussion session was put in place. In this experimental discussion session students were encouraged to discuss and explain problems to one another and the teaching assistant based on what they had already gathered from lecture. Students in the experimental group performed significantly better on thermodynamics questions on the midterm exam, scoring on average 72/94 problems correct while the control group scored 61/94 questions correct. This gain persisted to the final exam where the self-explaining group outperformed the control group on thermodynamics questions. Qualitative interviews with students in each discussion group about specific concepts covered in the discussions found that

students from the self-explaining group had a deeper functioning knowledge of bond enthalpy and thermodynamics. Thus, self-explanation not only works with students reading from a textbook, it also works in a much more dynamic class environment where students are prompted to self-explain to peers and instructors.

Building on the work of Chi et al. (1994), Bielaczyc et al. (1995) sought to determine if self-explanation strategies can be taught and implemented in a way that produced even greater gains than simply telling a student to “explain out loud” as they progress through a lesson. They worked with a group of 24 university students in computer programming. The strategies of high performing self-explainers were explicitly taught to half of the programming students. The other half served as a control group. Those students who had received instruction in self-explaining learned to self-monitor their comprehension of the activity at hand and strategies to clarify and address comprehension failures.

During the programming lessons both groups were asked questions to help self-monitor comprehension, but it was found that those who had direct instruction in how to monitor their own learning excelled in the problem-solving programming at hand. Those who had been taught to self-explain showed significantly greater gains between their pre- to post-intervention lessons as well as increased quality of the self-explanations they produced during the study. From this study one can deduce that metacognitive self-explanation strategies can be taught and used effectively to produce greater learning gains in a population.

Rationale for Study

Self-explanation has been shown to increase overall student performance and student performance on higher order questions (Chi et al., 1994). These results have been replicated with middle school (Chi et al., 1994) and college age students in disciplines from life science to

computer programming (Chi et al., 1994; Bielaczyc et al., 1995; Teichert, 2002). The improvement due to self-explanation has been demonstrated both in controlled experiments and in more realistic and dynamic classroom situations where students interact with one another as well as the instructor over an extended period of time.

Because of the demands for improved student performance and the financial strains on our educational system, teaching strategies improving student engagement and learning gains with little monetary investment by the teacher or institution are much needed. The use of self-explanation as a classroom tool to increase student achievement may be important in achieving this end. This study tested the hypothesis that middle school science students can be taught, prompted, and use effectively self-explanation strategies to produce significant learning gains compared to a traditional note and lecture class.

In order to test the effectiveness of self-explanation in a sixth grade classroom setting, a study was undertaken using students in two physical science classes that were taught units both with and without explicit directions to use self-explanation. Assessments of the students' gains in knowledge were made using a pre- and post-test protocol. All students were given a pre-test prior to the unit and a post-test covering the material in the pre-test at the conclusion of the units. The topics taught were lessons on density, changes in matter, sound waves, and electromagnetic (EM) waves. Students were given a typical lecture and note course for density and electromagnetic waves units followed by a post-test. For the units on changes in matter and sound waves, students were given a lecture and note class for each unit. After the traditional lecture, students were presented with eight concept-related photographs and were prompted to explain the photos to another student in the class using information from the lecture. Following the explanations

students were given the post-test for each unit. The performance of the students using these two teaching protocols were compared to assess the effectiveness of self-explanation in a sixth grade class setting.

MATERIALS AND METHODS

Design of Pre- and Post-tests

To assess student learning for the density, changes in matter, sound, and electromagnetic waves units, a pre- and post-test for each topic was designed using resources available through the Teacher's Edition of *Science A Closer Look* (Ride, Barrerra, American Museum of Natural History, 2012). The sound wave assessment is comprised of four multiple choice, one open response, and a short expository text (Cloze) with eight key words removed (Appendix B). The density (Appendix C), changes in matter (Appendix D), and electromagnetic wave (Appendix E) assessments contained four multiple choice, one constructed response, and a Cloze with nine key words removed. For each test the Cloze was accompanied with a word bank for students to choose from, students were instructed that words may be used once, more than once, or not at all. The assessments were chosen to represent a variety of question types that are appropriate for a sixth grade reading level and are representative of content directly related to the content in the Louisiana Comprehensive Curriculum.

Definition of the Study Population

The study population consisted of 41 sixth grade middle school science students at Woodlawn Middle School in Baton Rouge, Louisiana. Twenty-five of the students were in a Great Scholars class where students have scored at the Mastery level for two subtests of the iLEAP state exam. The remaining 16 students were in a traditional sixth grade science course and did not qualify for the Great Scholars Program. The ages of the students ranged from 11-14. All attended a sixth through eighth grade traditional Title One middle school where ethnic minorities are the majority (Table 1) and 74% of students received free or reduced lunch (Table 2). Overall, the study population showed a similar distribution to the school population. Due to a

transient population, absences, suspensions and expulsions varying numbers of students participated in each test. A total of 34 participants took the pre and post-test sequences for density and changes in matter. A total of 35 participants took the pre and post-test sequences for sound waves for electromagnetic waves.

Table 1. Ethnic make-up of study population compared to school population. (eschoolPLUS)

Ethnic Make-Up of Woodlawn Middle School Baton Rouge, LA		
	Study Population	School Population
Black	53.7%	64.5%
White	24.4%	25%
Hispanic	14.6%	6.5%
Asian	2.4%	4%
Other	4.9%	0%

Table 2. Free/reduced lunch status of school population. (eschoolPLUS)

Title 1 Free/reduced Lunch Population for Woodlawn Middle School Baton Rouge, LA	
Free	65%
Reduced	9%
Full Price	26%

Administration and Assessment of Control and Experimental Techniques

Before conducting research all participants and parent/guardians were made aware of educational research being conducted in the classroom. All participants and guardians in the study agreed to allow anonymous data to be collected from their scores on classroom activities. The parental consent and student assent forms used in this study (Appendix A) were approved by

the Institutional Review Board at Louisiana State University. This study received an exemption from the Institutional Review Board (E5996) and was approved by East Baton Rouge Parish School System Department of Accountability, Assessment, and Evaluation.

This study examined pre- and post-test data for a total of four units of study in the sixth grade classroom. An attempt was made to make control and experimental units closely related not only in content but depth and rigor. The first set of control and experimental units were density (control) and changes in matter (experimental). The second set of control and experiment units were sound waves (experimental) and electromagnetic waves (control). Additionally, a pilot study of the second unit was conducted in 2012 using a similar population of sixth graders. For the pilot study sound waves served as the control while electromagnetic waves served as the experimental treatment. For students requiring extended time and tests read-aloud these accommodations were provided for those individuals on both pre- and post-tests.

Two weeks before each unit of study students were administered pre-tests for the control and experimental units to follow. As incentive for students to fully apply themselves they were offered bonus points for each correct answer on the pre-test. Aside from tests read aloud as required by law, students were not provided any clarification or assistance on these exams. Students could view their earned bonus points on the online grade book interface but had no indication as to what was answered correctly or incorrectly. For the control units, density and electromagnetic waves, students were given guided notes and lectured via PowerPoint on the materials for one class period. If questions were asked during the lecture, they were answered to the whole class at that time. Lecture pace was adjusted to fit student needs, which differed between the Great Scholars and standard education classes. Afterward, students were given the

opportunity to study their guided notes on their own for approximately ten minutes and ask any questions they needed before the administration of the post test.

