THE EFFECT OF METACOGNITIVE STRATEGIES ON SUBSEQUENT PARTICIPATION IN THE MIDDLE SCHOOL SCIENCE CLASSROOM

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I have examined the final copy of this Thesis for form and content and recommend that it be accepted in partial fulfillment of the requirement for the degree of Master with a major in Curriculum and Instruction.

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DEDICATION

This thesis is dedicated to all my students, past and present, with disabilities. They have taught me how to function as a “normal” person, in spite of trying circumstances.

ABSTRACT

Metacognitive activities allow students to monitor the way in which they think, which encourages sustained thinking about science concepts. Teachers can sanction procedures that allow students to articulate the thinking process which in turn may foster greater voluntary participation. Research has shown that metacognitive strategies allow students to link concepts together, resulting in deeper understanding of science concepts. This promotes more in-depth questioning and understanding. In this research, eighth grade middle school students took part in two different types of metacognitive activities while learning about density: think-pair-share and answering metacognitive questions. This study examined the relationship between the strategies and voluntary participation in subsequent class discussions. Results indicated that the overall percentage of participation did differ significantly by group (chi square = 11.01, $p<.004$), with the rankings (highest to lowest) as follows: Metacognition Questions group (mean rank=16.50), Think-Pair-Share (mean rank=15.25), Control group (mean rank=5.75). When gain scores were calculated by using day 1 as a baseline and comparing it to the average of days 2-7, no statistical significance was shown between groups. The study also examined the relationship between the strategies and student achievement. There was no statistical significance between groups for student achievement. The study also examined the relationship between the strategies and long-term retention. There was no statistical significance between groups for long-term retention.

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CHAPTER ONE

THE PROBLEM

Rationale

Many challenges await a teacher when stepping into the science classroom. The teacher will encounter a variety of students from different backgrounds and experiences. The distinctive blend of experience, personalities, and learning styles comes together to create a unique situation for each group of students and their teacher. Each student comes to the science classroom with different degrees of background knowledge on the various topics that are taught. The informal information gathered by the author each school year bears this out over and over. One student may have earned a scout badge over electricity; one student may have traveled extensively and have first-hand knowledge of oceans and rivers; and another student may have a considerable amount of information about the effect of radon gas in residential homes from overhearing the conversations of his parents who are realtors. Classroom observations, casual conversation with students, graded assignments, test scores, and end-of the-year surveys have all allowed the author to appreciate the distinct differences among students. Since individual students connect to various types of lessons differently, teachers utilize a variety of activities that address the needs of learners using the various multiple intelligences and learning styles.

Howard Gardner's *Frames of Mind (1983)* extended the traditional definition of intelligence. Gardner defines intelligence as "the ability to solve problems that one encounters in real life, the ability to generate new problems to solve, the ability to make something or offer a service that is valued within one's culture." (Silver, Strong, & Perini, 2000, p. 7).

From Gardner's definition, the perception of intelligence was expanded from the traditional two intelligences of verbal and computational to seven intelligences: logical-mathematical, linguistic, spatial, musical, bodily-kinesthetic, intrapersonal, and interpersonal. Gardner maintains that "all human beings possess not just a single intelligence. . . Rather, as a species we human beings are better described as having a set of relatively autonomous intelligences (Gardner, 2004, p. 4). Learning styles address the way in which students learn. The different learning styles include the following: mastery learners—"efficient and result-oriented, preferring action to words, and involvement to theory", understanding learners—"prefer to be challenged intellectually and to think things through for themselves", self-expressive learners—"dare to dream, are committed to their values, are open to alternatives, and are constantly searching for new and unusual ways to express themselves", and interpersonal learners—"sensitive to people's feelings—their own and others" (Silver et al., 2000, pp. 25-27). Access to this information challenges teachers to think about their students' abilities beyond the traditional mode, expanding from conventional ways of teaching.

Even after learning about science concepts through activities that address the various intelligences and learning styles, many students do not choose to participate in classroom discussions. Instead a select few students answer teacher generated questions and develop their own questions on the topic, while the rest of the students remain mute. A wealth of information from the students' unique backgrounds and experiences may go untapped. Even when prodded to respond by the age-old inquiry by the teacher, "Does anyone have any questions?" the same select few respond. Based on the lack of response from the majority of the students, many times the teacher assumes the students that do not speak up have mastered the material, but the results of an assessment over that topic frequently indicate something different. This can lead to frustration for both the student (Willingham, 2003) and the teacher.

Metacognition may offer a solution. Flavell states that "Metacognition refers to one's knowledge concerning one's own cognitive processes or anything related to them, e.g., the learning-relevant properties of information or data" (Flavell as cited in Dantonio & Beisenherz, 2001, pp. 43-44). Quite simply, metacognition is thinking about thinking. Any process in which students examine the method that they are using to retrieve, develop or expand information is deemed to be metacognitive in nature. Therefore, questions generated by the teacher would be considered metacognitive in nature if the questions invoke the process used to arrive at a response rather than soliciting a correct answer based on the student's memory of the material.

In a previous action research project that investigated participation, students first answered metacognitive questions in a journal, shared the information from their entry with a classmate, and then discussed the topic as a whole class (Stuever, 2005). Results showed that a greater percentage of students were willing to participate in subsequent whole class discussions, answering questions created by the teacher and posing well-thought out questions about the topic. As an outcome of the increased participation, students were willing to discuss the topic at hand, allowing for misconceptions to be uncovered. The increase of in-depth conversations gives the teacher and the students the opportunity to assess their comprehensive understanding of the concepts being taught (Beeth, 1998; Blank, 2002; Hennessey, 1999; Stuever, 2005). The author's previous study used a journal activity to combine both metacognitive questions and the think-pair-share strategy. The metacognitive questions forced students to examine their own process of thinking by writing their responses in a journal. The students then used the think-pair-share strategy thus giving the students the opportunity to discuss their answers with another student before volunteering to share their entry with the entire class. Think-pair-share strategies engage students in thinking about their response first, and then allow students to discuss their ideas with a partner before sharing their ideas with the whole class.

The think-pair-share strategy is easily implemented in the science classroom with little extra effort on the part of the teacher and can fit smoothly into most discussions in the science classroom. Anytime the teacher needs feedback about the students' level of understanding, the think-pair-share strategy could be used. After posing a question over the current topic, the students could jot down their answers to a question, turn to their neighbor, and talk about their answers before sharing with the entire class. Not only is this strategy easy to put into place, it forces students to use metacognition to examine their thinking, analyze their position, and explain their point of view to their classmates. Developing metacognitive questions about the topic at hand would be more labor intensive for the teacher. The teacher would have to change her/his mind-set and pose questions that truly require the students to examine the way in which they were thinking instead of coming up with correct answers. From past experience, metacognitive questions require the teacher to analyze the existing links to other common experiences and material, determine which processes the student may possibly use, and formulate questions accordingly. Simply asking a content question is not good enough. Answers and the resulting questions from the metacognitive processes that are generated by the student responses require flexibility from both the teacher and the students. Each student is linking information to their unique set of experiences. Some of the questions that are posed during the course of the discussion can be meaningful and multifaceted, therefore requiring extended investigation and analysis. Since the students' answers and questions determine the direction of class discussions, the amount of time that any one discussion will last is difficult to predict. Plus, the path these discussions will lead is difficult to predict. This strategy would require some forethought until the teacher and the students alike are acclimated to this shift in focus.

Questions

Is it possible that using only one piece of the strategy in isolation will increase participation? If either the think-pair-share strategy or the metacognitive question would encourage voluntary participation from a wider range of students, then both the teacher and the individual students that participate in the discussions would have a better perception of the level of understanding of a certain topic. Through the course of the discussion the depth of the students' understanding of the topic could be evaluated and expanded. The misconceptions that are uncovered during the conversation could be corrected. By pulling apart the previously blended approach, the teacher could concentrate on the element of the strategy that was most effective in increasing participation: think-pair-share or metacognitive questions.

This research seeks to clarify if using the think-pair-share strategy or answering metacognitive questions in a journal and sharing their entries with the class will increase voluntary participation of the students in subsequent whole class discussion while learning about the concept of density. The study will also look at the impact the two metacognitive strategies have on both student achievement at the conclusion of the unit and if the knowledge gained will be maintained long term. The three questions addressed by this study are as follows:

- Question 1: In what ways and to what extent will the think-pair-share strategy and metacognitive questions change participation in the science classroom?
- Question 2: How will using the think-pair-share strategy and metacognitive questions relate to student achievement?

- Question 3: How will using the think-pair-share strategy and metacognitive questions relate to long-term retention of content knowledge?

During the course of this study it will be assumed that the students will engage in metacognition during the use of the think-pair-share strategy. The framework of the strategy provides multiple opportunities to use metacognitive strategies. By the design of the think-pair-share strategy, students are given opportunities to engage in metacognition by probing their thinking, writing about what they are thinking, and then comparing their ideas to those of their classmates. When a pair of students shares their conclusions with the class, they will defend their findings while examining and comparing other students' ideas to their own. It is understood that metacognitive strategies such as think-pair-share and metacognitive questions are beneficial to eighth grade students. At the middle school level, students are able to think about their cognitive process. The literature supports the use of metacognitive strategies for all age groups (Hacker, 1998).

The focus of this study will be participation in class discussions and subsequent achievement due to students' usage of metacognitive strategies. The degree to which the students actually engage in metacognition will not be measured, so this study will not judge the amount of metacognitive engagement or try to discern when the thinking processes of the students are cognitive or metacognitive in makeup.

Overview

The next chapter will provide a review of the literature regarding metacognition, metacognition in education, and metacognition in the science classroom. The third chapter will define the methodology and procedures of the study. The fourth chapter will outline the results of the study, and the fifth chapter will provide an analysis and discussion of the results.

CHAPTER TWO

REVIEW OF THE LITERATURE

Metacognition is a fairly new term in the context of education. In order to understand the implications of metacognition in the classroom, an explanation of the term and a broad understanding of what it entails are necessary. The effective use of metacognition in the educational context needs to be examined. Finally, specific metacognitive research related to the science classroom gives concrete examples of methodology that have been studied in the science classroom. In this review of the literature, an overview of metacognition will be given, a meta-analysis of educational studies that used metacognition interventions will be examined, and specific examples of metacognitive research in the science classroom will be reviewed.

Metacognition

In the late 1970s, John Flavell came up with an innovative word, metacognition, to describe the method of thinking about one's own process of thinking (Livingston, 1997; Walsh & Sattes, 2005). According to Flavell's own definition in 1981, "Metacognition has usually been broadly and rather loosely defined as any knowledge or cognitive activity that takes as its object, or regulates, any aspect of any cognitive enterprise" (Flavell, Miller, & Miller, 2002, p. 164). Since that time, much has been added to that definition.

In order to apply metacognitive strategies in the classroom, an understanding of the components of metacognition is needed. Different metacognitive components are used when students are processing information. First, students connect new information to previous knowledge in order to determine their level of understanding (Blakey & Spence, 1990; Hacker, 1998; McCormick & Pressley, 1997). Then the students must select and regulate effective strategies that facilitate the task at hand (Blakey & Spence, 1990; Hacker, 1998; McCormick & Pressley, 1997; Olsen, 1990).

> Although students will consciously and sometimes quite slowly execute strategies when they are first acquiring them, good thinkers eventually automatize the strategies they know. This means that they can quickly recognize when it is appropriate to use particular strategies and can execute them with ease. (McCormick & Pressley, 1997, p. 8)

"The sophisticated learner possesses knowledge about when various strategies are appropriate . . . . Mature strategy users monitor effectiveness, enjoyableness, and difficulty of strategies as they execute them" (Pressley, Forrest-Pressley, Elliott-Faust, & Miller, 1985, p. 9).

As learners become more experienced at monitoring the different components of metacognition, they also need to be attentive when evaluating the different nuances of the task at hand. The nature of the task, the depth of the material involved, and how demanding the task is must be taken into account (Flavell et al., 2002; Livingston, 1997). In addition, the students need to chart the direction their thinking takes them, keep an eye on their progress, and validate their thinking processes (Blakey & Spence, 1990; Olsen, 1990). After selecting metacognitive strategies which incorporate "sequential processes that one uses to control cognitive activities" and which also confirm that "the cognitive goal will be achieved, the person must continue to evaluate the processes" (Livingston, 1997, p. 2). "These processes help to regulate and oversee learning, and consist of planning and monitoring cognitive activities, as well as checking the outcomes of those activities."

