

THE EFFECTS OF METACOGNITIVE AWARENESS ON THE  
DEVELOPMENT OF MATHEMATICAL PROBLEM-SOLVING SKILLS  
IN FOURTH-GRADE HOMEWORK ASSIGNMENTS

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## Abstract

Presently, research is questioning the value of homework, especially at the elementary level. One reason homework is considered important is that it allows for the opportunity to practice and reinforce skills. Currently, elementary students in the United States are assigned homework in mathematics three or more times a week. Since homework assignments extend learning beyond the classroom environment, these assignments need to demonstrate an effective use of students' and teachers' time and energy.

Research has shown that mathematical problem-solving skills improve when students are metacognitively aware of the process they follow as they solve these problems, and this metacognitive awareness improves as students consistently practice and reinforce these skills. This study investigated the effects of metacognitive awareness on the development of problem-solving skills when metacognitive awareness practice was included as a part of mathematical problem-solving skills homework assignments of fourth-grade students.

This quasi-experimental study examined the effects of the independent variable of homework assignments with or without metacognitive awareness practice, on the dependent variables of mathematical problem-solving achievement, completion, accuracy, independence, and quality of responses. Although there was no significant effect of homework assignments, with or without metacognitive awareness practice, on these dependent variables, there was a significant correlation between independence and mathematical problem-solving, completion, accuracy, and quality. Students who independently completed their homework had higher achievement scores than students who did not. Students who received assistance on their homework showed a temporary improvement in the completion, accuracy, and quality of their responses. In other words, help with homework improved the homework assignment but did not

carry over to improve achievement scores. The results of this study pointed out the need to explore how the construct of homework can be effectively utilized as an important element in the development of independent learners.



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Doctor of Education Dissertation

*The Effects of Metacognitive Awareness on the Development of Mathematical Problem-Solving Skills in Fourth-Grade Homework Assignments*

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## CHAPTER 1: INTRODUCTION

### The Effects of Metacognitive Awareness on the Development of Mathematical Problem-solving Skills in Fourth-Grade Homework Assignments

Can metacognition be helpful to the development of problem-solving skills when included in homework assignments? While metacognition, thinking about thinking, has been shown to impact student learning (Flavell, 1979), its specific influence on homework has not been thoroughly investigated (Bacon, Chovelak, & Wanic, 1998). Flavell (1979) suggested that additional resources focus on the development of metacognitive skills in different situations when he stated:

I find it hard to believe that children who do more cognitive monitoring would not learn better both in and out of school than children who do less. I also think that increasing the quantity and quality of children's metacognitive knowledge and monitoring skills through systematic training may be feasible as well as desirable (p. 910).

As Flavell (1979) has stated, providing more opportunity for children to practice cognitive monitoring is important to improving the quality of their thinking. Flavell also pointed out that these opportunities should be experienced outside the school environment as well as within it. Since homework is defined as tasks that are assigned by school teachers for students to complete during non-school hours (Cooper, 1989 a.), effectively designed homework can be an avenue for the training and monitoring of metacognition in students.

Working independently outside the classroom, students must think about how to think. According to Turvey (1986), "The basic aim of homework should be learning how to learn, not merely preparation or practice" (p. 33-34). In addition, Alleman and Brophy (1991) believed that homework assignments will have their greatest impact if they are "structured and scaffolded in

ways that will help students to carry them out with metacognitive awareness of their goals and purposes and metacognitive control of their strategies” (p. 18-19). Furthermore, Costa (1991) stated that: “[h]aving children describe the mental processes they are using, the data they are lacking, and the plans they are formulating causes them to think about their own thinking, to metacogitate” (p. 114). Metacognitive processing has resulted in more flexible approaches to problem-solving and the use of more complex and effective strategies (Dominowski, 1998).

Eilam (2001) reported that performance of academic tasks including homework was shown to be enhanced by students’ explicit attendance to and activation of cognitive and metacognitive strategies (Chi, Leeuw, Chiu, & Lavancher, 1994; McCrindle & Christensen, 1995; Palincsar & Brown, 1984). However, unlike classroom assignments, homework is mostly unsupervised and is or should be mostly self-regulated (Corno, 1995; Corno & Xu, 1998). As a part of self-regulation skills, cognitive strategies help a person process and manipulate information such as taking notes, asking questions, or filling out a chart. These strategies tend to be very task specific, implying that certain cognitive strategies are useful only when learning or performing certain tasks. In contrast, metacognitive strategies are executive in nature. They are the strategies a student uses when planning, monitoring, and evaluating learning or strategy performance. They are also self-regulatory strategies (Vaidya, 1999). Designing homework to include these cognitive skills and metacognitive practices is an important component for educators to consider in developing effective homework.