For the experimental units, changes in matter and sound waves, students were again given guided notes and lectured via PowerPoint for one class period. However, in the experimental units students were given a series of pictures, available through Google Images, after the notes to facilitate the explanation of concepts to one another. Before beginning the explanation process students were guided to use statements like "I know this because.." or "This is like…." or "This happens because…." While students were explaining concepts aloud to peers they were monitored by the instructor to maintain focus and participation.

For example, after changes in matter lecture, students were asked to decide whether a picture illustrated a chemical or physical change, and then they were prompted to explain to their partner how they knew what type of change it was. After students were given the opportunity to share their reasoning with each other one or two explanations were chosen to share with the class before moving along to the next photo. For each experimental unit a total of eight photos were used to facilitate self-explanations over the course of approximately ten minutes. After viewing the pictures and explaining to their partners students were then administered the post-test.

After the second unit of study, Sound and EM waves, students were given an eight question survey (Appendix F) to gather feedback on their perception of each instructional technique. To avoid bias in the survey results students were given the survey before they were made aware of their post-test scores. The survey was constructed as a set of statements that students could rate on a scale of one to five with one being strongly disagree and five being strongly agree. The survey was aimed at identifying which instructional methods they enjoyed more and which they thought allowed them to learn more.

Dealing with Absences and Transient Populations

As with any school, students come and go, miss days, or change schedules. For these reasons several student scores were excluded from the study data. Students missing one or more pre- or post-test scores from a unit were excluded from the study. In the first unit, density and changes of matter, three students were excluded from the study for this reason. Also in the first unit of study, one student made a perfect score on the pre-test; for this reason those data points were excluded in the learning gains analysis. In the second unit, sound and EM waves, three unique students were excluded for missing scores. Aside from those students whose absences affected their having all data points, several students moved to or from the study populations between units. Three students who were included in the data set for the first unit of study moved from the school before the second unit was initiated. Likewise, five new students entered the population after the first unit of study, and their scores were included in the second unit study population.

Statistics Analysis

Pre- and post-test data were analyzed with a Friedman test and Dunn's post-test using GraphPad InStat version 3.00 for Windows 95, GraphPad Software, San Diego California USA, www.graphpad.com. The effects of three separate variables were analyzed: teaching strategy, traditional or Great Scholars class grouping, and unit of study (e.g. Density and Changes of Matter or Sound and EM waves). Learning gains were calculated for each unit of study using Hake's (1998) formula for learning gains: learning gain = (post-test – pre-test) ÷ (max score – pre-test). Learning gains were analyzed by class type and instructional method with a Kruskal-Wallis test with Dunn's post-test, as well as a Wilcoxon matched-pairs signed-ranks test using GraphPad InStat.

RESULTS

Analysis of Pre-and Post-test Scores with Learning Gains

In the first unit of study, Properties of Matter, students received traditional lecture instruction for density and self-explanation instruction for changes in matter. In the Great Scholars class, for the lecture instruction, there was significant improvement in post-test averages ($P < 0.05$) over the pre-test class average (Figure 1). The self-explanation post-test mean score was improved over the pre-test average score for the class ($P < 0.001$). For the traditional class, improvement in post-test average was only observed only for the material taught with self-explanation ($P < 0.01$). There was no significant difference between the lecture pre-test (7.00 ± 0.834) and lecture post-test (8.20 ± 0.634) class averages (Figure 2).

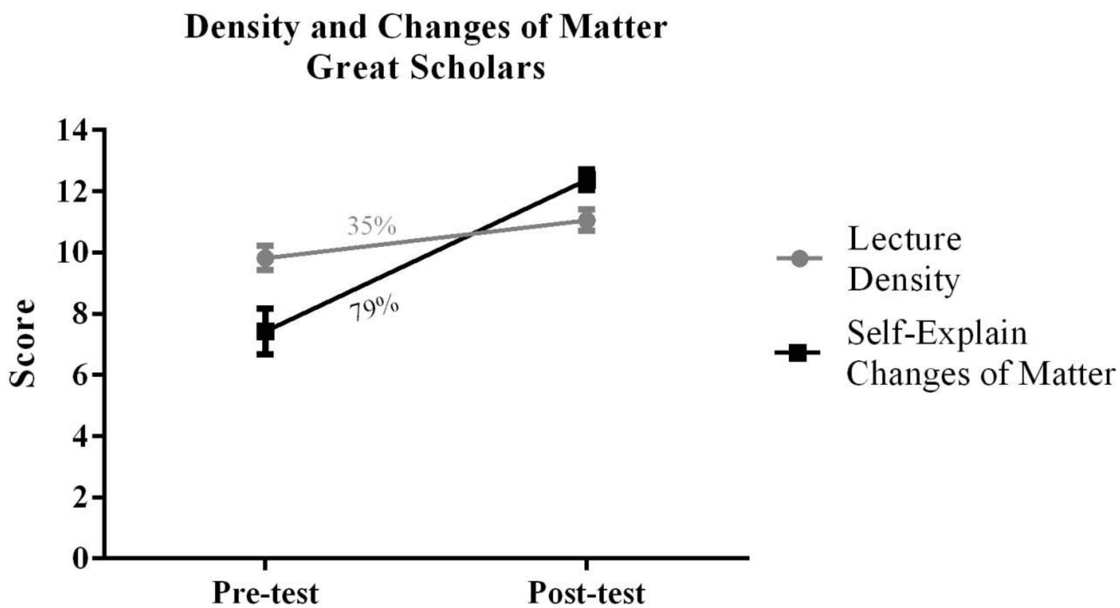

Figure 1. Pre- and Post-test scores for Great Scholars students covering density with a traditional lecture style instruction, and chemical vs. physical changes using self-explanation instruction. Means and standard errors are shown. N = 19. The percent learning gains are indicated.