"Cognitive psychologists refer to metacognition as consisting of three types of knowledge: declarative, procedural and conditional" (Dantonio & Beisenherz, 2001, p. 44). Declarative knowledge is the general sense of what we know—"the facts, the rules, or other knowledge that efficiently communicate ideas." This refers to the students' ability to accurately evaluate the knowledge they have stored. Many times students are familiar with a topic because they have been exposed to the information, but they have little information associated with it in their memory (Willingham, 2003). In order to truly understand the topic, richer associations must be made; they must have recollection of specific sets of information. "Although familiarity and recollection are different, an insidious effect of familiarity is that it can give you the feeling that you know something when you really don't" (p. 82). The students' ability to know what they know is associated with declarative knowledge.

Another type of metacognitive knowledge is procedural. "Procedural knowledge is the mental steps, processes, or phases that represent how we arrive at information or the details of how a cognitive operation is carried out" (Dantonio & Beisenherz, 2001, p. 44). Kluwe (1982) describes procedural knowledge as "stored processes of a system" (Kluwe as cited in Hacker, 1998, p. 16). It gives students the details of the processes they should use in order to carry out the steps of a cognitive operation. Conditional knowledge is another type of metacognitive knowledge. It refers to the ability to know when tactics are appropriate. "It relays the conditions under which something is to be done or applied" (Dantonio & Beisenherz, 2001, p. 44).

Self-efficacy or students' appraisal of their own ability is another aspect of metacognition. It has been suggested that struggling readers' low expectations contribute to their lack of success because they believe that they lack an inborn aptitude that they are unable to alter (Reutzel, Camperell, & Smith, 2002). The learner's belief in their ability could affect their motivation to establish metacognitive strategies. If a person believes that they are horrible at mathematical story problems, when confronted with a situation that deals with a story problem, they are hesitant to proceed. Because they believe that it is impossible for them to solve a story problem, "they are little motivated to attempt a solution, and even less motivated to monitor and regulate their attempts" (Hacker, 1998, p. 10). "Thus, self-assessments concerning affective states often serve as the gateway to further assessments concerning the task, its demands, the knowledge necessary for its completion, and strategies for its completion" (p. 10).

Even though the term metacognition includes many facets and interpretations of the phenomenon, there is broad agreement among researchers about the meaning of metacognition. Metacognition incorporates the following ideas: "knowledge of one's knowledge, processes, and cognitive and affective states; and the ability to consciously and deliberately monitor and regulate one's knowledge, processes, and cognitive and affective states" (p. 11).

Metacognition in Education

Marzano (1998) completed a meta-analysis of different instructional strategies that have been used in education. Marzano proposed a model that embraces "four elements of human information processing—the self-system, the metacognitive system, the cognitive system, and knowledge" (p. 11). The four systems were then broken down into subcategories. For the sake of analysis, metacognition has been broken down into "four different categories: (1) goal specification, (2) process specification, (3) process monitoring, and (4) disposition monitoring" (p. 65). Effect size, "one of the most commonly used indices of the impact of an independent variable . . .on a dependent variable" (Marzano, 2003, p. 190) was used for the meta-analysis of the different instructional strategies. "In essence, an effect size is the difference between the means (e.g. treatment minus control) divided by the standard deviation of the two conditions. It is the division by the standard deviation that enables us to compare effect sizes across experiments" (Thalheimer & Cool, 2002, p. 3). "Percentile gain or Pgain, is the expected gain (or loss) in percentile points of the average student in the experimental group compared to the average student in the control group" (Marzano, 2003, p. 191).

When Marzano examined the cognitive system of his model, he found 19 studies reviewing instructional techniques which dealt with the subcategory "information processing functions" (p. 107). Although these instructional techniques focused on the cognitive system, they were considered metacognitive in nature for various reasons. These studies addressed "identifying specific objectives," "wait time," and "feedback." The instructional technique that identified specific objectives was classified as metacognitive because students were given specific goals that were to be attained, which fits with the "goal specification" subcategory of metacognition. Three studies were shown to have an effect size of 1.37 "indicating a percentile gain of 41 points" (p. 107). The instructional technique, "wait time," was classified in the process specific subcategory of metacognition because it was assumed that "the teacher's use of wait time increases the probability that the student will seek clarity or resist impulsivity as they practice that skill" (p. 108). Two studies involving wait time showed an effect size of 1.27 with a percentile gain of 40 points. There were 14 studies that used instructional techniques that utilized feedback using both the subcategory of process specification and the subcategory of process monitoring function both of which are part of the metacognitive system. The analysis of the 14 studies showed an effect size of 1.13 with a percentile gain of 37 points. "Although the number of studies analyzed for this category of cognitive processes was relatively small (n=19), one might conjecture that the metacognitive system is a powerful tool in enhancing student skill in the information processing functions" (p. 108).

Marzano also reviewed studies that were intended to improve student proficiency in the metacognitive system and in the self-system. Two of the studies used process monitoring of the metacognitive system through the use of "verbalization" techniques. This produced an effect size of 1.38 showing a percentile gain of 42 points. "Here the process monitoring function of the metacognitive system is being used to enhance the metacognitive system as a whole. Additionally, teaching students about the nature and function of the dispositions enhanced their ability to monitor these dispositions" (p. 117).

In addition, 48 studies using experimental inquiry showed an effect size of .51 on metacognition with a percentile gain of 69 points. "Perhaps providing students with explicit learning objectives renders them more efficient at tasks which in turn makes them perceive themselves as more competent" (pp. 117-118). It is Marzano's belief that inquiry based learning is multifaceted and vigorous enough that it can "both stimulate students' use of the metacognitive system and enhance it" (Marzano, 1998, p. 118). In the self-system, which addresses "students' beliefs about their self-attributes," studies were cited that used the metacognitive system. One component of the metacognitive system is the process monitoring function. One study of verbalization, an instructional strategy which incorporates the process monitoring function, had an effect size of .99 with a percentile gain of 34 points. "Apparently, the act of verbalizing their thoughts while monitoring the execution of a complex task provides students with insights into the effect of their beliefs about their attribute on their performance." Other techniques given are feedback, which "also stimulates the process monitoring function of the metacognitive system and has the indirect effect of enhancing students' beliefs about self-attributes" and "setting overt instructional objectives." Even though the techniques used were intended to make use of the metacognitive system, it could be concluded from these studies that "the metacognitive system provides 'automatic' access to the self-system."

> Both the metacognitive and self-system seem most influenced by instructional techniques that employ the idea specification function of the cognitive system in conjunction with the process monitoring function of the metacognitive system. The combined effect on the metacognitive and self-system for techniques that utilize the combined strategy was .99 (n=186, SD=.72), indicating a percentile gain of 34 points. These combination strategies provide students with an awareness of the manner in which their minds work (specifically

> the metacognitive and self-systems) and then require students to monitor their mental activity. (Marzano, 1998, p. 121)

Instructional techniques which highlight metacognition show a link to increased achievement and provide the students with a better individual understanding of their own metacognitive process.

Metacognition in the Science Classroom

In the science classroom, students are called upon to take concrete examples and associate them with abstract theories. In a study of six eighth grade science classrooms, lessons were taught with an inquiry-based curriculum with emphasis on relational causality, which the author defines as ". . . the relationship between two things [that] accounts for a certain outcome beyond the two things" (Mittlefehldt & Grotzer, 2003, p. 6). The study was conducted during units over density and pressure. Students were trained to question different models that were presented by both other students and the teacher using metacognitive questions that addressed three areas: intelligibility—"Does this make sense to me?", wide-applicability—"Are there pieces of this idea that relate to other ideas I learned about?", and plausibility—"Should I believe this idea? Does this idea seem likely to be true?" Results from the study showed that students were able to gain a greater understanding of certain causal scientific relationships if they examined their ideas for believability while considering if the connections between ideas made sense to them (p. 19). Additionally, Mittlefehldt and Grotzer found that "students engaged in metacognitive activities seemed more likely to transfer their understanding of causal structure between topics than those students who were not engaged in metacognitive activities" (p. 21). The findings of this study also indicate that students in group settings are more likely to assess their ideas by implementing a larger array of metacognitive strategies than if they are working as an individual.

As the demands on teachers increase, the pursuit of many teachers is to find a way in which to include metacognition in the science classroom in an efficient and effective manner. In Patry's (2004) study of a 10th grade physical science course, students were rapidly trained in concept mapping in an effort to develop metacognition. The duration of the training was brief in order to "avoid an increase in the teachers' workload" (p. 1) and because of the demanding nature of the course. Only students in the experimental group were introduced to concept mapping in a 75 minute class initially. This initial session was followed by five, 45 minute sessions that gave instructions on how to use the concepts. The 45 minute sessions were interspersed through four months of normal classes. A posttest was given to both the control and experimental group two months after the end of the treatment. Results from the study showed that the short term training in concept mapping had no apparent effect on the development of metacognition.

A study conducted at the middle school level compared the Science Curriculum Improvement Study (SCIS) Learning Cycle with the Metacognitive Learning Cycle (Blank, 2002). The Science Curriculum Improvement Study Learning Cycle gives the students a chance to explain their ideas regarding science concepts, but does not allow for a set, planned opportunity for students to think about their ideas. In contrast, the Metacognitive Learning Cycle stresses that students and teachers have a set, planned opportunity to discuss their ideas about science concepts. "The Metacognitive Learning Cycle differs form the SCIS Learning Cycle because it allows for directed reflection" throughout the cycle (p. 490). Two different classes studied the exact same material about ecology: one class used the Science Curriculum Improvement Study Learning Cycle while the other class used the Metacognitive Learning Cycle. Working together with the researcher, a highly-respected seventh-grade science teacher planned a three month unit on ecology. Results show there was no significant difference in the level of understanding in the ecology concepts that were taught. However, results from long-term assessments show students in the Metacognitive Learning Cycle group appeared to have "permanently restructured their understandings of ecology" (p. 503). The teacher in the study reported being frustrated with the discussions conducted with the students for a variety of reasons. Many times students did not agree with scientific concepts, "even if they could talk intelligently about them" (p. 494). Because of the discord, the pace in the metacognitive class was slower and "required the teacher to relinquish his expectation of what direction the class would take" (p. 495). It seemed that the students were only interested in defending their own ideas and unwilling to accept information that did not fit with their current understanding. In fact the students at times said that they thought the teacher was lying presumably because the data they were given did not fit with their level of understanding. "One of the conclusions made by the teacher was that the level or quality of dialogue in the MLC classroom was different, more thoughtful when compared to the SCIS classroom" (p. 498). Even with this positive improvement, the teacher discontinued the use of the Metacognitive Learning Cycle at the end of the research because of the time needed to develop lessons in this manner.

In a case study of a fifth grade class, students were instructed on how to talk about their science conceptions using metacognition while studying about force and motion (Beeth, 1998). Beeth sought to examine and analyze the instructional practices of Sister M. Gertrude Hennessy, an accomplished science teacher of 20 years. His research was conducted in an effort to show how "Sister Gertrude's instruction does serve to demonstrate how student learning can be enhanced through the use of metacognition" (p. 343). Many times the research focuses on trying to uncover students' misconceptions and correcting them. Instead in this classroom, students were taught how to examine their science concepts using the "status construct of intelligibility and plausibility." Students, with the guidance of their teacher, defined both of the words intelligibility and plausibility and then evaluated their science concepts based on the agreed upon definitions. The role of the teacher was one of facilitator. She focused on giving the students feedback on their use of the metacognitive strategy of reflecting on their scientific beliefs by putting them to the test of intelligibility (does it make sense) and plausibility (is it believable). The teacher required that all statements made by the students be examined for intelligibility and plausibility. The researcher found that the metacognitive, thoughtful, in-depth nature of the classroom conversations gave the teacher insight into the students' concepts of force and motion allowing her to plan her instructions accordingly. "The instruction this teacher presented to her students changed their roles as learners from passively receiving information from an external authority to one of negotiating the meaning of the reasons that support scientific ideas" (p. 355).