Specifically, effective homework is homework designed to improve how students’ think. Although homework is assigned regularly for most students, there is controversy surrounding effective homework design (Kohn, 2006). One of these controversies is focused on whether or not it is an effective learning tool for students at the elementary level (Marzano, Pickering,

Pollock, 2001). Throughout the world, homework appears to be rarely used in a way that would build cognitive skills or give students accurate knowledge of the skills and concepts they need for the ongoing development of self-regulation (Baker & LeTendre, 2005). For example, on the National Assessment of Educational Progress (NAEP) exam in the area of mathematics homework, fourth-grade students who reported spending an hour or more on homework scored lower than their peers who did not do homework (Braswell et.al, 2001). In addition, teachers reported that 71 percent of United States fourth graders are assigned mathematics homework three or more times per week (NCES, 1997). More specifically, when comparisons involving the different subskills of mathematics were made, homework appeared to affect success in mathematical problem-solving less than computation or conceptual skills affected success (Cooper, 2001).

Research examining the relationship between metacognitive knowledge and achievement indicated that children who are aware of why, when, and how strategies should be used are more likely to be able to use those strategies successfully (Pressley, 1994). Also, Carr and Biddlecomb (1998) stated that cross-sectional studies have indicated that children develop this knowledge during the elementary school years and that the development of this knowledge benefits their performance over time.

In fact, Baker and LeTendre (2005) noted that many countries with the highest-scoring students on achievement tests have teachers who assigned little homework to those students. These results have led Baker and LeTendre (2005) to the conclusion that more homework may actually undermine national achievement. As recently as 2006, there has been no empirical evidence that any amount of homework improved the academic performance of elementary school students (Cooper, Robinson, & Patall, 2006). Despite these results, homework continues

to be a part of the school environment. Stakeholders in this process--researchers, teachers, administrators, students, parents, and community members--have questioned the value and quality of homework. Determining whether or not homework activities were worth the time and energy invested is a current concern (Bennett & Kalish, 2006; Kohn, 2006). It is time to investigate how student thinking impacts learning, especially in regards to homework activities.

### Rationale

An increase in the quality of student thinking especially in the area of problem-solving in mathematics is important. The difference between being a good or a poor problem solver often lies in the ability of a person to think about his or her problem-solving activities (Gardner, 1991). Knowledge about problem-solving in general and about their own mental processes in particular helps students become better problem solvers (Davidson & Sternberg, 1998). Therefore, teachers need to know how to make learning activities both in and out of school more meaningful for students. These activities include homework assignments.

The National Council of Teachers of Mathematics' (NCTM) *Principles and Standards* provided the most current and comprehensive set of recommendations for improving the teaching and learning of mathematics in the classroom, which incorporates homework assignments. These NCTM documents outlined a vision for school mathematics that included a curriculum that was mathematically challenging and coherent; that covered a broad range of mathematical content; that focused on engaging students in mathematical problem-solving; and that outlined instruction that was conceptually oriented, emphasizing thinking and reasoning as well as applying information (NCTM, 2000). To have an effect, homework needs to reflect these standards.

Research has shown that metacognitive activities can help to improve a student's understanding of mathematical problem-solving skills. Specifically, research has demonstrated that certain self-regulatory and metacognitive skills predict problem-solving success as well as or better than traditional predictors of general ability such as achievement scores (Swanson, 1990). Furthermore, Desoete, Roeyers, and DeClercq, (2003) stated that metacognitive training improved pupil performance in mathematical problem-solving and was found to have a sustained effect on mathematical problem-solving over time.

For several years, mathematical problem-solving has been an area of focus for assessment on the Connecticut Mastery Test (CMT). The skills and concepts included on the CMT are representative of and aligned with the content and performance standards in Connecticut's *Mathematics Curriculum Framework* and the recommendations of the National Council of Teachers of Mathematics (NCTM, 2000). In both the Third and Fourth Generation test reports, the Mathematics Applications' percentages for students attaining mastery were the lowest percentages of all the content strands. In fact, these percentages fell below 50 percent for two recent testing periods (CMT, 2004; CMT, 2006). Clearly, these mathematical problem-solving scores need improvement. Designing homework that supports the development of these skills can be beneficial. Therefore, mathematical problem-solving homework assignments that incorporate metacognitive awareness can be a more effective homework design than assignments that do not foster metacognitive thought.