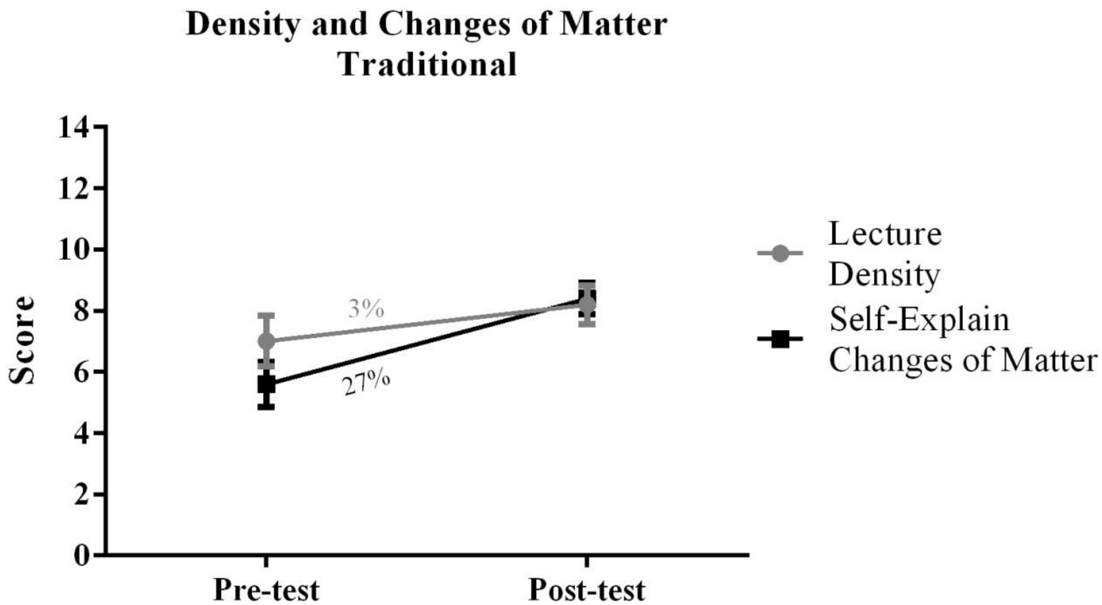

Figure 2. Pre- and Post-test scores for traditional students covering density with a traditional lecture style instruction, and chemical vs. physical changes using self-explanation instruction. Means and standard errors are shown. N = 15. The percent learning gains are indicated.

Learning gains for the first unit of study were calculated using Hake's (1998) formula (Table 3). One student in the Great Scholars class made a perfect score on the pre-test and his scores for that test were excluded from the data set. In the Great Scholars class learning gains for the self-explanation instruction were significantly higher than with lecture instruction($P < 0.001$). The Great Scholars class also showed significantly greater gains with self-explanation when compared to the traditional course ($P < 0.001$). No significant differences were found in the learning gains of the traditional class between lecture and self-explanation instruction.

Table 3. Learning gains for the first unit of study, Density and Changes of Matter. Means and standard errors are shown for the two instructional modes used.

	Lecture Instruction	Self-Explanation Instruction
Great Scholars (N =18)	0.351 ± 0.071	0.785 ± 0.047*
Traditional (N =15)	0.036 ± 0.161	0.265 ± 0.103

*A Wilcoxon matched-pairs test determined that in the Great Scholars class Self-Explanation gains were significantly greater than gains in the lecture course ($P= 0.0007$).

The second unit of study occurred in the second semester and covered sound and EM waves. For the sound lesson students used self-explanation and for EM waves students received traditional lecture instruction. In the Great Scholars class there was improvement in post-test average over pretest averages in the lecture presentations ($P < 0.001$) and the self-explanation instruction ($P < 0.05$) (Figure 3). For the traditional class, improvement was observed between the lecture pre- and post-test scores ($P < 0.05$). There were no differences between the self-explanation pre-test (4.39 ± 0.661) and post-test (7.12 ± 0.640) averages (Figure 4).

Learning gains for the second unit of study were calculated using Hake's (1998) formula (Table 4). No significant differences were found in the gains between instructional method or class type.

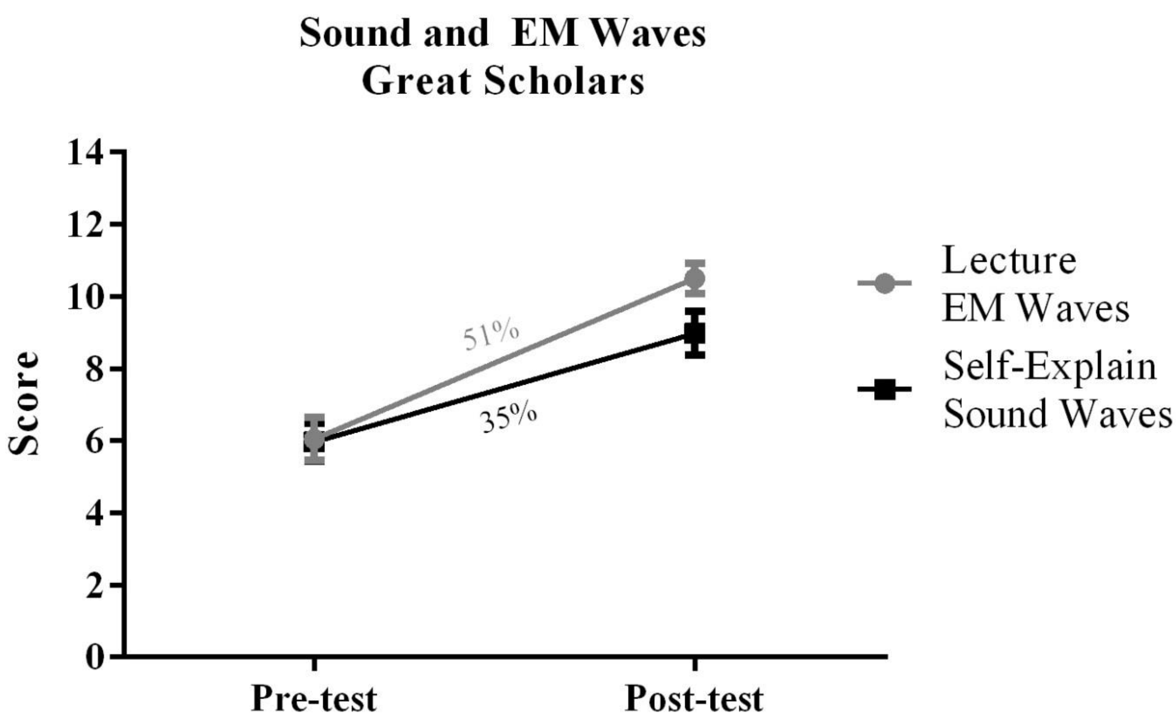

Figure 3. Pre- and Post-test scores for Great Scholars students covering EM Waves with a traditional lecture style instruction, and Sound waves using self-explanation instruction. Means and standard errors are shown. N = 22. The percent learning gains are indicated.