In a long term study that spanned three years, a promising link to the development of metacognition was found (Hennessey, 1999). This study followed groups of students in grades 1-6 for three years while enrolled in science classes in a rural parochial school located in the Midwest. The study focused on the development of higher level metacognition, the way in which students change their metacognitive strategies with experience, and the role of the teacher in the process. By attaining this information, both the teacher and the student were able to determine the development of more complete and accurate understanding of specific science concepts by allowing links from previous experiences to new concepts. The study indicated that teaching metacognition in the classroom is not an easy task. Time must be set aside for students to develop new ideas along with models and experiences that support their growth. The interviews with the students in this paper give some insight to the basic belief systems of students in science and their ability to challenge their own beliefs by being exposed to the ideas of other students. While acting as the science specialist in the study, Hennessy found that a learner's "metacognitive ability changes over time" (p. 43). When the atmosphere of the classroom is shifted to a constructivist, hands-on classroom with open discussion about the students' conceptual understanding of different science concepts, there seems to be a increase in metacognitive ability along with accompanying shifts in conceptual change and vice versa.

Summary

Metacognition, thinking about thinking, entails many processes. Metacognition is the ability to connect current information to previous situations. It engages the conscientious selection of appropriate strategies. Metacognition involves planning, monitoring, and evaluating during the thinking process.

After examining the meta-analysis of research about instructional strategies involving metacognition, it is clear that gains can be attained (Marzano, 1998). When the instructional strategies of identifying specific objectives, wait time, and feedback invoked metacognition in the students, gains were seen. Two instructional strategies that focused directly on metacognition, verbalization and experimental inquiry, both showed gains. Clearly metacognition has the ability to improve student achievement.

Research on metacognition in the science classroom showed mixed results. In the traditional setting of Patry's (2004) study, the short-term training in concept mapping in an effort to develop metacognition showed no gains in achievement.

In contrast, the metacognitive studies that were conducted in an inquiry-based setting showed changes. This is consistent with Marzano's meta-analysis of the 48 studies which used experimental inquiry. The studies that used experimental inquiry, which is classified as part of the metacognitive system, showed gains. The focus for research in inquiry-based classroom was on students examining their own science concepts for understanding. Mittlefehldt and Grotzer's (2003) research showed that students seemed to apply causal relationships between topics. The study also indicated that students working in groups used more metacognitive strategies when evaluating their ideas. In Blank's (2002) research that compared the Science Curriculum Improvement Study with the Metacognitive Learning Cycle, there was no difference in the level of understanding in the ecology concepts that were taught. However, results from long-term assessments showed that students who participated in structured reflection provided by the Metacognitive Learning Cycle "permanently restructured" their understanding of the topic.

The studies involving Hennessy's classroom also were conducted in an inquiry-based setting. When Hennessy tracked her students' development over a period of three years, it was found that metacognitive ability increases over time (1999). Beeth's (1998) case study involving Hennessy's students showed that conversations could be metacognitive, thoughtful, and in-depth when students were trained to examine their concepts. The teacher's role was one of facilitator, planning her lessons to fit with the students' current understanding of a topic.

These findings present a dilemma for science teachers. Even though there is a direct link between metacognition and the ability to process information, it would seem that in order to see any dramatic changes in the way that students monitor their own thinking processes, the traditional method of teaching in the science classroom would need to be discarded. With the current emphasis on content and testing, the likelihood of teachers radically changing the delivery of instruction seems unlikely. Is there some way in which to promote metacognitive strategies in the science classroom that would take into account the pressure to conform to the established standards?

The use of either the think-pair-share strategy or metacognitive questions would be easy to put into practice in the science classroom even with the pressure to conform to current standards. By combining content questions with think-pair-share, students would be exposed to situations where metacognition is likely to occur. Many different metacognitive practices are contained within the think-pair-share strategy. Students could write in a journal for the thinking component of the strategy which would allow them to examine their knowledge. When they pair with a classmate, the students would be forced to discuss how they are thinking. By then sharing information with the entire class, students would be able to evaluate themselves while gathering information from other classmates. The teacher would also have the opportunity to evaluate the students' understanding based on the content of the discussions. An increase in class discussions would give the teacher a more detailed profile of student comprehension.

Another option is to have the students answer metacognitive questions for daily journal entries. Students would then discuss their entries as a whole class. Students would be prompted to use metacognitive strategies through the use of metacognitive questions. When sharing their answers with the entire class, students could compare their strategies to those of their classmates while the teacher could evaluate the students' level of understanding about the current topic. Here again, an increase in student participation in class discussions would give the teacher more information about the students' understanding of current concepts.

If either treatment promotes increased participation in class discussions, the students have an even greater opportunity to examine their ideas and execute metacognitive strategies. The teacher would then be able to plan activities according to the students' level of understanding. This research examines the following questions:

- Question 1: In what ways and to what extent will the think-pair-share strategy and metacognitive questions change participation in the science classroom?
- Question 2: How will using the think-pair-share strategy and metacognitive questions relate to student achievement?
- Question 3: How will using the think-pair-share strategy and metacognitive questions relate to long-term retention of content knowledge?

CHAPTER THREE

DESIGN OF THE STUDY

Experimental Design

This study uses a quasi-experimental design to compare the impact of think-pair-share strategies and metacognitive questions on participation in subsequent classroom discussions, achievement, and long-term retention of middle school science material. Three intact eighth grade classes learned about density using a variety of lessons that incorporated models, teacher demonstrations, labs, reading, worksheets, and discussions. The three 43 minute classes were taught by the same teacher.

The study consisted of three different treatments: a control group, think-pair-share (TPS) group, and a metacognitive questions (MQ) group. The control group started most classes with a journal entry, answering cognitive questions that were related to the material being taught. (Because of time constraints students did not have journal entries on lab days.) Students wrote in their journal for two to three minutes daily. After writing in their journals, students were asked to share the information from their entries with the entire class if they so desired. This is a standard procedure in this classroom, and one that has been in place for the entire school year.

The TPS group followed the basic journal entry procedure used by the control group with one modification. Individual students in the TPS group answered the same cognitive questions as the control group, but then each TPS student was paired off with a classmate to discuss their respective journal entries one-on-one before sharing the information about the topic with the entire class. The MQ group followed the basic journal entry procedure used by the control group with one modification. Instead of answering cognitive questions, the MQ group answered metacognitive questions about the same topic, and then shared the information from their entries as a whole class. The metacognitive questions ask students to examine how they arrive at an answer versus the cognitive questions which are based on content. The standard procedure of this classroom has been to use cognitive questions for the journal entries. An example of a cognitive question would be, “What is the density of this object?” compared to a metacognitive question, “What type of information do you need in order to find the density of this object?” The cognitive question focuses on attaining the correct answer compared to the metacognitive question that focuses on the processes used to attain the correct answer. Daily cognitive questions were used for both the control group and the TPS group (see Appendix A) for the duration of the study. Daily metacognitive questions were used for the MQ group (see Appendix B) for the duration of the study.

All three of the classes were taught about density using the same models, teacher demonstrations, labs, readings, and worksheets. The three treatment groups were taught the same science lessons on a daily basis. Only class discussions, which were generated by members of the individual classes, varied from class to class. All three treatment groups were given a pretest to gauge their understanding of the topic of density. No grade was taken on the pretest. A similar test was given as a posttest to determine the mastery of the material presented. A grade was assigned on the posttest. The same test that was given as a posttest was given when testing long-term retention of content knowledge. No grade was given for the maintenance test that measured retention.

Three classes--second, third and fourth hour--were selected for this study. Morning classes were selected for the study so both students and the teacher would be fresh for the demands of the study. First hour had to be eliminated from the study because of time taken from that particular hour for morning announcements, leaving second, third and fourth hours as possible participants in the study. The teacher preferred to teach the first two classes of the day the same in order to gauge the overall success of the lesson. Therefore, second hour was chosen as the control. Third hour was chosen as the class to receive the think-pair-share treatment because the journal questions for this treatment would be the same and only the discussion following the journal questions would be different. Fourth hour was selected for the metacognitive question treatment because this class was directly before lunch and the teacher would have a chance to regroup before returning to the usual format for the afternoon classes.

It is assumed that the ability level of the three classes in the study is approximately the same. There are no special education students in any of the classes, but there is a wide range of academic ability in each of the classes. The overall average science grade for the three classes was within a three percent range for the first quarter and at the same grade point average at the beginning of this study.

There are some limitations to this study. Due to the nature of teaching three different classes with diverse mixes of students, it is impossible to deliver content and instruction to all classes exactly the same. Although each class received the same information about the topic of density, the way in which the information was provided might have varied. Since the amount and type of questions and participation might have varied from class to class, some classes may have received more detailed information over certain parts of the topic.

The Sample

The participants for the study were in a school district in the Midwest with a total of 5,938 students enrolled. The ethnicity of this district was 86.56% White, 2.37% African-American, 5.49% Hispanic, and 5.57% other. The gender breakdown for the district was 49.29% females and 50.71% males. The percentage of students in the district that were economically disadvantaged was 8.61% (KSDE, 2005). The middle school had a total of 833 seventh and eighth graders enrolled. The ethnicity of the school was 86.83% White, 6.12% Hispanic, 2.64% African-American, and 5.04% other. The building had 49.46% females and 50.54% males. The building had 6.80% of its students in special education, which did not include self-contained mentally retarded students or gifted students (SASIxp, 2004). Information about economically disadvantaged students is unavailable.

Second hour, the control group, had a total of 24 students. The breakdown of the ethnicity for second hour was 91.67 % White and 8.33 % other. Second hour had 58.33 % females and 41.67 % males. Third hour, which was the TPS treatment group, had a total of 22 students. The breakdown of the ethnicity for third hour was 95.45 % White and 4.55 % Hispanic. Third hour had 59.09 % females and 40.91 % males. Fourth hour, which was the MQ treatment group, had a total of 20 students. The breakdown of the ethnicity for fourth hour was 80.00 % White, 15.00 % Hispanic, and 5.00 % other. Fourth hour had 60.00% females and 40.00 % males (SASIxp, 2004). There were no special education students in any of the classes.

Instruments and Measures

Data for participation was collected in three ways. First, the teacher tracked voluntary participation on the days of class discussions (Day 2, Day 4, Day 5, Day 6, Day 7, Day 8, and Day 10) by recording the number of times each student participated in all three hours with tally marks on a class seating chart. Second, counts were taken of the number of students that participated in class discussions any number of times, be it once or several times, for the entire class time for all three groups. The number of students that participated in any capacity was divided by the number of students present for that discussion giving the overall participation. Third, daily discussions within each of the three classrooms were audio taped every day except for lab days. The tapes were reviewed in order to determine if misconceptions were uncovered and the quality of the discussions in the class could be evaluated. The tapes provided precise information regarding the conversations in the classroom to determine if more in-depth answers or questions were generated by the students of the treatment groups.

A teacher-made pretest and posttest on density was given to all groups. Content over density is commonly taught in middle school chemistry and is somewhat generic in nature, so face validity was assumed for both tests. The questions from the tests were distilled from a variety of science textbooks and worksheets. Most answers on both the pretest (see Appendix C) and the posttest (see Appendix D) were worth one point each, but essay questions were worth two points each (see Appendices C and D for the key to the tests). The objectives for the unit over density are as follows:

- Students will identify that both the mass and volume of a substance/object determine its density.
- Students will be able to correctly measure mass and volume for a liquid, a rectangular prism solid, and an irregularly shaped solid.
- Students will be able to describe the effect density has on density currents.
- Students will be able to calculate the density of different substances using the formula for density.
- Students will be able to determine which substances will float on other substances, based on their density.
- Students will be able to use density to determine the identity of a substance.
- Students will be able to explain why the density of a pure sample does not change with sample size.

Procedure and Timeline

After informed consent (see Appendix E) was received, all three classes, the control group, the TPS group, and the MQ group, learned about density using a variety of lessons. These lessons included models, teacher demonstration labs, reading, worksheets, and discussions. For every activity that involved writing in their journals, each of the three classes followed a different procedure. Students in the control group (second hour) answered questions in their journal and then discussed the questions as a class. Students in the TPS group (third hour) answered the same questions as the control group, but then paired off with classmates to discuss their answers, and then shared with the class. The students in the MQ group (fourth hour) answered metacognitive questions related to the same topic and then discussed their answers as a class.