In addition, mathematics instruction, which includes mathematics homework, has to support the development of mathematics as a life skill. The Organization for Economic and Cooperative Development (OECD) in a series of assessment studies entitled the *Program for International Student Assessment* (PISA) made the following statement:

Mathematics literacy refers to the capacity to identify, to understand, and to engage in mathematics and make well-founded judgments about the role that mathematics plays, as needed for the individual's current and future private life, occupational life, social life, and with peers and relatives and for life as a constructive, concerned and reflective citizen. (PISA, 2003, p. 23)

Regarding the role of mathematics as a life skill, Bempechat (2004) argued that homework can have positive outcomes for students that go beyond improvements in academic achievement. She stated that when homework is developmentally appropriate, it can help build a self-concept that will assist in turning children into lifelong learners. Furthermore, she stated that if a teachers' goal is to prepare children for the demands of secondary schooling and beyond, then teachers must pay as much attention as possible to the development of skills that help children take initiative in their learning and maintain or regain their motivation when it wanes.

Teachers and curriculum leaders need to focus on the different purposes that can be served by well-designed homework assignments, and they need to design homework so that students experience purposeful work. Epstein (2001) stated that rather than giving students more homework, educators should focus on giving more meaningful homework assignments. The main new issue underlying homework was not about time spent on homework but about its purpose and design. Since one of the most common instructional purposes for assigning homework is to provide opportunities for students to practice, prepare, or elaborate on learning activities (Marzano, Pickering, & Pollock, 2001), it is important that these assignments should support quality math instruction and engage students in purposeful thinking. The past decade has seen growing interest in homework intervention research, which has primarily addressed helping students develop homework completion skills (Bryan & Burstein, 2004). However, these goals

have received very little empirical support to date (Zimmerman & Kitsantas, 2005).

Consequently, it may behoove educators to consider how to develop problem-solving activities to compensate for a student's metacognitive weaknesses. This can also pertain to improving the quality of homework design. Research is needed on how to accomplish this goal.

### Statement of the Problem

Homework needs to be designed effectively to be of value to teachers, students, and parents. Marzano, Pickering, and Pollock (2001) stated that communicating clearly with students and parents can decrease potential homework-related tensions that can grow between teachers and students, between teachers and parents, and between parents and students. Most teachers do not take courses specifically on homework during teacher training (Aloia, 2003) and therefore have had limited instruction or professional development on how to develop quality homework assignments. Therefore, school, parent, and community partnerships have become an educational priority for teacher education programs at both the state and federal level (Flanigan, 2007).

For instance, in a survey of faculty representing schools of education at Illinois Professional Learners Partnership Universities, Flanigan (2007) researched the question of whether or not preservice teachers were adequately prepared for partnering with parents and communities. With regard to course topics covered in this partnership, the surveyed faculty reported that only 30 percent of students were effectively prepared to work with parents and communities. Furthermore, 59 percent of that faculty stated that it devoted two to four class sessions on topics relating to this partnership, and only 42 percent of these course sessions addressed how to design interactive homework for students to share with parents. Consequently, there is a need to determine empirically how homework activities can be designed to improve the learning process at the elementary level. The results of this research may guide teachers in

designing more effective mathematics homework assignments for elementary students, thus extending learning beyond the immediate school environment.

#### Definition of Key Terms

The following terms were relevant to this study. The definitions that follow each term applied to the use of the term within this particular study.

1. *Accuracy* was the state of being accurate or free from errors (“Accuracy,” 1. 2005).
2. *Completion* of a mathematical problem meant that it had all the necessary parts, elements, or steps (“Complete,” 1.a., 2005).
3. *Computation* was the process of determining by mathematics, especially by numerical methods, an amount or number (“Computation,” 2008).
4. *Conceptual understanding* was comprehension of mathematical concepts, operations, and relations. It referred to an integrated and functional grasp of mathematical ideas (Kilpatrick, 2001).
5. *Homework* was a task assigned by the classroom teacher to the student intended to be carried out during non-school hours (Cooper, 2001).
6. *Independence* was not looking to others for opinions or for guidance in conduct (“Independent,” 1 b.2, 2005).
7. *Knowledge of cognition* was what individuals knew about their own cognition or about cognition in general. It included three different kinds of metacognitive awareness: declarative, procedural, and conditional (Brown, 1987).
8. *Mathematical applications* referred to the solving of extended numerical and statistical problems (*CMT, Fourth Generation Mathematics Handbook*, 2006).