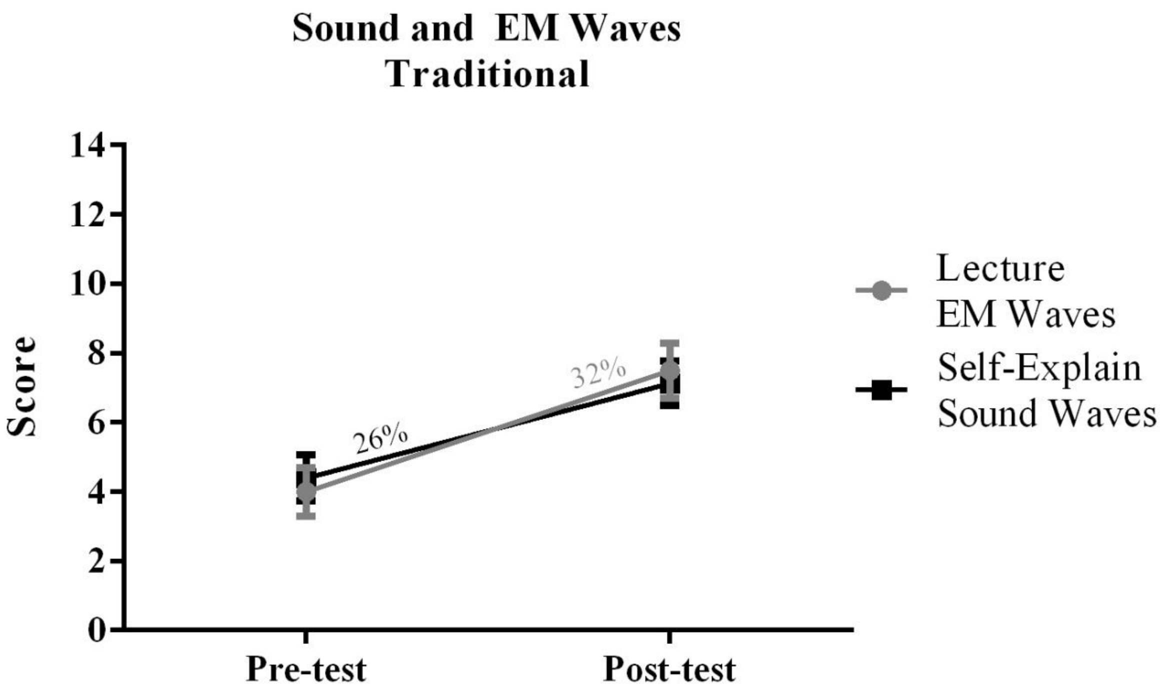

Figure 4. Pre- and Post-test scores for traditional students covering EM Waves with a traditional lecture style instruction, and Sound waves using self-explanation instruction. Means and standard errors are shown. N = 13. The percent learning gains are indicated.

Table 4. Summary of learning gains for the second unit of study, Sound and EM Waves. Means and standard errors are shown for the two instructional modes used.

	Lecture Instruction	Self-Explanation Instruction
Great Scholars (N = 22)	0.508 ± 0.068	0.353 ± 0.082
Traditional (N = 13)	0.323 ± 0.088	0.260 ± 0.082

Opinion Survey

In an attempt to quantify student enjoyment for each instructional method in the second unit of study students were given an eight question opinion survey. This survey can be found in appendix F. Students responses were ranked from one to five, one being strongly disagree and five being strongly agree. Data from the survey were analyzed using Kruskal-Wallis test and

Dunn's post-test using GraphPad InStat (Figure 5). Significant differences (P <0.05) were found between questions 3 and 5 (I enjoyed X), 4 and 6 (X helped me understand the topic better), and 7 and 8 (I think X waves are easier to understand and learn about).

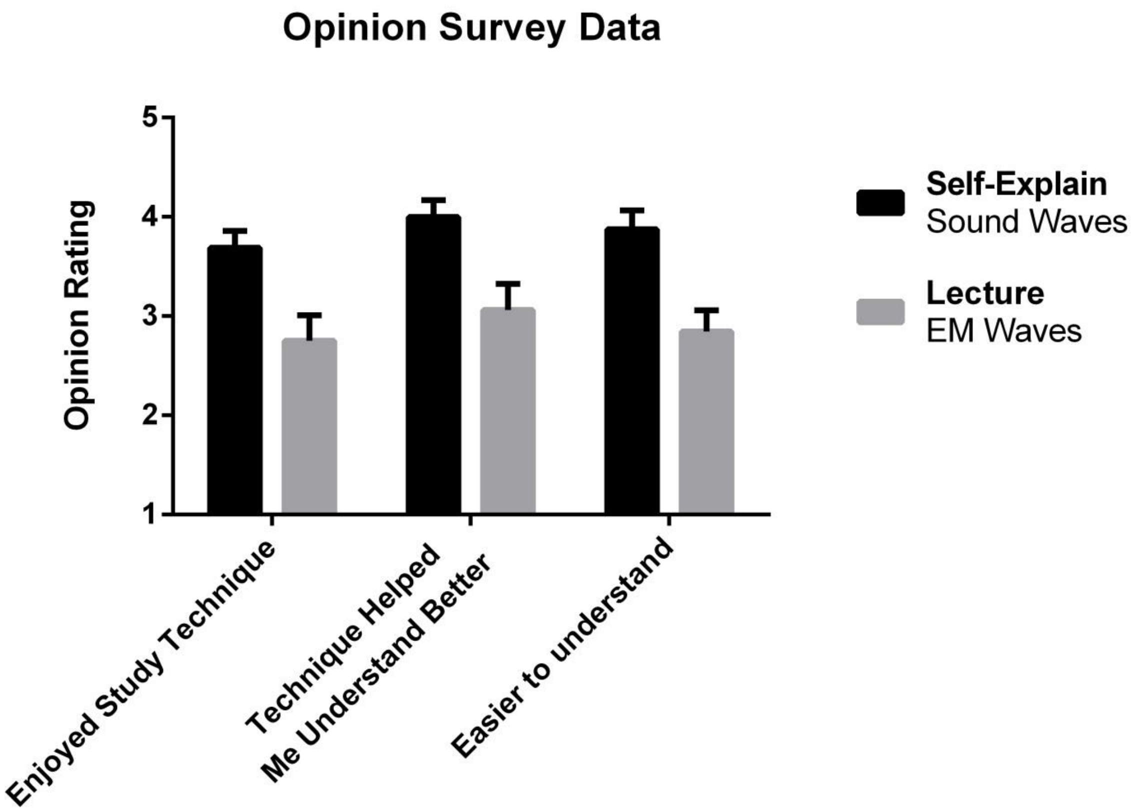

Figure 5. Summary of the opinions expressed by students after the completion of the second unit, sound and EM waves. Students were surveyed about their opinions on which a Likert scale was used; opinions were ranked from one (strongly disagree) to five (strongly agree) for each question on the survey. N = 32. For each of the questions above significant differences were found (P < 0.05).

Pilot and Study Data

Pilot data for this study were collected in the Spring semester of 2012 covering the sound and EM waves unit with a similar population of sixth grade traditional and Great Scholars students. In contrast to present study data, the pilot study used lecture instruction for the sound waves lesson and self-explanation for the EM waves lesson. Pre and post-test data were analyzed

using a Kruskal-Wallis Test with post-test comparisons (Figure 6). Improvements were seen between both the lecture pre- and post-tests (P <0.001) and the self-explanation pre- and post-tests (P <0.001). No differences were found between the pre-tests and post-tests across instructional treatments.

Because of the nature of the inverse treatments between pilot and study data, pre-and post-test scores for sound waves (Figure 7) and EM waves (Figure 8) were compared across treatment types. No differences were found between post-test scores for either group.