Day 1: Students in all three classes were given a pretest (see Appendix C) over density.

Day 2 (Discussion 1): All students started the class with a journal entry. Students in the control group and the TPS group answered cognitive questions about how the spinning angel chimes work (see Appendix A) in their journals. After writing in their journals, the control group discussed their entries as whole class, while the TPS group paired off with a partner to discuss their answers before discussing their journal entries as a whole class. The MQ group answered metacognitive questions (see Appendix B) in their journals, and then discussed them as a whole class. Students in all three classes were introduced to "The Mediterranean Puzzle" (Borgford et al., 2002, p, 243), (see Appendix F). Students were given a map to locate the Mediterranean Sea and the Strait of Gibraltar (see Appendix G). A photo of the Strait of Gibraltar taken from the space shuttle was shown to the students (Apt, Helfert, &Wilkenson, 1996). Students were asked to think of solutions to the puzzle, and they voluntarily shared their answers.

Day 3: Students in all classes conducted an experiment (see Appendix H) that modeled density currents and presented a feasible answer to the Mediterranean Sea puzzle. The questions that went with the experiment were assigned as homework in all classes.

Day 4 (Discussion 2): All students started with a journal entry. Students in the control group and the TPS group answered cognitive questions (see Appendix A) about the solution to the Mediterranean Sea puzzle based on the experiment from the previous day. After writing in their journals, the control group discussed their entries as whole class, while the TPS group paired off with a partner to discuss their answers before discussing their journal entries as a whole class. The MQ group answered metacognitive questions (see Appendix B) about the solution in their journals, and then discussed them as a whole class. All classes went over the questions that they answered as homework that went with the experiment. The teacher gave corrections as necessary. The formula for calculating density was introduced.

Day 5 (Discussion 3): All students started with a journal entry. Students in the control group and the TPS group answered cognitive questions (see Appendix A) about what they thought the density of a liquid meant and how they might calculate the density of a liquid. After writing in their journals, students in the control group discussed their entries as a whole class, while students in the TPS group paired with partners to discuss their answers before discussing their journal entries as a whole class. The MQ group answered metacognitive questions (see Appendix B) in their journals about the density of a liquid, and discussed the questions as a whole class. Students in all classes were introduced to the concept of calculating the density of a liquid. They calculated the actual density of the two salt solutions used in the model of the density currents from the previous day. Students in all hours were given a homework assignment (see Appendix I) to practice calculating the density of different liquids.

Day 6 (Discussion 4): All students started with a journal entry. All students were shown a Galileo thermometer without being told what it was or its function before the journal entry. Students in the control group and the TPS group answered cognitive questions (see Appendix A) about what they thought the object was and how it worked. After writing in their journals, the students in the control group discussed their entries as a whole class, while the students in the TPS group paired with partners to discuss their answers before discussing their journal entries as a whole class. The MQ group answered metacognitive questions in their journals (see Appendix B) about the object and its function and then discussed the questions as a whole class. All classes graded their own homework during class. All classes then watched a teacher demonstration about the density of hot/cold water and salty/tap water and filled out a worksheet (see Appendix J) during the demonstration lesson. Two jars were filled with different liquids, hot/cold water and salty/tap water. The jars were stacked on top of each other at the opening, separated by a note card. Students first predicted what happened when the note card was pulled out. They then observed what actually happened and explained why it happened by talking about the densities of each of the liquids. Students were then asked to explain why the bottom sphere in the Galileo thermometer started dropping when the teacher's hands were placed around the thermometer. Their answers were discussed as a whole class.

Day 7 (Discussion 5): All students started with a journal entry. All students answered questions about how to tell the difference between gold and fool's gold. Students in the control group and the TPS group answered cognitive questions (see Appendix A). After writing in their journals, the control group discussed their entries as a whole class, while the TPS group paired with a partner to discuss their answers before discussing their journal entries as a whole class. The MQ group answered the metacognitive questions (see Appendix B) about the same topic. Students in all classes verbally reviewed mass, weight, and volume. All students read information about density from the textbook. All students were given a homework assignment where they had to apply the concept of density to different scenarios (see Appendix K).

Day 8 (Discussion 6): All students started by reading a worksheet (Morrison et al., 2002) that described a situation in which different liquids had been mixed together, but one particular liquid was needed for an experiment (see Appendix L). All students answered questions about how to solve the problem. Students in the control group and the TPS group answered cognitive questions (see Appendix A) about the problem. After writing in their journals, the students in the control group then discussed their entries as whole class, while the students in the TPS group paired off with partners to discuss their answers before discussing their journal entries as a whole class. The MQ group answered metacognitive questions (see Appendix B) about the same problem. Students from all classes completed the worksheet after the journal entry and discussed their answers as a whole class. All classes checked their own homework from the previous day. The teacher demonstrated how to find the density of both regular and irregular shaped solids. All students tried to order six density blocks from most dense to least dense. The procedure for the next day's density lab was previewed.

Day 9: All classes participated in a lab (see Appendix M) in which the density of a liquid, a regular shaped solid, and an irregular shaped solid were determined.

Day 10 (Discussion 7): All students started with a journal entry. All students answered questions to review for the test. Students in the control group and the TPS group answered cognitive questions (see Appendix A). After writing in their journals, the students in the control group then discussed their entries as a whole class, while the students in the TPS group paired off with partners to discuss their answers before discussing their journal entries as a whole class. The MQ group answered metacognitive questions (see Appendix B) about the same topic. Students in all classes who did not finish the density lab from the previous day completed the lab. Other students calculated the actual density of the density cubes and tried to determine the material that the cube was made of. Other students calculated the density of different cubes of zinc and determined the percent of purity for each sample. A review over density (see Appendix N) was given to all classes as homework.

Day 11: After grading the review over density in class, the posttest (see Appendix D) was given to all classes.

After six weeks, all classes took the posttest again to check long-term retention of the concept of density.

Analysis of Data

Data was examined for violations of normality by using the Shapiro Wilks test of normality. It was determined that all variables violated assumptions of normality so nonparametric statistics were employed. Next, because the pre and posttests are researcher-generated measures, reliability or internal consistency was examined.

In order to answer the first question, “In what ways and to what extent will think-pair-share strategy and metacognitive questions change participation in the science classroom?” voluntary participation for each student was determined. This information was gathered by tallying each time a student participated in daily discussions per class period. Initially, gain scores were calculated to determine the amount of change between the first discussion day which was used as a baseline, and the mean of discussion days two through seven, regardless of group membership. The baseline was then compared to the mean of the remaining days. This analysis took into account the number of times each student participated. These gain scores were then statistically examined using Kendall’s tau test to see if instruction (regardless of type) had differential effects on students’ participation once the intervention was initiated. Student data were then divided into the respective three intervention groups (i.e., (1) those receiving instruction as usual—control, (2) those receiving instruction using Think Pair Share—experimental group 1, and (3) those receiving instruction using Metacognitive Questioning—experimental group 2). To determine if performance differed based on group membership (i.e., the control group, Think Pair Share, and Metacognitive Questioning), gain scores were calculated to illustrate growth in participation following intervention. To determine if overall participation varied by group membership, a Kruskal Wallis test was computed using the overall participation percentages. Counts were taken of the number of students that participated in class discussions any number of times, be it once or several times, for the entire class time for all three groups. The number of students that participated in any capacity was divided by the number of students present for that discussion giving the overall percent of participation. The overall daily participation was then averaged for each treatment group. In addition to the quantitative analysis, tapes of the class discussions were reviewed to determine if differences in the quality of the discussions varied by intervention.

The data were analyzed in the same way for the next question "How will using metacognitive questions and the think-pair-share strategy relate to student achievement?" Initially, gain scores were calculated to determine the amount of change between pre and post-intervention scores, regardless of group membership. These gain scores were then statistically examined using Kendall's tau test. Student data were then divided into the respective three intervention groups (i.e., those receiving instruction as usual—control, those receiving instruction using Think Pair Share—experimental group 1, and those receiving instruction using Metacognitive Questioning—experimental group 2). To determine if performance differed based on group membership (i.e., the control group, Think Pair Share, and Metacognitive Questioning), gain scores (posttest minus pretest) were calculated to illustrate growth in science content knowledge following intervention. These gain scores were then statistically examined using the Kruskal Wallis test.

Finally, analyses addressed the third research question "How will using metacognitive questions and the think-pair-share strategy relate to long-term retention of content knowledge?" A Kruskal Wallis test was computed using the posttest that was given six weeks after the unit was taught.

CHAPTER FOUR

RESULTS

Preliminary Analyses

Descriptive statistics for the measures are provided in Table 1 and Table 2. Scores for the participation represent the number of times a student participated during the day. The mean for student participation ranged from .88 to 2.27 with a maximum of 10 contributions by a single student (see Appendix O). During the study there were four students that never participated in a discussion.

Table 1

Descriptive Statistics for Participation (N = 66)

Participation	*Minimum*	*Maximum*	*Mean*	*S D*
Discussion 1 (Day 2)	.00	9.00	1.59	1.93
Discussion 2 (Day 4)	.00	10.00	2.27	2.71
Discussion 3 (Day 5)	.00	8.00	1.48	1.76
Discussion 4 (Day 6)	.00	6.00	1.14	1.47
Discussion 5 (Day 7)	.00	6.00	1.81	1.66
Discussion 6 (Day 8)	.00	6.00	1.46	1.59
Discussion 7 (Day10)	.00	3.00	.88	.93

Test scores are percentages. There was a range from no correct answers to an 85% in the pretest, a range from a 36% to 100% in the posttest. Two students' scores were excluded because they were absent for either the pretest or the posttest. There was a range from 4% to 96% in the maintenance scores. Three students did not take the maintenance test.

Table 2

Descriptive Statistics for Achievement

Variable	*Minimum*	*Maximum*	*Mean*	*S D*
Pretest (N = 65)	.00	86.00	13.00	17.00
Control (N = 24)	.00	81.00	10.25	17.17
Think-Pair-Share (N = 21)	.00	86.00	22.10	.19.37
Metacognitive Questions (N = 20)	.00	33.00	7.35	9.35
Posttest (N = 65)	36.00	100.00	83.00	16.00
Control (N = 23)	44.00	100.00	79.65	16.24
Think-Pair-Share (N = 22)	36.00	100.00	80.64	18.83
Metacognitive Questions (N = 20)	62.00	100.00	88.90	10.94
Maintenance (N = 63)	4.00	100.00	75.00	21.00
Control (N = 22)	24.00	100.00	72.45	22.91
Think-Pair-Share (N = 21)	40.00	100.00	77.81	16.84
Metacognitive Questions (N = 20)	4.00	96.00	73.70	23.25

To determine if the data were normally distributed, which would dictate use of parametric or nonparametric statistics, the data were examined for violations of normality. Using the Shapiro Wilks test of normality, it was determined that all variables violated assumptions of normality (p=.001). Given that the variables violated assumptions of normality and given the small sample size, nonparametric statistics were employed.

Next, because the pre and posttests are researcher-generated measures, reliability or internal consistency was examined. Results indicated that the responses on the pretest were highly reliable (α=.88). Additionally, performances on the posttest were highly consistent (α=.82).

Primary Quantitative Analyses

Analyses first addressed the primary research question (i.e., In what ways and to what extent will the think-pair-share strategy and metacognitive questions change participation in the science classroom?). This analysis determines if instruction (regardless of type) had differential effects on students' participation once the intervention was initiated. Initially, gain scores were calculated to determine the amount of change between day one which was used as a baseline, and the mean of days two through seven, regardless of group membership. The baseline was then compared to the mean of the remaining days. These gain scores were then statistically examined using Kendall's tau test. This, like many non-parametric tests, uses the ranks of the data rather than their raw values to calculate the statistic. With this nonparametric statistical test, gain scores are ranked from low to high (regardless of direction). The ranks associated with negative differences are summed and the ranks associated with positive differences are summed. The statistical test is then computed. Table 2 illustrates the results of these analyses for the participation variable. Results indicate that differences between baseline and during intervention participation scores were statistically significant (with the during intervention participation receiving a higher rank). These results indicate that, regardless of group assignment, the students' participation improved during intervention.