9. *Mathematical problem-solving activity* was an open-ended mathematical problem that required knowledge, application, and reasoning to determine its solution (NCTM, 2000).
10. *Metacognition* was the active monitoring and consequent regulation and orchestration of mental processes. It was the ability to evaluate one's own comprehension and understanding of subject matter and to use that evaluation to determine how well one might perform a task (Flavell, 1976).
11. *Metacognitive Experiences* were the subjective internal responses of an individual to his own metacognitive knowledge, goals, or strategies (Flavell, 1979).
12. *Metacognitive knowledge* was the knowledge or beliefs about the factors that affect cognitive activities. The three categories of knowledge factors are person variables, task variables, and strategy variables (Flavell, 1979).
13. *Regulation of Cognition* was a set of activities that helped students control their learning. It included planning, monitoring, and evaluating (Brown, 1987).

## Research Questions and Hypotheses

### *Research Questions*

This study investigated five research questions.

1. Is there a significant difference in mathematical problem-solving skills of fourth-grade students as measured by mathematics achievement when homework assignments include the practice of metacognitive awareness as compared to when homework assignments do not include this practice after controlling for individual differences in mathematical problem-solving?;
2. Is there a significant difference in the frequency of completed mathematical problem-

solving homework responses for fourth-grade students when homework assignments include the practice of metacognitive awareness as compared to when homework assignments do not include this practice after controlling for individual differences in mathematical problem-solving?

3. Is there a significant difference in the frequency of accurate mathematical problem-solving homework responses of fourth-grade students when homework assignments include the practice of metacognitive awareness as compared to when homework assignments do not include this practice after controlling for individual differences in mathematical problem-solving?
4. Is there a significant difference in the frequency of independent mathematical problem-solving homework responses for fourth-grade students when homework assignments include the practice of metacognitive awareness as compared to when homework assignments do not include this practice after controlling for individual differences in mathematical problem-solving?; and
5. Is there a significant difference over time in the quality of mathematical problem-solving strategies and solutions for fourth-grade students as measured by a mathematical applications' scoring rubric when homework assignments include the practice of metacognitive awareness as compared to when homework assignments do not include this practice after controlling for individual differences in mathematical problem-solving?

#### *Hypotheses*

1. There will be a significant positive effect on mathematical problem-solving skills of fourth-grade students as measured by mathematics achievement when homework

assignments include the practice of metacognitive awareness as compared to when homework assignments do not include this practice after controlling for individual differences in mathematical problem-solving.

2. There will be a significant positive effect on the frequency of completed mathematical problem-solving homework responses of fourth-grade students when homework assignments include the practice of metacognitive awareness as compared to when homework assignments do not include this practice after controlling for individual differences in mathematical problem-solving.
3. There will be a significant positive effect on the frequency of accurate of mathematical problem-solving homework responses of fourth-grade students when homework assignments include the practice of metacognitive awareness as compared to when homework assignments do not include this practice after controlling for individual differences in mathematical problem-solving.
4. There will be a significant positive difference in the frequency of independent mathematical problem-solving homework responses for fourth-grade students when homework assignments include the practice of metacognitive awareness as compared to when homework assignments do not include this practice after controlling for individual differences in mathematical problem-solving; and
5. There will be a significant positive effect over time on the quality of mathematical problem-solving strategies and solutions of fourth-grade students as measured by a mathematical applications' scoring rubric when homework assignments include the practice of metacognitive awareness compared to when homework assignments do not include this practice after controlling for individual differences in mathematical

problem-solving.

## Review of Related Literature

### *Theoretical Foundation*

In its broadest sense, metacognition refers to the awareness one has about his or her thought processes (Hall & Esposito, 1984). Metacognition is cognition of cognition (Flavell, 1976). Metacognition can lead to selection, evaluation, revision, or deletion of cognitive tasks, goals, and strategies (Flavell, 1979). These actions can help the individual make meaning and discover behavioral implications of metacognitive experiences.

Flavell (1979) proposed that metacognition consisted of both metacognitive knowledge and metacognitive experiences or regulation. Metacognitive knowledge includes the knowledge or beliefs about the factors that affect cognitive activities. Metacognitive knowledge, which can be used to control cognitive processes, refers to knowledge of person, task, and strategy variables. Metacognitive experiences can provide internal feedback about current progress, future expectations of progress or completion, and degree of comprehension, or the connection of new information to old. According to Flavell (1979), metacognitive experiences can also be a stream-of-consciousness process in which other information, memories, or earlier experiences can be recalled as resources in the process of solving a current cognitive problem.