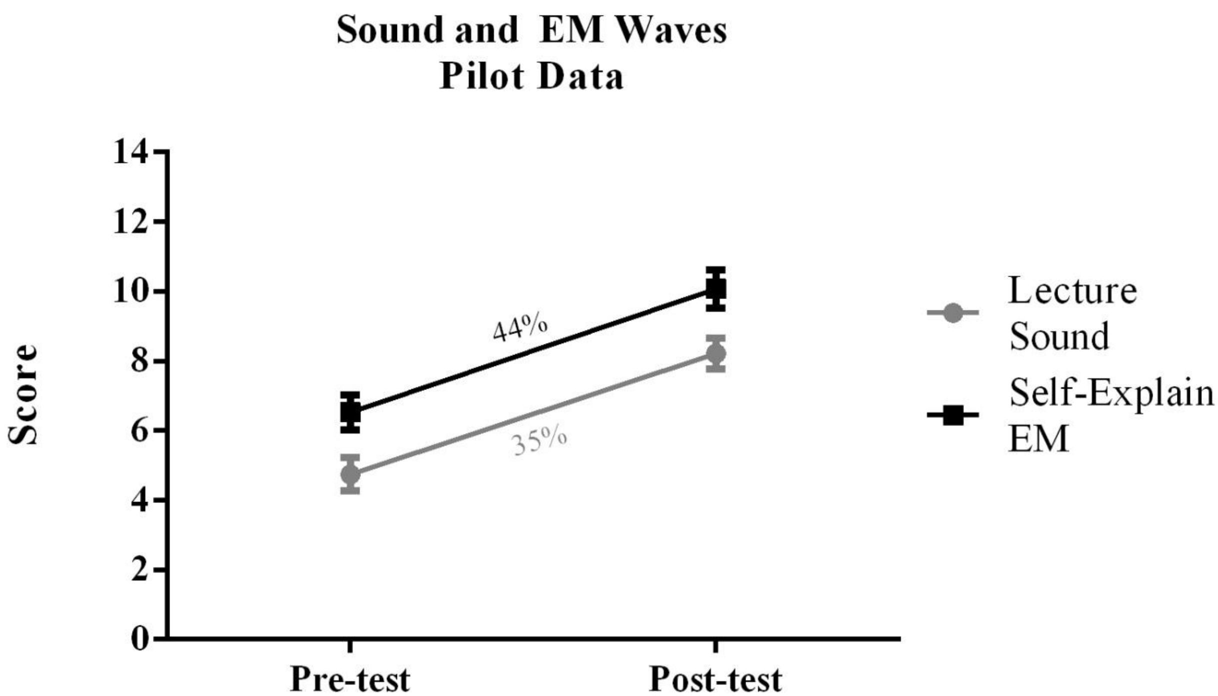

Figure 6. Pre- and post-test scores for pilot data collected in 2012. Means and standard errors are shown for the two instructional modes used. The sound lesson used lecture instruction and had a sample size of N = 35. The EM lesson used self-explanation and had a sample size of N = 38. The percent learning gains are indicated.

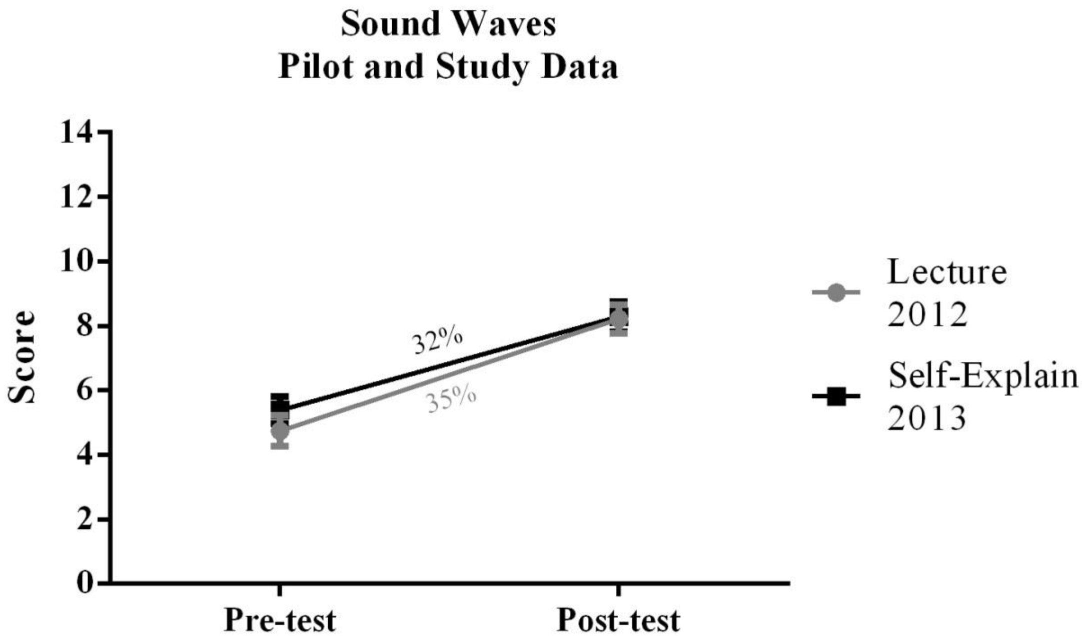

Figure 7. Pre- and post-test scores from pilot and study data on sound waves. Pilot data for sound waves used lecture instruction while study data for sound wave used self-explanation. Means and standard errors are shown for the two instructional modes used. For lecture 2012 N =35. For Self-explanation 2013 N= 35. The percent learning gains are indicated.

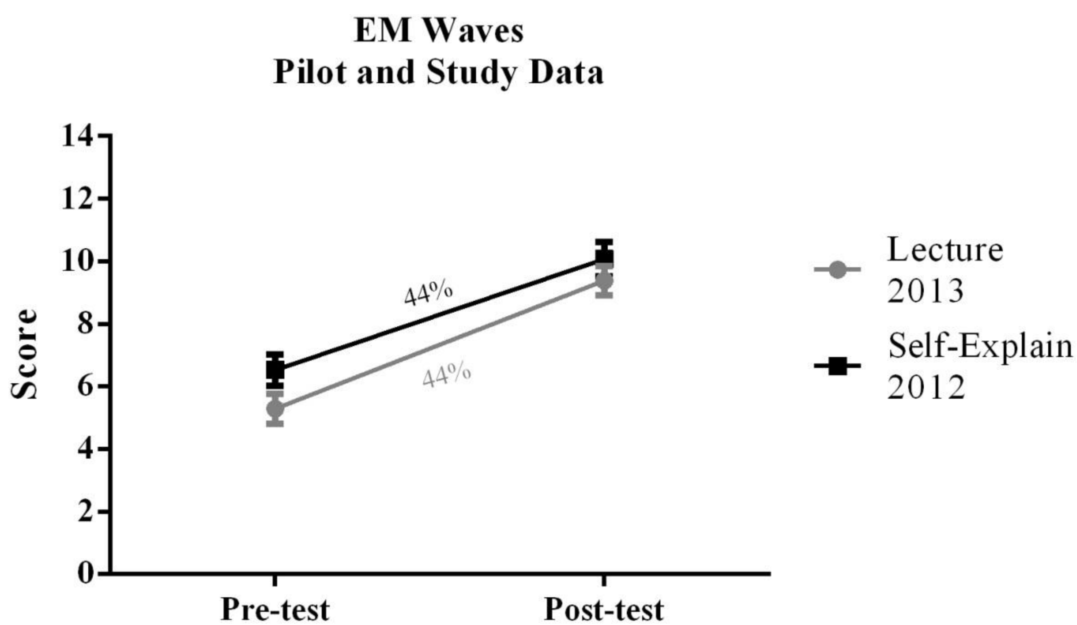

Figure 8. Pre- and post-test scores from pilot and study data on EM waves. Pilot data for EM waves used self-explanation while study data for EM wave used lecture instruction. Means and standard errors are shown for the two instructional modes used. For lecture 2013 N = 36. For Self-explanation 2012 N= 38. The percent learning gains are indicated.