Analyses then addressed the second research question (i.e., How will using metacognitive questions and the think-pair-share strategy relate to student achievement?). Initially, gain scores were calculated to determine the amount of change between pre and post-intervention scores, regardless of group membership. These gain scores (posttest minus pretest) were then statistically examined using Kendall's tau test. Table 2 illustrates the results of these analyses for content knowledge. Results indicate that differences between pre and posttest scores were statistically significant (with the posttest scores receiving a higher rank). These results indicate that, regardless of group assignment, the content knowledge improved following the intervention.

Table 3

Statistical Analysis of Differences in Participation and Pre and Posttest Scores

Variable	*Kendall's W*[a]	*p value*
Participation	.82	.001*
Content Knowledge	1.00	.001*

Note. N=20, *=statistically significant, [a] Kendall's coefficient of concordance, Participation=day 1 compared to mean of days 2-7, Content knowledge=pretest compared to posttest.

Student data were then divided into the respective three intervention groups (i.e., those receiving instruction as usual—control, those receiving instruction using Think Pair Share—experimental group 1, and those receiving instruction using Metacognitive Questioning—experimental group 2). To determine if performance differed based on group membership (i.e., the control group, Think Pair Share, and Metacognitive Questioning), gain scores (posttest minus pretest) were calculated to illustrate growth in participation and/or science content knowledge following intervention. These gain scores were then statistically examined using the Kruskal

Wallis test. This test is an alternative to the independent group analysis of variance (ANOVA), when the assumption of normality or equality of variance is not met. This, like many non-parametric tests, uses the ranks of the data rather than their raw values to calculate the statistic. With this nonparametric statistical test, gain scores are ranked from low to high (regardless of direction). The ranks associated with negative differences are summed and the ranks associated with positive differences are summed. The statistical test was then computed. This analysis determined if the intervention had differential effects on students based on group assignment. Results indicated that changes in participation (from day 1 through the course of the intervention) did not differ significantly based on group membership following intervention (chi square = 2.03, $p<.36$). In terms of the science content knowledge, the same analysis was used to compare pretest and posttest changes by group. Results indicated that science content knowledge did not differ significantly based on group membership following intervention (chi square = 4.03, $p<.13$).

To determine if overall participation varied by group membership, a Kruskal Wallis test was computed using the overall participation percentages. Counts were taken of the number of students that participated in class discussions any number of times, be it once or several times, for the entire class time for all three groups. The number of students that participated in any capacity was divided by the number of students present for that discussion giving the overall participation (see Appendix P). The overall daily participation was then averaged for each treatment group. Results indicated that the overall percentage of participation did differ significantly by group (chi square = 11.01, p<.004), with the rankings (highest to lowest) as follows: Metacognition Questions group (mean rank=16.50), Think-Pair-Share (mean rank=15.25), Control group (mean rank = 5.75).

Finally, analyses addressed the third research question (i.e., How will using metacognitive questions and the think-pair-share strategy relate to long-term retention of content knowledge?). A Kruskal Wallis test was computed using the maintenance scores. Results indicated that maintenance of content knowledge did not differ significantly based on group membership (chi square = .20, $p<.91$)

Primary Qualitative Data

Although formal qualitative analyses did not take place, additional qualitative data often supplement or enhance the quantitative findings. For two of the variables, interesting anecdotal recordings are reported.

Discussions. After reviewing the tapes of the conversations of the three classes, the control group, the Think-Pair-Share group (TPS), and the Metacognitive Questions (MQ) groups, the following trends were observed. The optimum time to participate in discussions in all groups occurred directly after the journal entry. There was a marked difference in the amount of time the classes spent discussing the journal entry from day to day and from class to class. The type and quality of the discussions also varied from day to day and class to class. The control group and the TPS group both answered cognitive questions for their journal entry. There was a trend that indicated the discussions resulting from the journal entry questions which were cognitive in nature had a propensity to generate straightforward answers. Students in both the control group and the TPS group directed their answers to the teacher without scrutinizing the answers of their fellow classmates, even when the teacher asked the students if they had anything to add or could they describe the answers that were given in a different way. In contrast, the discussions generated from the students that answered metacognitive questions for their journal entry (MQ group) were frequently interactive in nature. Students in the MQ group tried to explain their insight about the topic to the teacher and also to other students in the class. Students in the MQ group critiqued the answers given by their classmates and offered suggestions on how to understand the topic in a slightly different way.

On Day 4 of the study there was a dramatic difference in the length and the type of conversation that followed the journal entry. While the control group and the TPS group spent about the same amount time discussing their journal entries (three minutes and one minute, respectively), the students that answered the metacognitive questions spent considerably more time discussing their journal entries. The control group discussed how the model they made the previous day related to what is happening at the Strait of Gibraltar. After the first student gave his explanation, the students moved on and asked to see the picture of the Strait of Gibraltar (Apt et al., 1996) which was displayed on Day 2. The students in the control group spent the rest of the time asking about the features of the picture. The TPS group spent less time (one minute compared to three minutes) discussing the same cognitive questions the control group answered (see Appendix A). After two students directed their answers to the teacher, no other students volunteered to talk.

The students from the MQ treatment group spent about a third of the class period (14 minutes) discussing their answers to metacognitive questions (see Appendix B) about the same topic (see Appendix Q for an excerpt of the conversation). Students spent time trying to help a classmate understand how the model demonstrated what was actually happening at the Strait of Gibraltar. During the course of the class discussion, groups of students would break off into spontaneous conversations amongst themselves, debating the best way to describe how the model compared to what was actually happening at the Strait of Gibraltar.

One student in the think-pair-share group, who had never participated in class discussions previous to the study, participated in the discussions twice during the course of the study.

English as a Second Language students. Based on personal observations, the English as a second language (ESL) students in all groups were reluctant to participate in class discussions. One ESL student did not participate in classroom discussions in any capacity during the duration of the study. When the maintenance test was given unannounced, one of the ESL students in the metacognitive questions group asked to speak to the teacher in the hall. This student was crying and visibly upset when the teacher went to the hall to speak to her. She told the teacher that she was in so much pain because of cramps that she could not take the test and needed to go to the nurse. When she returned to the science classroom, she answered one question about volume and then wrote “I don’t remember how to find density” on the top of her test. After class she confided in the teacher that she was not crying because she was in pain, but because she didn’t know anything about density.

CHAPTER FIVE

DISCUSSION

The goal of this study was to investigate the impact varying metacognitive strategies had on classroom participation, science content knowledge, and long-term retention by answering the following questions:

1. In what ways and to what extent will metacognitive questions and the think-pair-share strategy change participation in the science classroom?
2. How will using metacognitive questions and the think-pair-share strategy relate to student achievement?
3. How will using metacognitive questions and the think-pair-share strategy relate to long-term retention of content knowledge?

In order to answer the first question, "In what ways and to what extent will metacognitive questions and the think-pair-share strategy change participation in the science classroom?", three pieces of data were examined. First, the Kendall's tau showed that participation increased when the first day of participation was used as a baseline and then compared to the average participation for the remaining days of discussion. There was no significant difference among the groups. In other words, participation increased after the first day no matter which group was considered. Collecting data in this way averaged all responses for every student. If one student carried the bulk of the conversation, the average may have been higher because that student had a disproportionate number of responses. The second type of data examined was overall participation. Sets of data were taken using of the number of students that participated in class discussions any number of times, be it once or several times, divided by the total number of students in the class to find the overall percentage of participation for each discussion. The overall daily participation was then averaged for each treatment group. The Kruskal Wallis test showed there were significant differences in overall participation according to the treatment groups. The scores for the metacognitive questions group and the think-pair-share group were far above the control group scores. The response to the metacognitive strategies appears to be dramatic and immediate. The third part of the data that was examined was the qualitative data. By reviewing the tapes of the discussions there appeared to be a trend toward longer and more in-depth discussions in the metacognitive questions group.

The second question to be addressed was, “How will using metacognitive questions and the think-pair-share strategy relate to student achievement?” The Kendall’s tau showed increase in content knowledge for all groups. The Kruskal Wallis test was used to compare pretest and posttest changes by group. The scores show there was no significant difference based on group membership. It appears that the metacognitive treatments did not impact student achievement either positively or negatively. The increase in the amount of time that was devoted to the class discussions for the metacognitive questions groups does not appear to be detrimental to student achievement. The results could be due to the fact that the study was of a short duration and conducted with a small sample size. To be statistically significant one must have adequate numbers and variability.

The third question to be addressed was “How will using metacognitive questions and the think-pair-share strategy relate to long-term retention of content knowledge?” A Kruskal Wallis test was computed using the maintenance scores. The scores show there was no significant difference based on group membership. It appears that the metacognitive treatments did not impact long-term retention of content knowledge either positively or negatively. The increase in the amount of time that was devoted to the class discussions for the metacognitive questions group does not appear to be detrimental to long-term retention of content knowledge. The results could be due to the fact that the study was of a short duration and conducted with a small sample size. To be statistically significant one must have adequate numbers and variability.

Educational Implications

It was anticipated that one of the metacognitive strategies, think-pair-share or metacognitive questions, would show a distinct increase in students' voluntary participation in class discussion and result in more in-depth discussions. Studies from the literature did not address the amount of participation in class discussion. However, when metacognitive strategies that encouraged students to examine their understanding of science concepts were in place, meaningful, in-depth conversations were observed (Beeth, 1998; Blank, 2002; Hennessey, 1999). Using metacognitive questions for a journal entry and then sharing information from the entries with the whole class showed a trend of more in-depth conversations than using the think-pair-share strategy. Students in the metacognitive questions group critiqued each other's responses while offering their own understanding of the concepts. Some of the students in the metacognitive questions group directed their personal understanding of the topic to students that were confused instead of directing their answers to the teacher. Students in group settings are more likely to assess their ideas by implementing a larger array of metacognitive strategies than if they are working as an individual (Mittlefehldt & Grotzer, 2003). During the course of classroom discussions, some students in the metacognitive group verbalized the processes they were using in order to explain difficult parts of certain concepts. For example, when a student did not understand how the model of the Mediterranean represented what was actually happening at that location, one student verbalized how he tied the information together by going step-by-step through the process. Instead of regurgitating an answer, the student's explanation utilized the metacognitive processes that were used to arrive at the answer. According to Marzano (1998), when students verbalize "their thoughts while monitoring the execution of a complex task" (p. 118) (in this case, explaining how the model of the Mediterranean Sea demonstrates the actual current at the location) students are also gathering insights of how their belief in their personal ability affects their performance. It appeared that the metacognitive group as a whole was trying to work collectively to go beyond the surface explanation of their observations. Although there was a trend toward more in-depth conversations in the megacognitive questions group, it did not result in an improvement in achievement.

Experimental inquiry has been linked to increased metacognition (Marzano, 1998). Although some of the activities during the study would be in the category of experimental inquiry, there were also activities that would be associated with a more traditional approach. The conversation of the metacognition questions group that dealt with explaining how the model was related to the actual current at Strait of Gibraltar was the most in-depth discussion during the study. This conversation occurred the day after the students were engaged in what could be considered experimental inquiry. Perhaps the cumulative effect of combining experimental inquiry with the metacognitive questions worked together to stimulate more thoughtful, interactive responses from students.

In contrast the quality of the discussion of the think-pair-share group seemed shallow. Answers were rote and directed to the teacher. Answers to the cognitive questions by students in this group seemed to be accepted without being scrutinized or extended. Questions were seldom generated during the course of the discussion. By observing the interactions between the pairs of students when discussing their journal entries, it appeared that students were trading answers instead of defending or explaining their entries. Guidelines should have been put into place in order to insure that students were actually using metacognitive strategies during the treatment. In order to generate discussions that are more in-depth and of a higher quality, it appears that metacognitive questions should be used.

Although the metacognitive questions group showed a trend toward higher quality discussions, the amount of participation in all treatments showed mixed results. When the number of students that voluntarily participated at any time during conversation was divided by the total number of students in the class and then averaged, there was a statistical significance for both metacognitive strategies. The results appear to indicate that either metacognitive strategy will increase overall participation. When the average participation of students on the first day of the study was compared to the average participation of students from the other six days of discussion, no statistical significance was shown. Perhaps data should have been collected for voluntary participation in class discussions before the study started over a variety of different topics. This would have been a more accurate way to determine if either of the treatments had an effect on voluntary participation in discussions.