Brown (1987) defined metacognition by its two components: knowledge of cognition and regulation of cognition. Knowledge of cognition refers to what individuals know about their own cognition or about cognition in general (Brown, 1987). Regulation of cognition refers to a set of activities that help students control their learning (Schraw, 1998).

Metacognition can optimize learning. Students benefit from multiple opportunities to practice the metacognitive process of making the unconscious conscious (Willis, 2006).

Furthermore, one way to become better at metacognition is to practice it (Panaoura & Philippou 2007). Therefore, the practice of metacognition can improve the ability of the students to understand how they think and how they learn.

### *Metacognition and Problem Solving*

Metacognition has been identified by many researchers as a key factor in the problem-solving domain (Hacker, et al., 1998; Hartman, 1998; Schoenfeld, 1985). Also, Bruce et. al. (2001) found that high levels of metacognitive self-regulation compensated for low overall abilities. Knowledge of cognition, objectivity, and problem representation were important self-regulatory variables for effective problem-solving (Bruce et al., 2001). Furthermore, cognitive science studies of problem-solving have documented the importance of adaptive expertise as well as of metacognition (Kilpatrick, 2001). Goldberg and Bush (2003) stated that for students to become proficient mathematical problem solvers, teachers at all grade levels must learn how to develop and assess metacognitive skills in their students. Teachers are searching for instructional strategies that will help students plan, monitor, and evaluate their own thinking during problem-solving. Teachers need instructional strategies that help students become better problem solvers (Goldberg& Bush 2003).

### *Homework*

In a synthesis of the research, Cooper, Robinson & Patall (2006) noted that homework was an important part of most school-aged children's daily routines. Cooper also stated that whatever impact homework might have on achievement varied from student to student, depending on how much each student was assigned or actually completed. He suggested that one focus for future studies of the effect of homework on achievement should include students in multiple grades, especially the early elementary grades (Cooper, Robinson, & Patall 2006). Kohn

(2006) reported that homework continued to be assigned in even greater quantities despite the evidence that it is not necessary or even helpful in most cases. In addition, Willis (2006) was surprised by the large number of students who think of homework as something they need to do for their grades rather than as something they will learn from. Willis said students need to see that homework has a real purpose (2006). Finally, Marzano (2007) also identified the importance of teachers assigning purposeful homework.

## Methodology

### *Sample*

The population for this study was an accessible sample of convenience selected from members of fourth-grade classrooms in a school district in New England. This school district represented a white, suburban, upper-middle-class community. The initial sample included 45 students from School A and 67 students from School B for a total of 112 participants. However, two students dropped out of the study bringing the number of actual total participants to  $n = 110$ . The students in the sample were from the eight heterogeneously grouped, self-contained fourth-grade classrooms ranging in class size from seventeen to twenty-four students.

### *Instrumentation*

#### *KeyMath-3Diagnostic Assessment (KeyMath-3DA)*

The *KeyMath-3Diagnostic Assessment (KeyMath-3DA)* is a comprehensive, norm-referenced measure of essential mathematical concepts and skills (Connolly, 2007). The *KeyMath-3DA* is an untimed, individually administered instrument. For this study, the Applications content area of the KeyMath-3 DA, alternate Forms A and B, were used for pre-testing and post-testing, respectively.

*Connecticut Mastery Test Scoring Rubric for Scoring 3-Point Extended-Task Mathematical Items*

The *Connecticut Mastery Test Scoring Rubric for Scoring 3-Point Extended-Task Mathematical Items* was used to score open-ended student responses on the Fourth Generation Connecticut Mastery Test (CMT, 2006) (see Appendix A ).

*Thinking about Thinking Inventory (TAT-4).*

The researcher designed the Thinking about Thinking Inventory for Fourth-Grade students (TAT-4, see Appendix B) based on Schraw and Dennison's Metacognitive Awareness Inventory (Schraw & Dennison, 1994).

*Dependent Variables*

*Completion*

For this study, the dependent variable of completion of responses was calculated by counting the number of completed responses on each homework assignment for both the treatment and the control group participants. A percentage of completion for seven homework assignments was determined.

*Accuracy*

The dependent variable of accuracy of responses was calculated by counting the number of accurate responses on each homework assignment for both the treatment and the control group participants. A percentage of accuracy for seven homework assignments was determined.

*Independence*

The dependent variable of independence was calculated by counting the number of independent responses on each homework assignment for both the treatment and the control

group participants. A percentage of independence for seven homework assignments was determined.