DISCUSSION

Pre- and Post-test Scores by Class Type

In the density and EM waves lessons the study Great Scholars students had higher pre-test scores than traditional students (Mann-Whitney test) indicating that they came to the lessons with a greater amount of background knowledge. Great Scholars students also consistently had higher post-test scores (Figure 1, Figure 2, Figure 3, Figure 4) and more pronounced gains from pre- to post-test than their traditional peers (Table 3, Table 4). These differences could be attributed to a multitude of variations between the populations including: frequency of learning and behavioral disabilities, levels of oral and written communication skills, reading levels, and intrinsic motivation to learn. However, even with the traditional students being lower scoring overall, their pre- to post-test trends still followed the trends of the Great Scholars students in each unit and lesson, just to a lesser degree.

Pre- and Post-test Scores by Instruction Type and Unit

In the first unit of study, density and changes of matter, students had more pronounced significance from the pre-test to post-test scores when the self-explanation instruction was used compared to lecture instruction (Figure 1, Figure 2). Significantly greater learning gains were observed using self-explaining in the Great Scholars class (Table 3). In the second unit of study, sound and EM waves, significant differences were seen from the pre- to post-test in the lecture instruction for all students (Figure 3, Figure 4) as well as self-explanation instruction in the Great Scholars class (Figure 3). No significant gains were found across instructional methods for either class (Table 4). In the pilot study data for the second unit of study no significant differences were found in pre-and post-test data between lecture instruction and self-explanation instruction (Figure 6).

Qualitative Observations and Opinion Survey

Initially the gains from each unit of study across instructional type seem to be conflicting and thus inconclusive to the effects of self-explanation. Results of the opinion survey given after the second unit of study suggest that while there was no significance between learning gains in self-explanation or lecture instruction, students continually rated self-explanation learning higher on the Likert scale than lecture instruction (Figure 5). From a teaching perspective, producing higher levels of student enjoyment and creating positive perceptions of lessons carries great weight in the overall success or failure of a lesson.

Other observational data from each unit of study adds some insight when viewed in conjunction with data. The first unit of study occurred approximately one month into the school year; students were very focused and not yet casual in the classroom with their peers. There was near 100% participation in both the lecture and self-explanation activities, and self-explanation was taught after the lecture lesson to prevent the use of the technique in the control group. Principle-based and elaborative explanations, as well as monitoring, paraphrasing, and false self-explanations were observed during these lessons. Both topics in the first unit, density and changes in matter, were topics where students had significantly more of background information on the subject which was evident by their pre-test scores (Kruskal-Wallis test).

The second unit, sound and EM waves, was taught eight months into the school year where the classroom climate is markedly different than in the first few months. Self-explanation instruction was used before lecture instruction which could have possibly contributed to students voluntarily using self-explanation techniques internally during the lecture lesson. Principle-based and elaborative explanations, positive monitoring statements, and paraphrasing were also observed in these lessons. However, there was a higher frequency of negative monitoring

statements and false self-explanations than in the first unit of study. By this point in the year students had become more casual. They had also begun to show signs of difficulty with the material due to lack of prior knowledge. Often in these particular classrooms this lack of background knowledge can act as a motivational barrier to participation and engagement since students may feel like they don't have much to contribute, or may not have the correct framework to ask appropriate questions (Legault, Green-Demers, & Pelletier, 2006). In both the lecture instruction and the self-explanation instruction of the second unit students had to be reminded frequently to stay on task, follow along, and participate as directed.

Comparison of Pilot and Study Data

To further explore the lack of significant differences in the second unit of study, sound and EM waves, an analysis of pilot data provided some insight. Similar to the study data, no significant differences were found in the pre- and post-test scores for self-explanation instruction when compared to lecture instruction (Figure 6). Additionally, due to the inverse nature of the pilot study's instructional treatments, it was possible to analyze each lesson, sound and EM waves, by instructional treatment. Again, no differences were found for either instructional treatment in either of the lessons (Figure 7, Figure 8).

Comparison of Data to Previous Findings

It was hypothesized that self-explanation with the added element of peer interaction would increase student understanding and engagement and middle school science. In the examination of the first unit of study significant gains were found with self-explanation to peers when compared to lecture based instruction (Figure 1, Figure 2, and Table 3). These data are consistent with gains seen in previous self-explanation (Chi, 1994 Bielaczyc, 1995, Tiechert

2002) and peer-to-peer communication studies (Hake, 1998, Anderson, 2005, Lake, 2001, Costin, 1972, Crouch, 2001).

While the second unit of study and the pilot data indicate no detectible differences between self-explanations and lecture instruction (Figure 3, Figure 4, Table 4, Figure 7, Figure 8) the opinion survey suggests higher levels of enjoyment with the self-explanation learning technique (Figure 5). Similar results were found in a meta-analysis of cooperative learning research at the college level, showing that some lectures show gains on the lower end of gains found in cooperative learning classrooms, but that overall students perceive greater levels of social support both from other students and the instructor in cooperative college classrooms than in individualistic ones (Smith, 2005). Lake (2001) and Crouch (2001) found the opposite to be true in college students, with student perceptions of interactive course design being lower while their performance ranked higher when compared to traditional lecture-based course model.

Many studies on cooperative learning and self-explanation have taken place at the post-secondary level where the socioeconomic and ethnic makeup of students is markedly different than what is seen in this study (College Board, 2013). Low socioeconomic status has been widely used as a dropout predictor, and is linked to lower cognitive achievement in academic settings (Bradley & Corwyn, 2005). It has also been linked to a growing disparity in knowledge over the course of a student’s academic career due to lack of stimulation in the summer months (Alexander, Entwisle, & Olson 2001). Variations in the results of this study may differ from those in previous studies due to these population differences.

Researching and studying the efficacy of teaching strategies in an ongoing classroom provides unique research challenges. There are many factors out of the control of the researcher that can impact the success or failure of a lesson. Student absences, student behavior, transient

populations, small sample sizes, school-wide interruptions, behavioral disorders, learning disabilities, and reading levels can all impact the outcome of a lesson and are beyond the researcher's ability to control. Thus differences in the treatment and control teaching strategies, no matter how small, could potentially be hinting at significant increases in student learning. Ideally the effects of self-explanation could be further studied with extension of the experiment over multiple years. This would allow the instructional treatments to be rotated among lessons as well as a larger sample for both Great Scholars and traditional students. The use of self-explanation in life and earth sciences could also offer some insight to whether or not the amount of background knowledge has an effect on the efficacy of self-explanation in the classroom.