No increase in student achievement or long-term retention was seen in either the think-pair-share group or the metacognitive questions group. This study lasted for ten days without any direct instruction on what metacognition is or how to implement metacognitive strategies. Both strategies were adopted in the science classroom without any explanation of how the treatment can be beneficial. This is consistent with the results of Patry's (2004) study which showed that short-term instruction in the use of metacognition strategies was ineffective in developing metacognition. Metacognitive ability has the ability to change over time (Hennessey, 1999). It is possible that given a longer time frame, the metacognitive strategies could affect student achievement and long-term retention. Direct instruction about the uses and the advantages of the different metacognitive processes could have shown a difference in the results. In this study, none of the metacognitive strategies were continued during the time between the posttest and the maintenance test. If the metacognitive strategies would have continued during this time, it is possible that there would have been changes in long-term retention. Additionally, adding the tests of intelligibility, wide-applicability, and plausibility (Mittlefehldt & Grotzer, 2003) to the students' responses during the course of the study may have resulted in positive changes for long-term retention.

An example of self-efficacy in conjunction with metacognition (Reutzel et al., 2002) surfaced during the study. One ESL student in the metacognitive questions group became visibly upset when the maintenance test was given unannounced. Before trying to process or regulate the information, the student gave up. Her attitude was evident by the note she wrote on the test, "I remember nothing about density." She appeared to be unable to access any metacognitive strategies that would enable her to evaluate and select a thinking process to alleviate her frustration.

Limitations

One of the most obvious limitations of this study is the students' knowledge of the research. There were daily questions in all groups that revolved around the use of the tape recorder to document the discussions in the class. The increase in participation for all treatment groups could be the result of the students wanting to appear favorable in the researcher's report. Students in the control group repeatedly asked if they could pick fake names to be used in the researcher's report. A teacher in a different content area reported that students in the control group were discussing how they were trying to say "smart things" during science class so they could be included in the researcher’s paper. On the seventh day of the research during a class discussion, a student in the control group asked if the researcher was marking down on a paper how many times they raised they hands. After that question, there appeared to be an increase in the number of students in the control group that volunteered to participate in class discussions. If the students felt like there was an advantage to participating in class discussion this could have skewed the results.

It is difficult to tell if the students in the think-pair-share group were indeed using metacognitive strategies. Based on the lack of interaction between partners, and the shortage of insightful conversation, it is possible that the students were not using metacognitive processing to arrive at their answers. Instead, it would appear that students were giving rote answers to many of the cognitive questions that were posed. Training the students to be critical of each others’ answers during the partner phase and whole class sharing phase could increase their use of metacognitive strategies when implementing the think-pair-share treatment.

Another limitation of the study was the manner in which instruction was delivered. The direction of class discussion for each group was different on each day for each class. The exact wording of instructions and the amount of time spent on instructions varied by group. When the discussions of the metacognitive questions group ran longer, less time was available for direct instruction, practice, or preview of the homework. In addition, the type, length, and timing of interruptions for each class varied on a daily basis. If an interruption came in the middle of a discussion or during instruction, the class would have to regroup and try to start where they left off.

The small sample size may have affected the results of the study for all of the questions that were addressed. Future endeavors should include a greater number of classes in the study.

Future Research

For future research it would be interesting to see if combining metacognitive questions with the think-pair-share strategy would show increased participation in class discussions, increased achievement, and increased long-term retention. Previous research showed positive results for increased participation when the strategies were combined (Stuever, 2005), but it is unknown if those results can be duplicated.

A study that explores the effects of direct instruction about the use of metacognitive strategies and process would allow teachers to evaluate how much instructional time should be devoted to direct instruction about metacognition. It would be valuable to know if metacognitive practices can be successfully implemented in the classroom without sacrificing valuable instructional time over content.

Since the metacognitive questions strategy resulted in both longer and more in-depth conversations, it would be interesting to study if that particular approach affects students' attitude toward science. It appeared that the students in the metacognitive questions group were more in tune and engaged with the direction of the discussion. Possibly using this metacognitive strategy would allow students to develop a better appreciation for science.

The classrooms that successfully incorporated metacognition as an essential part of the daily routine could all be described as inquiry based (Beeth, 1998; Blank, 2002; Hennessey, 1999; Mittlefehldt & Grotzer, 2003). The question still stands—is it possible to incorporate metacognition in the more traditional classroom without drastically changing the delivery of instruction? This study showed promise because of the quality of discussions in the metacognitive questions group and an increase in overall participation for both metacognitive strategies. A study to determine to what extent metacognition could occur in a traditional science classroom versus an inquiry-based science classroom could be helpful. Teachers could determine which course to take while encouraging the development metacognitive strategies for their students.

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APPENDICES

APPENDIX A

COGNITIVE QUESTIONS FOR JOURNAL ENTRIES

CONTROL GROUP AND THINK-PAIR-SHARE GROUP

Cognitive Journal Questions for Discussion 1 (Day 2)

Look at the angel chimes. What makes the angels spin? How could you make them spin the opposite direction?

Image taken from http://www.dpent.ca/Images/16242.jpg

Cognitive Journal Questions for Discussion 2 (Day 4)

Explain the Mediterranean Puzzle. Use the lab from yesterday to help you explain what is happening at the Strait of Gibraltar.

Cognitive Journal Questions for Discussion 3 (Day 5)

How do you calculate the density of a liquid? What does it tell you? Explain how you would calculate the density of a liquid step-by-step.

APPENDIX A (continued)

Cognitive Journal Questions for Discussion 4 (Day 6)

What is the object? What is it used for? Use what you know about density to help you explain how it works.

Cognitive Journal Questions for Discussion 5 (Day 7)

You have a nugget that looks just like gold. How can you tell if the nugget is really gold or just worthless fool's gold?

Cognitive Journal Questions for Discussion 6 (Day 8)

Read "A Matter of Density". How will you remove the red liquid from the tank?

Cognitive Journal Questions for Discussion 7 (Day 10)

Tell me everything you know about density. Include definitions, the formula, Mediterranean Sea density current, yesterday's experiment, and anything else you can think of.

APPENDIX B

METACOGNITIVE QUESTIONS FOR JOURNAL ENTRIES

METACOGNITIVE QUESTIONS GROUP

Metacognitive Journal Questions for Discussion 1 (Day 2)

Look at the angel chimes. What makes the angels spin? What else do you know that might relate to this? Can the angels spin in the opposite direction? What information can you use to help you explore this?

Image taken from http://www.dpent.ca/Images/16242.jpg

Metacognitive Journal Questions for Discussion 2 (Day 4)

What do you understand about yesterday's lab? What part about yesterday's lab was difficult to understand? How can you link yesterday's lab to the solution of the Mediterranean Puzzle?

Metacognitive Journal Questions for Discussion 3 (Day 5)

How do you calculate the density of a liquid? What information do you need to complete this task? Where will you get the information? What will you do if you get stuck as you are finding the answer?

Metacognitive Journal Questions for Discussion 4 (Day 6)

Look at the object on the demo table. What is it? What do you know that could apply to the way this object works? By observation, what do you know about the object? What can you infer? How could you get more information about the object and its function?

Metacognitive Journal Questions for Discussion 5 (Day 7)

You have a nugget that looks just like gold. How can you tell if the nugget is really gold or just worthless fool's gold? Do you understand how to apply what we learned last week? What do you need to know to tell if it is gold or not? Do you need help understanding how to tell the difference? What questions could you ask?

Metacognitive Journal Questions for Discussion 6 (Day 8)

Read "A Matter of Density". What method will you use to solve the problem? What have you learned previously that will help you?

Metacognitive Journal Questions for Discussion 7 (Day 10)

Tell me everything you know about density. Include definitions, the formula, Mediterranean Sea density current, yesterday's experiment, and anything else you can think of. Which parts of density do you understand? What parts are still difficult for you? How can you remember the information for the test tomorrow?

APPENDIX C

PRETEST OVER DENSITY

1. What is the difference between mass and weight?
Mass is the amount of matter an object has; weight is the gravitational pull on the object. (1 point)

2. How do you measure each?
Mass- mass is measured in grams or kilograms on a balance (any one part of the answer-1 point)
Weight-weight is measure in newtons (or pounds) with a spring scale (any one part of the answer-1 point)

3. What is volume?
Volume is the amount of space an object takes up (1 point)

4. How would you measure the volume of the following?
liquid-Use a graduated cylinder, read the markings (1 point)
cube of solid-Measure one side and cube it. OR measure length, width and height, multiple length times width times height (1 point)
irregular solid- Use water displacement (1 point)

5. Explain what density is.
Density is the amount of matter in a given space (1 point)

6. What two measurements are needed to find density?
1. Mass (.5 points
2. Volume (.5 points)

7. Write the formula for density.
Density = mass/volume OR D = m/v (1 point)

8. Describe a density current like the one at the Strait of Gibraltar. Explain the effect density has on the movement of this type of current.
The water of the Atlantic Ocean flows in on the top because it is less dense, while the more dense water of the Mediterranean Sea flows out on the bottom. (2 points)

9. Finish this table. Don't forget your labels

Material	Mass	Volume	Density
lead	171 g	15 cm^3	11.4 g/cm^3(1pt)
aluminum	148 g	40 cm^3	3.7 g/cm^3(1pt)
mercury	4725 g	350 cm^3	13.5 g/cm^3(1pt)

Use the following information to help you answer questions 10-12.

Material	Mass of 30 mL	Density
water	30.0 g	?
alcohol	21.0 g	?
ice	27.6 g	?
salt water	33.0 g	?
egg	31.5 g	?

10. Which material(s) would float on fresh water? Alcohol and ice (1 point)
Explain your answer. Both alcohol and ice are less dense than water. (1 point)

11. Which material(s) would float on alcohol? None of them (1 point)
Explain your answer. None of the other substances are less dense than alcohol(1 point)

12. Which material(s) would float on salt water? Water, alcohol, ice, and egg (1 point)
Explain your answer. All of these substances are less dense than salt water (1 point)

APPENDIX D

POSTTEST OVER DENSITY

1. What is the difference between mass and weight?
Mass is the amount of matter an object has; weight is the gravitational pull on the object. (1 point)

2. How do you measure each? (Give the unit and the instrument used to measure each.)
   Mass- mass is measured in grams or kilograms on a balance (1 point)
   Weight-weight is measure in newtons (or pounds) with a spring scale (1 point)

3. What is volume?
Volume is the amount of space an object takes up (1 point)

4. How would you measure the volume of the following?
   liquid-Use a graduated cylinder, read the markings (1 point)
   cube of solid-Measure one side and cube it. OR measure length, width and height, multiple length times width times height (1 point)
   irregular solid- Use water displacement (1 point)

5. Explain what density is.
Density is the amount of matter in a given space (1 point)

6. What two measurements are needed to find density?
   1. Mass (.5 points
   2. Volume (.5 points)

7. Write the formula for density.
Density = mass/volume OR D = m/v (1 point)

8. Describe a density current like the one at the Strait of Gibraltar. Explain the effect density has on the movement of this type of current.
The water of the Atlantic Ocean flows in on the top because it is less dense, while the more dense water of the Mediterranean Sea flows out on the bottom. (2 points)

9. Finish this table. Don't forget your labels

Material	Mass	Volume	Density
lead	171 g	15 cm^3	11.4 g/cm^3(1pt)
aluminum	148 g	40 cm^3	3.7 g/cm^3(1pt)
mercury	4725 g	350 cm^3	13.5 g/cm^3(1pt)

APPENDIX D (continued)

Use the following information to help you answer questions 10-12.

Material	Mass of 30 mL	Density
water	30.0 g	?
alcohol	21.0 g	?
ice	27.6 g	?
salt water	33.0 g	?
egg	31.5 g	?

10. Which material(s) would float on fresh water? Alcohol and ice (1 point)
Explain your answer. Both alcohol and ice are less dense than water. (1 point)

11. Which material(s) would float on alcohol? None of them (1 point)
Explain your answer. None of the other substances are less dense than alcohol(1 point)

12. Which material(s) would float on salt water? Water, alcohol, ice, and egg (1 point)
Explain your answer. All of these substances are less dense than salt water (1 point)

13. You have two test tubes that contain two different samples of a clear, odorless liquid. One of the test tubes has water in it; the other test tube is an unknown liquid. Using density, how can you tell which test tube has the water in it?
Find the mass and volume for both samples, then calculate the density of each one. One of the sample should have density of the know density of water, 1 g/mL. The other sample will be the unknown. (1 point)

14. You have three samples of pure gold. One sample has a mass of 52.4 g, one sample has a mass of 67.8 g, and the other sample has a mass of 97.3 g. Which sample has the greatest density? Explain.
All the samples have the same density because the density is the same for the gold no matter how much of the substance you have.