### *Quality*

The dependent variable of quality was calculated by counting the number of 0-3 responses on each homework assignment for both the treatment and the control group participants. The variation among individuals, treatment occasions, and the residual variation was determined.

### *Design and Analysis*

The design for the first research question was quasi-experimental with a pre-and post-test using a treatment and a control group. The dependent variable was math problem-solving achievement. The independent variable was homework assignments with two levels: students who practiced metacognitive awareness using the TAT-4 and students who did not practice metacognitive awareness using the TAT-4. A one-way ANCOVA was used to analyze these data, controlling for post-test differences using pre-test scores (SPSS, 1999). All analyses were tested at the  $p \leq .05$  level of probability.

The design for the second, third, and fourth research questions was post-test only with a treatment and a control group. This design was post-test only since the dependent variables, frequency of completion, accuracy, independence, and quality of mathematical homework assignments, were not available as pre-testing data. Frequencies for completion of responses were attained by counting the number of completed responses in the seven mathematical problem-solving homework assignments for the experimental and control groups. Accuracy was determined by counting the number of accurate responses in the same seven mathematical

homework assignments, and independence was also determined by counting the number of independent responses in the same seven mathematical homework assignments.

Descriptive statistics were determined for these research questions, and a one-way Analysis of Covariance (SPSS, 1999) procedure, using pre-test standard total scores from the Applications content area of the KeyMath-DA-3 as a covariant, was used to examine the mean differences between groups.

The fifth research question was addressed using a post-test only treatment and control group design. The control group and the treatment group were originally randomly assigned. The dependent variable was quality of mathematical problem-solving responses in homework assignments. The independent variable was homework assignments with two levels, students who practiced metacognitive awareness using the TAT-4 and students who did not practice metacognitive awareness using the TAT-4. Quality of response was determined by applying the Connecticut Mastery Test Scoring Rubric for Scoring 3-Point Extended-Task Mathematical Items to the seven homework assignments. A repeated-measures ANCOVA (SPSS, 1999) was used to examine the results of these data. Pre-test standard total scores from the Applications content area of the KeyMath-DA-3 were used as a covariant.

*Treatment.* The researcher attained permission to research this study from the Institutional Review Board (IRB) in February of 2006 (see Appendix C). Consent forms were sent to all fourth-grade students in school A and school B (see appendix D). All fourth-grade classroom teachers in School A and School B, (n = 8) agreed to be part of the study. Teacher participants in four of the eight classrooms were randomly assigned to the treatment group. All student participants were administered the Applications content area of the KeyMath-3 DA, Form A (Connolly, 2007) to assess problem-solving skills. The Applications content area has

two subtests, Foundations of Problem Solving and Applied Problem Solving. Total standard scores on the Applications content area are computed by totaling the subscale scores and determining a total standard score. Upon completion of the pre-test, students in classrooms randomly assigned to the treatment group were given a math problem to solve for homework once a week for seven weeks. The researcher selected the homework assignments based on mathematics application sample practice problems (see Appendix E) from the *Connecticut Mastery Test Handbook, Fourth Generation* (CMT, 2006). These assignments were the math homework every Tuesday night during this data collection period. In addition to responding to the homework assignment, students in the treatment group also responded to the TAT-4 attached to the mathematics problem-solving homework assignment. This inventory appeared at the beginning, middle, and end of the treatment window. Assignments for both treatment and control groups were coded, so this information remained confidential. All homework assignments were delivered and collected by the researcher each week in sealed envelopes.

#### *Control*

The control group participants were selected in the same manner as the treatment group. Upon completion of the pre-test, students in control group classrooms were given the same math problems to solve for homework once a week for a period of seven weeks. Upon completion of the homework data collection process, students in both the treatment and control groups were administered the Applications content area of the KeyMath-3 DA, Form B, as a post-test. As with Form A, the Applications content area Form B has two subtests, Foundations of Problem Solving and Applied Problem Solving. Again, the total standard scores on the Applications content area were computed by totaling the subscale scores and determining a total standard score. Test statistics on problem-solving as well as test statistics for completion, accuracy,

independence, and quality of mathematical problem-solving homework responses were then determined.

### *Data Collection*

In February of 2006, the researcher successfully defended her proposal for this study and was given permission from the IRB to proceed with the necessary research (see Appendix C). In April, 2007, the researcher presented an overview of the study to interested stakeholders: parents, administrators, teachers, community members, and students. In June 2007, informational letters along with consent forms were sent home with students who were members of the classrooms participating in the study (see Appendix D). Pre-testing of participating students took place throughout October, 2007. Pre-testing and post-testing of the Applications content area of the KeyMath-3 DA, were administered by qualified teachers and scheduled so as not to interrupt the classroom and school schedule. Data collection took place during November and December, 2007. When all data were collected, the Applications content area of the KeyMath-3 DA, Form B, was administered. The researcher then completed the analysis of the study.