SUMMARY AND CONCLUSION

This study compared self-explaining to a peer with traditional lecture to determine if the self-explanation instructional method had an effect on student learning outcomes. There were significant learning gains in both lecture instruction and self-explanation instruction. Trends in the first unit of study suggest that students using self-explanation to a peer experience had greater learning gains (Table 3) and post-test scores (Figure 1, Figure 2) than in in the lecture course. No significant differences were found between self-explanation and lecture instruction in the second unit of study; it is possible that this is due to lower levels of background knowledge upon which to build explanations. It is also important to note that in the second unit of study self-explanation was equally as effective as lecture instruction (Figure 3, Figure 4, Table 4). However, students reported greater satisfaction with the self-explanation to a peer than with traditional lecture (Figure 5). The results of this study suggest that self-explanation to a peer can produce significant learning gains and more positive student perceptions toward learning new material.

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APPENDIX A
STUDENT ASSENT AND PARENT CONSENT FORMS

Study Exempted By:
Dr. Robert C. Mathews, Chairman
Institutional Review Board
Louisiana State University
203 B-1 David Boyd Hall
225-578-8692 | www.lsu.edu/irb
Exemption Expires: 6/3/2015

Student Assent Form

I,________________________________, agree to be in a study to find ways to help students better learn and retain knowledge. I will have to do normal school work in my classroom, without extra outside work being added. I have to follow all the classroom rules, and will follow the instructions as outlined by my teacher. I can decide to stop being in the study at any time without getting in trouble.

Child's Signature:____________________________ Age:______ Date:____________

Witness* ___________________________________ Date:_________________

- (N.B. Witness must be present for the assent process, not just the signature by the minor.)

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Study Exempted By:
Dr. Robert C. Mathews, Chairman
Institutional Review Board
Louisiana State University
203 B-1 David Boyd Hall
225-578-8692 | www.lsu.edu/irb
Exemption Expires: 6/3/2015

Parental Permission Form

Project Title: The Impact of Prompted Reflection on Student Achievement.

Performance Site: Woodlawn Middle School

Investigators: Leah Thompson

The following investigators are available for questions about this study, Monday – Friday, 9:00 AM to 3:00 PM.
Dr. Joseph F. Siebenaller 225-578-1746 or 225-578-5224
Leah Thompson 225-751-0723

Purpose of the Study: The purpose of this research project is to determine the impacts of active and cooperative learning on student achievement in the science classroom.

Inclusion Criteria: Students in a basic Middle School Science classroom.

Exclusion Criteria: Students not in Middle School Science for the duration of the study.

Description of the Study: This study is designed to compare the learning impacts of traditional lecture and note taking science classes to a more interactive and reflective learning practice. All students will participate in both styles of learning over several units of study during the year. Pre and post-test scores will be collected and compared for the traditional and active learning styles.

The benefit of this study will be to enhance the collective understanding of effective science instruction in the middle school setting. Findings will be presented to fellow teachers throughout Louisiana to inform science instructors of the results of this study. Students will receive participation grades for all study related activities in the classroom, and thus an opportunity to enhance their overall average in class.

There are no known risks to this study.

Right to Refuse: Participation is voluntary, and a child will become part of the study only if both child and parent agree to the child's participation. At any time, either the subject may withdraw from the study or the subject's parent may withdraw the subject from the study without penalty or loss of any benefit to which they might otherwise be entitled.

Privacy: Investigators may review the pre and posttest scores of participants in this study. Results of the study may be published, but no names or identifying information will be included for publication. Subject identity will remain confidential unless law requires disclosure.

Financial Information: There is no cost for participation in the study, nor is there any compensation to the subjects for participation.

Signatures:

The study has been discussed with me and all my questions have been answered. I may direct additional questions regarding study specifics to the investigator. If I have questions about subjects' rights or other concerns, I can contact Robert C. Mathews, Chairman, Institutional Review Board, (225) 578-8692, irb@lsu.edu, www.lsu.edu/irb.

I will allow my child to participate in the study described above and acknowledge the investigator's obligation to provide me with a signed copy of this consent form.

Parent's Signature:______________________________ Date:__________________

APPENDIX B
SOUND PRE- AND POST-TEST

LESSON
Cloze Activity

Name ______________________________ Date ____________

Waves and Sound

Fill in the blanks.

compressions	intensity	pitch	spread apart
frequency	medium	rarefactions	wavelength

Sound is a type of wave called a compressional wave. Sound waves cause the particles making up a(n) __________________ to squeeze together and then __________________. The places in a sound wave where the particles are close together are called __________________. The places where the particles are spread apart are called __________________.

Sound waves have a(n) __________________, which is the distance from one crest, or point of greatest compression, to the next. Sound waves also have a(n) __________________, which is the number of compressions that pass a point in one second. The frequency of a sound wave determines its __________________. The amplitude of a sound wave is a measure of the wave's __________________. The loudness of sound is measured in a unit called the decibel. Regular speech has a volume of about 60 decibels.

Name ______________________________ Date ____________

Lesson 2 Test

Circle the best answer for each question.

1. Which term is matched to its correct definition?
   - **A.** wavelength—number of crests that pass a point in one second
   - **B.** frequency—distance between wave crests
   - **C.** amplitude—distance between the crest and the midpoint of a wave
   - **D.** pitch—amount of time it takes for a wave to complete one complete revolution

2. A wave passes through a medium. As the wave passes through, the particles that make up the medium
   - **A.** can consist of only liquids and gases.
   - **B.** do not transfer energy to one another.
   - **C.** become permanently displaced.
   - **D.** return to about the same position after the wave has passed.

3. Use the table to predict the decibel level for an ambulance siren.

Sound	Decibel Level (dB)
Normal conversation	60
Vacuum cleaner	80
Automobile horn	115
Jet engine (30 meters away)	140
Rocket engine (50 meters away)	200

   - **A.** 75 dB
   - **B.** 90 dB
   - **C.** 120 dB
   - **D.** 210 dB

4. When two sound waves meet in constructive interference, they
   - **A.** have a larger amplitude.
   - **B.** have a lower sound.
   - **C.** cancel each other.
   - **D.** increase in frequency.

Critical Thinking Explain why you can hear people talking even after they walk around the corner of a building.

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APPENDIX C
DENSITY PRE- AND POST-TEST

LESSON
Cloze Activity

Name ______________________ Date __________

Density and Buoyancy

Fill in the blanks.

buoyant force	float	pushes
density	less	sink
distances	particles	solid

The ______________ of an object is found by dividing its mass by its volume. When an object is placed in a fluid, the fluid ______________ in on the object. This push is called the ______________. If a fluid is denser than the object, the object will ______________. If the object is denser than the fluid, the object will ______________.

The density of an object depends on the mass of the ______________ that make up the object and the ______________ between them. In general, a(n) ______________ is the densest state of matter. However, solid water is ______________ dense than liquid water. The particles in ice are more spread out than the particles in liquid water. Because of this, ice floats on water.

Name ______________________ Date __________ **Lesson 2 Test**

Circle the best answer for each question.