APPENDIX E

INFORMED CONSENT/ASSENT LETTER

December 6, 2005

Dear Parents/Guardians,

I am conducting a study in my classroom in order to fulfill the requirements of the Master's Program at Wichita State University. I want to see if certain metacognitive strategies can increase voluntary participation of my students in classroom discussions. Normal classroom procedures will be in place for the duration of the study. If you have any questions feel free to contact me. I appreciate your help in reaching my goal.
Thank you,

Ms. Stuever

PURPOSE: Your child is invited to participate in a study of metacognitive strategies. I hope to learn ways to increase voluntary participation in class discussions and activities.

PARTICIPANT SELECTION: Because this study will take place in the morning hours, your student has been chosen to take part in this research. Everyone in this class (20-25 students) will participate in the activities designed for the project. The data from only those students who have parental consent will be used in the written report I must submit at the end of the semester.

EXPLANATION OF PROCEDURES: If you decide to let your child participate, your child will participate in normal classroom activities. Classroom discussions will be audio recorded to confirm the types of participation that occur. The study will last about two months.

BENEFITS: Participating in activities that develop thinking skills.

CONFIDENTIALITY: Any information obtained in this study in which your child could be identified will remain confidential and will be disclosed only with your permission. None of the written information from this research will identify specific students; instead pseudo names will be assigned. Results of this study will be submitted to Wichita State University.

COMPENSATION OR TREATMENT: None

(OVER)

APPENDIX E (continued)

REFUSAL/WITHDRAWAL: Participation in this study is entirely voluntary. Your decision whether or not to participate will not affect your future relations with me with Wichita State University, and/or Maize USD 266. If you decide not let your student participate in this study, he or she will still participate in the classroom activities, but I will not use their data for my research. If you agree to allow your child to participate in this study, you are free to withdraw your child from the study at any time without penalty.

CONTACT: If you have any questions about this research, you can contact:

Donna M. Stuever	or contact	Dr. Jeri Carroll
3701 North Tyler		1845 North Fairmount, Box 28
Wichita, KS 67205		Wichita State University
(316) 722-0421 x 2548		Wichita, KS 67260
(316) 978-3322		

If you have questions pertaining to your child's rights as a research subject, or about research-related injury, you can contact:
Office of Research Administration
Wichita State University
Wichita, KS 67260-0007
(316) 978-3285.

Your signature indicates that you have read the information provided above and have voluntarily decided to let your child participate.
Thank You!

____
Ms. Donna M. Stuever

____
Dr. Jeri A. Carroll
I give permission for my student, ______________________, to participate in the study in Ms. Stuever's 8th grade science classroom in the second semester.

____ __________________
Signature of Parent or Legal Guardian Date
*******Please keep one copy of the form and return one copy with your signature to Ms. Stuever.***

Student Assent Form

I have been informed that my parents have given permission for me to participate, if I want to, in a study concerning thinking strategies. My participation in this project is voluntary and I have been told that I may stop my participation in this study at any time. If I choose not to participate, it will not affect my grade in any way.

____ ____________________
Signature of Student Date

APPENDIX F

THE MEDITERRANEAN PUZZLE

For thousands of years sailors have used winds and ocean currents to propel their ships. Ancient peoples spent much time speculating about causes of winds and oceans currents, but it was left to modern science to solve the puzzle of their origin. What causes these current in the ocean and atmosphere? Are they somehow related? What role do these currents play in the global climate? These are questions we will investigate in this lesson.

Let's start with an ancient puzzle that was finally solved by Count Luigi Marsili in 1679. Examine the map of the Mediterranean Sea. The Puzzle is this: sailors had long known that swift currents flowed into the Mediterranean from both the Black Sea and the Atlantic Ocean. Many rivers and streams also empty into it. The Mediterranean has no apparent outlet; therefore, the water level should rise, but it does not. Many explanations were offered—for example, the existence of hidden underground channels to drain the excess water. Can you solve this puzzle?

Count Marsili thought he could, and so he set up a model of the Mediterranean to test his idea. In the following Explorations you will trace the steps of Count Marsili as you discover the answer to the Mediterranean puzzle. At the end of Exploration 3, be prepared to describe the Mediterranean puzzle and explain its solution.

Text taken directly from *Science Plus Technology and Society: Level Blue.*

APPENDIX G

MAP OF THE MEDITERRANEAN SEA

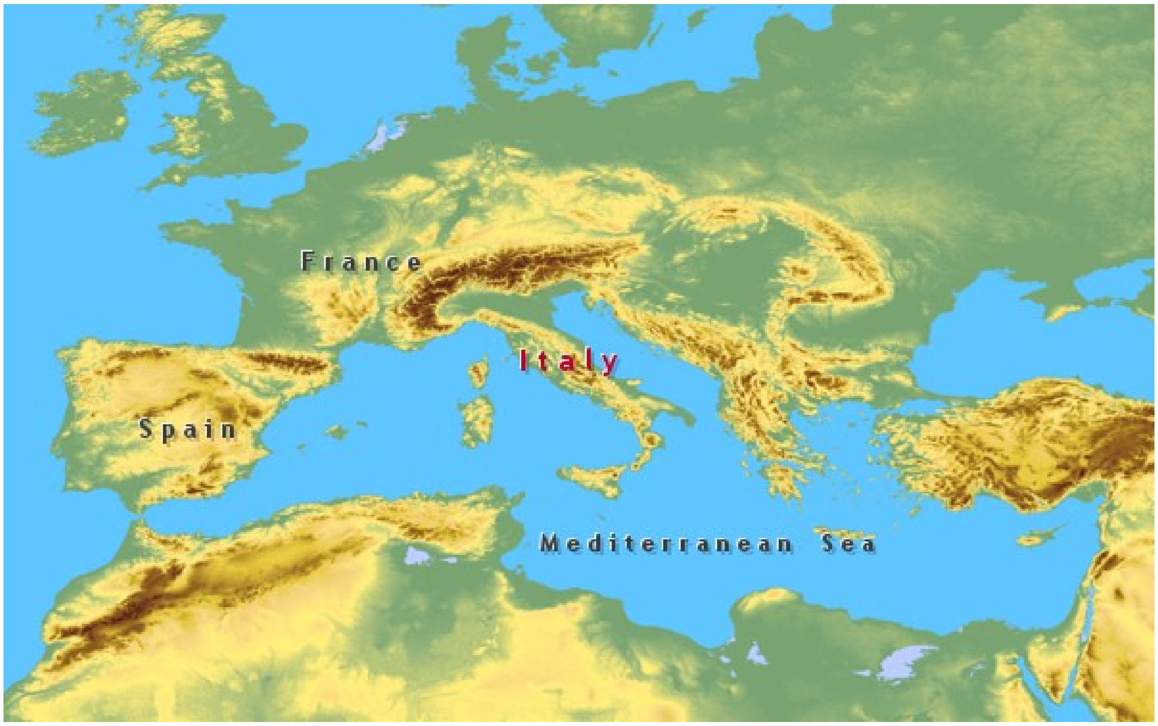


Image taken from:

http://www.casa-toscana-ag.com/map_mediterranean_sea.html

APPENDIX H

MEDITERRANEAN SEA—UNRAVELING THE PUZZLE

Materials: water and salt solution – Blue
water and salt solution – Yellow
clear container
6cm x10cm piece of aluminum foil
masking tape
pepper

Procedure:

1. Take a piece of foil (6cm X 10cm) and tape it to the center of the container. (FYI—Watch my demo before starting!)
2. After dividing the container into two parts, pour blue solution in one side while another person pours yellow solution in the other side.
3. When you are ready to poke holes into the barrier of foil, CALL ME TO YOUR TABLE!!!!!!!!!!!!
4. I WILL SPRINKLE PEPPER IN ONE SIDE OF YOUR CONTAINER.
5. Poke one hole in the barrier of foil just below the water with a pencil.
6. Quickly poke another hole in the barrier just above the tape on the bottom of the barrier.
7. Observe for 6 minutes. Draw a diagram every 2 minutes.
8. Clean up and answer the questions on the back with your partner.

Start	2 minutes
4 minutes	6 minutes

APPENDIX H (continued)

Interpreting Your Findings

1. How does this exploration serve as a model of the Mediterranean Sea?

2. Using what you have learned, draw a diagram of the Mediterranean Sea showing the flow in and out.

3. From your observations, which is saltier, the Atlantic Ocean or the Mediterranean Sea? Explain.

4. Which solution represents the Atlantic Ocean? How do you know?

5. Which solution represents the Mediterranean Sea? How do you know?

6. Why would the saltiness of the Mediterranean Sea differ from that of the Atlantic Ocean?

7. Marsili thought that he could explain how the saltiness of ocean water could set up currents. To test his idea he drew water from different depths in the Straits of Gibraltar. He then found the mass of equal volumes of each sample and compared them with the mass of an equal volume of fresh water. What do you think he found?

Modified from *Science Plus Technology and Society: Level Blue.*

APPENDIX I

CALCULATING DENSITY HOMEWORK

Material	Mass of 30 mL	Density
water	30.0	?
alcohol	21.0	?
ice	27.6	?
salt water	33.0	?
egg	31.5	?

The density of any material can be found using this formula: Density = mass/volume

1. Which liquid has the highest density? ______________________

2. Which liquid has the lowest density? ______________________

3. What are the densities of the materials listed below?
    - water ________
    - alcohol ________
    - ice ________
    - salt water ________
    - egg ________

4. Which material would float on fresh water? __________________

5. Which material would float on egg? ________________

6. Which material would float on salt water? __________________

Substance	**Density (g/cm^3)**
bronze	8.8
lead	11.4
tin	7.3
glass	2.6
rubber	1.2
bromine (liquid)	3.1
mercury (liquid)	13.6

APPENDIX I (continued)

7. Which substance(s) would float in mercury? ___________________________________

8. Which substance(s) would float in bromine? ___________________________________

9. If you had 10 cm^3 of each substance, which would have the least mass?_______________

FYI--1mL=1cm^3=1cc

Modified from *Science Plus Technology and Society: Level Blue.*

APPENDIX J

HOT & COLD/SALT & TAP WATER DEMO

Activity 1: Hot water on the top and cold water on the bottom.

Predict____
____

Observe____
____

Explain____
____

Activity 2: Cold water on the top and hot water on the bottom.
Predict____
____

Observe____
____

Explain____
____

Activity 3: Tap water on the top and salt water on the bottom
Predict____
____

Observe____
____

Explain____
____

Activity 4: Salt water on the top and tap water on the bottom
Predict____
____

Observe____
____

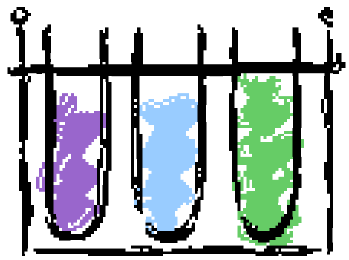
Explain____
____

Modified from Science Plus Technology and Society: Level Blue.

APPENDIX K

APPLYING DENSITY

1. You are a scientist in a big lab with a huge problem. You have just discovered the cure for apathy, but unfortunately the labels have fallen off of your test tubes. (Perhaps you didn't care enough to secure the labels tightly!) There are three test tubes without labels that contain clear liquids. You are pretty sure that one of the test tubes has distilled water in it, and one of the test tubes has alcohol in it. The other test tube contains your newly discovered potion. You are to deliver your new concoction to your boss in 15 minutes in order to start testing your discovery on lazy mice. How will you know which test tube to deliver?



____
____
____
____
____
____
____

2. You combine the blue salt solution of the Mediterranean Sea with the yellow salt solution of the Atlantic Ocean from our lab. What can you infer about the density of new green liquid? How could you test your inference?