### *Limitations*

This study was limited by its lack of generalizability to fourth-grade classrooms with demographics different from those included in the study. However, the study can be generalized to other schools that share the sampling demographics of School A and B. To address the threat of explicit description, the researcher needed to ensure that the experimental treatment was described in sufficient detail so that other researchers could reproduce it. Since the mathematical homework assignments used in the study were taken from sample standardized testing items, it would not be difficult to reproduce this study in other school populations. Also, pre- and post-test sensitivity influences result if these tests in mathematics interact with the experimental

treatment as a result of the amount of time between pre-and post-testing. However, the pre-testing and post-testing of the Applications content area of the KeyMath-3 DA were given a window of three months, following the directives for test administration (Connolly, 2007).

Given that this is a study of homework assignments completed outside the school environment, the researcher was cognizant of the fact that the internal threats of experimental treatment diffusion and compensatory rivalry by the control group were possible. To address these threats, the researcher made available to the control group members the opportunity to participate in the treatment at a future date and described to parents the importance of doing independent work at home. Teacher background may also be a limitation because students were given mathematics instruction from different teachers. To control for this threat, the researcher selected standardized math items to use for the homework data collection. This study was limited to metacognitive awareness and mathematics homework; however, it did provide a basis for future studies involving metacognition and homework assignments in different subject areas.

## CHAPTER 2: REVIEW OF THE LITERATURE

The literature review is organized into three main sections: metacognitive theory, metacognition and problem solving, and homework. With a focus on Flavell's (1979) and Brown's (1978) models, metacognitive theory is discussed first because it represents the theoretical foundation for the study. Since the dependent variables were facets of mathematical problem solving, metacognitive theory as it relates to mathematical problem solving is reviewed next. Third, research regarding homework was presented because the study involved metacognition and its effects on the development of mathematical problem solving in fourth-grade homework assignments.

### Theoretical Foundations

#### *Flavell's Metacognitive Framework*

The basic concept of metacognition as defined by John Flavell is the idea of thinking about one's own thoughts. Flavell (1963) referred to Jean Piaget as a source and contributor to the understanding of cognitive development. Flavell recognized that cognizant, directed thinking in regard to attaining a cognitive task is rooted in Piaget's conceptualization of formal operations, in which higher-ordered levels of thought operate on lower levels of thought. Flavell (1963) stated:

What is really achieved in the 7-11 year period is the organized cognition of concrete objects and events per se (i.e., putting them into classes, seriating them, setting them into correspondence, etc.). The adolescent performs these first-order operations, too, but he does something else besides, a necessary something which is precisely what renders his thought formal rather than concrete. He takes the results of these concrete operations, casts them in the form of propositions, and then proceeds to operate further upon them,

i.e., make various kinds of logical connections between them (implications, conjunction, identity, disjunction, etc.). Formal operations then are really operations performed upon the results of prior (concrete) operations. (pp. 205-206)

Furthermore, Flavell stated that for Piaget, intentionality, the deliberate pursuit of a goal by means of instrumental behaviors subordinated to this goal, is one of the hallmarks of intelligence (Flavell, 1963). He suggested that these metacognitive thoughts were deliberate, planful, intentional, goal-directed, and future-oriented mental behaviors that could be used to accomplish cognitive tasks (Flavell, 1971). When Flavell (1976) introduced the concept of metacognition, he defined it as follows:

In any kind of cognitive transaction with the human or non-human environment, a variety of information processing activities goes on. Metacognition refers to, among other things, the active monitoring and consequent regulation and orchestration of these processes in relation to the cognitive objects or data on which they bear, usually in service of some concrete goal or objective. (p. 232)

Flavell (1976) identified three processes that children gradually acquire in the context of information storage and retrieval: (a) The child learns to identify situations in which intentional, conscious storage of certain information may be useful at some time in the future; (b) the child learns to keep current any information which may be related to active problem-solving, and have it ready to retrieve as needed; and (c) the child learns how to make deliberate systematic searches for information which may be helpful in solving a problem, even when the need for it has not been foreseen.