1. The table below lists the densities of various liquids.

Liquid	Density (g/cm^3)
Acetic acid	1.05
Ammonia	0.82
Chloroform	1.49
Glycerin	1.26
Seawater	1.02
Turpentine	0.87
Water	1.00

Which substances will float on water?

A. seawater and acetic acid
B. ammonia and turpentine
C. chloroform and glycerin
D. glycerin and turpentine

2. A crown has a mass of 500 g. It displaces 25 mL of water. What is the density of the crown?

A. 5 g/cm^3
B. 20 g/cm^3
C. 25 g/cm^3
D. 50 g/cm^3

3. A can of soda pop with a mass of 605 g displaces 550 mL of water in a bucket. What is the buoyant force of the water on the can?

A. 1.1 g
B. 55 g
C. 550 g
D. 605 g

4. What happens to a sandwich that becomes flattened under the weight of a heavy backpack?

A. The density of the sandwich decreases.
B. The density of the sandwich stays the same.
C. The density of the sandwich increases.
D. The buoyancy of the sandwich increases.

Critical Thinking Alligators control their buoyancy in water by eating rocks. Use Archimedes' Principle to explain how rocks in its stomach can be an advantage to an alligator.

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APPENDIX D
CHANGES IN MATTER PRE- AND POST-TEST

LESSON
Cloze Activity

Name ______________________ Date __________

Physical and Chemical Changes

Fill in the blanks.

atoms	iron oxide	physical change
chemical changes	light	sharpening
color change	liquids	state

Matter can undergo changes. A(n) ______________ is a change that alters the form of an object without changing what type of matter it is. For example, ______________ your pencil is a physical change. Sharpening a pencil does not change the chemical makeup of the pencil. It is still a pencil. Changes of ______________ are also physical changes.

During some changes, new substances form. These changes are called ______________. For example, when iron rusts it combines with oxygen to form a new substance called ______________. After a chemical change, the ______________ in the substances that have formed are arranged differently from the original substances. The signs of a chemical change may include ______________, the formation of a gas, and the release of ______________ or heat. Another sign that sometimes occurs when two ______________ combine is the formation of a precipitate.

Lesson 5 Test Name ______________________________ Date ____________

Circle the best answer for each question.

1. Which is an example of a chemical change?
   A. sharpening a pencil
   B. iron rusting
   C. ice melting
   D. glass breaking

2. Which is <u>not</u> a sign of a chemical change?
   A. A solution evaporates when left at room temperature.
   B. A powdery, white precipitate forms.
   C. Gas bubbles begin to form.
   D. A solution suddenly becomes cold to the touch.

3. The diagram below shows logs burning.

   Which kind of change is occurring?
   A. neutralization
   B. physical change
   C. chemical change
   D. precipitation

4. Hot, melted wax is poured into a container. As it cools, a solid layer of wax forms at the top. What is <u>most likely</u> occurring?
   A. neutralization
   B. a physical change
   C. a chemical change
   D. precipitation

Critical Thinking Critique this statement: Physical changes are changes that are always easy to reverse, and chemical changes are always hard to reverse.

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APPENDIX E
EM WAVES PRE- AND POST-TEST

LESSON
Cloze Activity

Name ______________________________ Date ____________

Electromagnetic Waves

Fill in the blanks.

energy	infrared rays	radio waves
field	magnetic	space
harmful	medical	visible light

Electromagnetic waves can travel through matter or ________________. When an electric charge vibrates, its electric ________________ also vibrates. Changes in the electric field produce a corresponding change in the ________________ field. The range of electromagnetic waves forms the electromagnetic spectrum.

The longest waves in the electromagnetic spectrum are ________________. Next come microwaves and then ________________. The light that people can see, ________________, falls in the middle of the spectrum.

The shorter electromagnetic waves have greater ________________ and in large amounts are ________________ to living things. However, these electromagnetic waves also have ________________ uses. For example, they are used to kill bacteria and viruses.

Name ______________________________ Date ____________ **Lesson 4 Test**

Circle the best answer for each question.

1. An object appears black because it
   - **A.** reflects all visible light.
   - **B.** absorbs all visible light.
   - **C.** refracts all visible light.
   - **D.** emits very long wavelengths of light.

2. Which type of electromagnetic wave is related to thermal energy?
   - **A.** radio
   - **B.** infrared
   - **C.** visible
   - **D.** X-rays

3. The ozone layer absorbs much of the ultraviolet radiation Earth receives from the Sun. If the ozone layer grew thinner,
   - **A.** Earth would heat up.
   - **B.** cell phones would work better.
   - **C.** more people would develop skin cancer.
   - **D.** visible colors would appear brighter.

4. Study the table below.

Color	Wavelength (nanometers)
Red	680
Orange	600
Yellow	570
Green	510
Blue	475
Indigo	445
Violet	400

Which wavelength of light is not visible to the human eye?
   - **A.** 750 nanometers
   - **B.** 650 nanometers
   - **C.** 550 nanometers
   - **D.** 425 nanometers

Critical Thinking A rose with green leaves and red flowers was photographed in green light. What color will the leaves and flowers appear in the photograph? Explain your answer.

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APPENDIX F
OPINON SURVEY

Opinion Survey

Name:____________________________________

Put an X in the box for the answer that best matches your opinion for each statement

1. I liked the guided notes for sound better than electromagnetic waves

[ ] Strongly agree [ ] Agree [ ] No opinion [ ] Disagree [ ] Strongly Disagree

2. I liked the guided notes for electromagnetic waves better than sound waves

[ ] Strongly agree [ ] Agree [ ] No opinion [ ] Disagree [ ] Strongly Disagree

3. I enjoyed explaining the pictures after the sound waves notes

[ ] Strongly agree [ ] Agree [ ] No opinion [ ] Disagree [ ] Strongly Disagree

4. I think explaining the pictures after the sound notes helped me understand the topic better

[ ] Strongly agree [ ] Agree [ ] No opinion [ ] Disagree [ ] Strongly Disagree

5. I enjoyed studying on my own after the electromagnetic waves notes

[ ] Strongly agree [ ] Agree [ ] No opinion [ ] Disagree [ ] Strongly Disagree

6. I think studying on my own after the electromagnetic waves notes helped me understand the topic better

[ ] Strongly agree [ ] Agree [ ] No opinion [ ] Disagree [ ] Strongly Disagree

7. I think sound waves are easier to understand and learn about

[ ] Strongly agree [ ] Agree [ ] No opinion [ ] Disagree [ ] Strongly Disagree

8. I think electromagnetic waves are easier to understand and learn about

[ ] Strongly agree [ ] Agree [ ] No opinion [ ] Disagree [ ] Strongly Disagree

VITA

L. Ellis Thompson was born in Gainesville, Florida in 1988. She attended elementary and middle school in Palatka, Florida. She graduated from Palatka High School with Honors in May 2006. In August of 2006 she entered studies at Louisiana State University Agricultural and Mechanical College and in August 2010 earned the degree of Bachelor of Science in Biological Sciences. She entered the Louisiana State University Agricultural and Mechanical College in May 2010 as a candidate for the Master of Natural Sciences degree. She is currently a science teacher at Woodlawn Middle School in Baton Rouge, Louisiana.