____
____
____
____
____

3. You throw a large object into a bucket of water and it floats. You throw a small object into the same bucket of water and it sinks. What can you tell me about the density of each of the objects?

____

4. You have a tub of different size nails made from the same material. Which nail will have the greatest density: the small nail, the medium-size nail, or the large nail? Explain your answer.

Name ________________________________ Date ______________ Class ___________

CHAPTER 1 **REINFORCEMENT WORKSHEET**

A Matter of Density

Complete this worksheet after you finish reading Chapter 1, Section 2.

Imagine that you work at a chemical plant. This morning, four different liquid chemicals accidentally spilled into the same tank. Luckily, none of the liquids reacted with each other! Also, you know the liquids do not dissolve in one another, so they must have settled in the tank in four separate layers. The sides of the tank are made of steel, so you can only see the surface of what's inside. But you need to remove the red chemical to use in a reaction later this afternoon. How will you find and remove the red chemical? By finding the chemicals' different densities, of course!

The following liquids were spilled into the tank:

- a green liquid that has a volume of 48 L and a mass of 36 kg
- a blue liquid that has a volume of 144 L and a mass of 129.6 kg
- a red liquid that has a volume of 96 L and a mass of 115.2 kg
- a black liquid that has a volume of 120 L and a mass of 96 kg

1. Calculate the density of each liquid.

Green liquid: ________________________

Blue liquid: ________________________

Red liquid: ________________________

Black liquid: ________________________

2. Determine the order in which the liquids have settled in the tank.

First (bottom): ________________________

Second: ________________________

Third: ________________________

Fourth (top): ________________________

3. Use colored pencils to sketch the liquid layers in the container in the diagram on the next page.

4. What kind of property did you use to distinguish between these four chemicals?

a. a chemical property
b. a physical property
c. a liquid property
d. None of the above

APPENDIX M

FINDING DENSITY

Directions: Find the density of the following items. Answer the questions that follow.

Density Table

Material	Mass	Volume	Density
Block of Wood Block # ____			
Clear Liquid			
5 Washers			

1. You have an object that has a density of .75 g/mL. Will it float in the clear liquid? Explain your answer.

____

2. What would the density of 10 washers be?

____

3. List the item that has the greatest density?

____

APPENDIX N

DENSITY REVIEW

1. Define the following terms in your own words:
   volume-- ____
   ____
   mass-- ____
   ____
   weight-- ____
   ____

2. How do you find the density of the following:
   liquid-- ____
   ____
   ____
   irregular shaped solid-- ____________________________________
   ____
   ____
   rectangular solid-- ____________________________________
   ____
   ____

3. What is the formula for density?

____

4. What does density mean?

____

5. Describe the density current that forms at the Strait of Gibraltar. How does density affect the movement of the water?

____

____

6. Find the density of each of these materials. Don't forget your labels

Material	Mass	Volume	Density
Mercury (liquid)	4725 g	350 cm^3	
Iron (solid)	23.7 g	3 cm^3	
Copper (solid)	89 g	10 cm^3	

7. Which of the material(s) from the above chart will float on mercury?

____

8. You have samples of two different liquids. One is alcohol and the other one is unknown. How can you figure out which sample is the alcohol?

____

9. You have three samples of zinc. One sample has a mass of 11.5 g, one sample has a mass of 25.1 g, and the other sample has a mass of 65.8 g. Which sample has the greatest density? Explain your answer.

____

____

APPENDIX O

RAW DATA FOR DAILY PARTICIPATION, PRE/POSTTEST, AND MAINTENANCE

ID	Group	Sex	Day 2	Day 4	Day 5	Day 6	Day 7	Day 8	Day 10	Mean	Pre	Post	Main
1	0	0	9	5	3	0	AB	0	3	3.33	0.00	0.86	0.88
2	0	1	AB	0	0	0	0	0	0	0.00	0.05	0.58	0.7
3	0	1	2	0	0	0	1	AB	0	0.50	0.10	0.5	0.32
4	0	0	1	0	1	1	0	0	1	0.57	0.00	0.86	0.92
5	0	1	4	2	3	0	AB	0	0	1.50	0.14	0.8	AB
6	0	0	0	0	4	0	0	4	0	1.14	0.05	0.88	0.92
7	0	1	0	0	0	0	0	0	0	0.00	0.05	0.72	0.68
8	0	1	2	3	1	1	3	AB	3	2.17	0.05	0.44	0.54
9	0	1	0	1	0	0	0	0	0	0.14	0.05	0.54	0.24
10	0	1	5	8	2	4	4	2	3	4.00	0.07	0.92	0.88
11	0	1	0	0	0	1	2	0	0	0.43	0.00	0.84	0.4
12	0	1	0	1	4	0	3	2	0	1.43	0.00	0.84	0.9
13	0	1	0	0	2	0	1	1	0	0.57	0.05	1	0.88
14	0	1	1	0	0	0	1	0	0	0.29	0.05	1	0.84
15	0	0	1	0	0	0	1	0	0	0.29	0.05	0.8	0.88
16	0	0	4	8	4	3	4	5	3	4.43	0.81	0.92	1
17	0	0	1	0	0	0	1	0	0	0.29	0.05	0.62	0.38
18	0	1	AB	0	3	4	2	1	0	1.67	0.38	0.92	0.54
19	0	0	0	1	0	0	0	2	0	0.43	0.05	0.84	0.84
20	0	1	4	2	1	3	4	AB	AB	2.80	0.05	AB	AB
21	0	0	8	10	7	5	5	4	1	5.71	0.07	1	0.92
22	0	1	AB	0	1	2	0	1	1	0.83	0.24	0.82	0.96
23	0	0	0	6	2	6	3	3	3	3.29	0.05	0.92	0.68
24	0	1	0	0	1	0	0	0	0	0.14	0.05	0.7	0.64
25	1	1	2	8	2	1	3	4	1	3.00	0.21	0.92	0.8
26	1	1	AB	6	1	2	2	1	1	2.17	0.38	0.56	AB
27	1	1	3	5	1	1	4	1	0	2.14	0.19	0.82	0.8
28	1	0	2	AB	1	1	1	3	0	1.33	0.24	0.96	0.86
29	1	1	1	1	2	0	2	3	1	1.43	0.33	0.74	0.92
30	1	1	2	1	2	0	1	1	0	1.00	0.10	0.92	0.92
31	1	0	0	0	0	0	0	0	1	0.14	0.17	0.9	0.94
32	1	0	2	6	8	4	4	6	1	4.43	0.43	0.92	0.8
33	1	1	0	1	0	0	1	1	1	0.57	0.00	0.88	0.82
34	1	0	0	0	1	1	0	2	0	0.57	0.05	1	0.86
35	1	1	2	2	0	1	1	4	0	1.43	0.10	0.68	0.76
36	1	1	1	1	6	1	1	2	1	1.86	0.10	0.46	0.4
37	1	0	3	3	3	2	4	4	2	3.00	0.31	1	0.88
38	1	0	4	2	3	0	2	5	1	2.43	0.40	0.92	0.84
39	1	0	0	0	0	0	0	0	0	0.00	0.00	0.36	0.58
40	1	1	0	0	0	0	0	0	0	0.00	0.19	0.8	0.6
41	1	0	2	0	0	1	1	0	1	0.71	0.10	0.52	0.44
42	1	1	AB	2	1	1	1	1	1	1.17	0.05	0.7	0.62
43	1	0	0	0	1	0	0	0	1	0.29	AB	0.76	0.64
44	1	1	4	9	1	3	2	2	1	3.14	0.86	0.96	1

45	1	1	1	0	0	0	0	0	1	0.29	0.24	1	0.9
46	1	1	2	0	1	3	0	1	1	1.14	0.19	0.96	0.96
47	2	1	0	1	0	0	0	1	1	0.43	0.07	1	0.78
48	2	0	1	4	2	1	3	1	1	1.86	0.05	0.78	0.82
49	2	1	0	0	1	0	2	0	0	0.43	0.05	1	0.88
50	2	1	1	1	0	0	2	1	0	0.71	0.05	0.88	0.66
51	2	1	0	1	1	0	2	0	1	0.71	0.00	1	0.84
52	2	1	1	5	4	2	3	2	1	2.57	0.19	1	0.94
53	2	0	1	AB	0	1	3	2	3	1.67	0.05	0.88	0.9
54	2	0	0	1	0	0	0	1	1	0.43	0.00	0.62	0.4
55	2	1	0	3	0	0	1	0	1	0.71	0.00	0.84	0.04
56	2	1	1	2	0	2	3	1	2	1.57	0.10	0.94	0.68
57	2	1	5	6	3	4	4	5	2	4.14	0.02	0.94	0.88
58	2	0	3	2	2	0	3	1	2	1.86	0.07	0.92	0.9
59	2	0	2	3	3	2	6	3	2	3.00	0.10	0.9	0.88
60	2	0	3	6	2	3	3	3	0	2.86	0.33	0.98	0.76
61	2	0	0	0	0	0	4	0	1	0.71	0.00	0.92	0.56
62	2	1	1	4	1	2	6	1	1	2.29	0.05	0.78	0.76
63	2	1	2	4	4	1	4	2	0	2.43	0.05	0.98	0.96
64	2	1	0	0	0	0	0	0	1	0.14	0.00	0.84	0.82
65	2	0	3	6	2	3	2	2	2	2.86	0.29	0.92	0.9
66	2	1	0	2	0	2	0	0	1	0.71	0.00	0.66	0.38

Note. Groups 0=control, 1=TPS, 2=MQ; Sex 0=male, 1=female; Day 1 was the pretest; there was no class discussion on the Day 3 or Day 8 when students participated in labs; Day 11 was the posttest; the maintenance test was given six weeks after the posttest.

APPENDIX P

DAILY OVERALL PARTICIPATION

	Control Group	TPS Group	MQ Group
Day 2	57%	70%	66%
Day 4	46%	62%	75%
Day 5	63%	68%	55%
Day 6	46%	55%	55%
Day 7	59%	64%	80%
Day 9	48%	73%	65%
Day 10	35%	64%	70%
average	51%	65%	67%

Note. Day 1 was the pretest; there was no class discussion on the Day 3 or Day 8 when students participated in labs; Day 11 was the posttest.

APPENDIX Q

MQ GROUP—CONVERSATION FROM DAY 4

Emma: Well, I didn't think anything was difficult about the lab or anything, so I had nothing to write there, but ahh, ah the Mediterranean Sea was more dense than the ocean and so it was on the bottom and the ocean went over it and it kinda circulated.

Teacher: Anybody else have something to add?

Michael: The Mediterranean was on the bottom because it had more salt on it.

George: The Mediterranean was more dense because it had more salt in it than the ocean…

Kenzie: I understood that the Mediterranean Sea was denser and went on the bottom and the ocean was on the top, but I don't understand why it was more dense and how it got that way.

Teacher: Can somebody pull it together for her?

Emma: The reason why it was more dense is because it has more salt.

Kenzie: I understand that. I just don't know what's going on.

Teacher: So, are you asking how does the model help you understand what is going on at the Mediterranean Sea?

Kenzie: Yeah

Teacher: So you understood the model, but you just didn't understand how to translate the information? Is that what you are asking?

Kenzie: Yeah

Teacher: OK Can someone help her out with that?

Michael: Alright the blue solution represents the Mediterranean alright? The yellow solution represents the Atlantic. When, because the blue solution, since the blue solution is the

Mediterranean and the yellow's the Atlantic, it represents the direction, and the foil represents the Strait of Gibraltar, alright?

Teacher: Are you with him so far?

Kenzie: Uh-huh.

Teacher: OK

Michael: Alright, so all you have to do is picture that both of them are ocean water alright? So when they start flowing, the Mediterranean Ocean is going under and the Atlantic Ocean is going over through the Strait of Gibraltar. Got it?

At this point many students start talking at the same time about the topic.

Teacher: Sarah I hear you talking—say it again.

Sarah: The Mediterranean is going one way and the Atlantic Ocean is going the other way and changing and that is why . . .

Teacher: Ok, Kenzie does that help?

Kenzie: Yeah.

Teacher: Does anyone else have something to say to help clear this up?

Ellen: Like the yellow solution went like through the top hole that was just under the line thing and it sorta pushed down the other thing so the blue went to the other side?

Cole: [Responding to Ellen] There is an equal amount of water going in as is going out.