Flavell (1976) indicated that components of metacognition can be activated intentionally, as by a memory search aimed at retrieving specific information, or unintentionally, such as by

cues in a task situation. Thus, metacognition is not static but active. These processes can operate consciously or unconsciously, and they can be accurate or inaccurate. They can also fail to be activated when needed and can fail to have adaptive or beneficial effects. Metacognition can lead to selection, evaluation, revision, or deletion of cognitive tasks, goals, and strategies. These actions can also help the individual make meaning and discover behavioral implications of metacognitive experiences. Flavell (1977) stated that metacognition referred to one's knowledge concerning one's own cognitive processes and products or anything related to them, e.g., the learning-relevant properties of information or data.

Metacognition covers a wide range of learning domains in a variety of applications. Flavell (1979) stated that investigators have concluded that metacognition plays an important role in oral communication of information, oral persuasion, oral comprehension, reading comprehension, writing, language acquisition, attention, memory, problem-solving, social cognition, and various types of self-control and self-instruction.

In addition, extended practice and reflection play crucial roles in the construction of metacognitive knowledge and regulatory skills. This is especially true when students are given regular opportunities to reflect on their successes and failures (Kuhn, Schauble, & Garcia-Mila, 1992; Siegler & Jenkins, 1989). In fact, well-organized instruction or the use of effective learning strategies may in large part compensate for differences in IQ. In many cases, sustained practice and teacher modeling lead to the acquisition of relevant task-specific knowledge as well as general metacognitive knowledge that is either independent or moderately correlated with traditional IQ scores (Ericsson, Krampe, & Tesch-Romer, 1993).

### *Flavell's Metacognitive Model*

Flavell (1979) proposed a model of metacognition when he noted the significance of metacognition in a wide range of applications, including problem solving. He believed that the monitoring of this wide variety of cognitive enterprises occurred through the actions and interactions among metacognitive knowledge, metacognitive experiences, goals (or tasks), and actions (or strategies). Components of metacognition can be activated intentionally or unintentionally, consciously or unconsciously, and accurately or inaccurately. Since some metacognitive experiences are items of metacognitive knowledge that have entered consciousness, metacognitive knowledge and experiences form partially overlapping sets (Flavell, 1979). According to the model, the monitoring of cognitive enterprises proceeds through the actions of and interactions among metacognitive knowledge, metacognitive experiences, goals (or tasks), and actions (or strategies).

### *Metacognitive Knowledge*

Metacognitive knowledge consists primarily of knowledge or beliefs about what factors or variables act and interact to affect the course and outcome of cognitive enterprises (Flavell, 1979). Metacognitive knowledge can lead individuals to engage in or abandon a particular cognitive enterprise based on its relationship to their interests, abilities, and goals. It may be activated consciously for an effective strategy or unintentionally and automatically by retrieval cues in the task situation, and it can lead an individual to select, evaluate, revise, and abandon cognitive tasks, goals, and strategies in light of their relationships with one another and with abilities and interests with respect to that enterprise (Flavell, 1979).

*Person variables.* Flavell defined the substance of metacognitive knowledge in terms of three types of variables and their interactions. The first type is person variables. The second type

is task variables, and the third type is strategy variables. Type one, person variables, encompass everything that an individual could come to believe about the nature of self and other people as cognitive processors (Flavell, 1979). Person variables could be further categorized into beliefs about intra-individual differences, inter-individual differences, and universals of cognition. Person variables helped to determine who you are as a learner, an important factor when a learner was involved in completing an activity such as a homework assignment.

*Task Variables.* Type two variables, task variables, concern the information available during a cognitive enterprise. They include an understanding of variations for how the cognitive enterprise should best be managed and how successful the individual is likely to be in achieving a goal (Flavell, 1979). In this category of the model, individuals learn something about how the nature of information impacts the way in which they respond to that information. Task variables include knowledge of what the characteristics of a cognitive task imply regarding the difficulty of the task and how best to approach it. This type of knowledge guides a learner in the management of a task and gives information about the degree of success in the production of that task. Applying this metacognitive knowledge, the learner can determine a range of possible acceptable goals and realize the level of task difficulty and resources necessary to be successful in the completion of the task. For example, to be effective, homework design should utilize this metacognitive knowledge. Knowledge of task variables includes knowledge about the nature of the task as well as the type of processing demands a task will place upon the individual (Livingston, 2003).

*Strategy Variables.* Type three variables are strategy variables. Flavell described this type of variables as having the knowledge that could be acquired concerning what strategies are likely to be effective in achieving sub-goals and goals in cognitive undertakings (Flavell, 1979). As

Flavell (1979) noted, children may understand that one good way to learn and retain many bodies of information is to pay particular attention to the main points and try to repeat them to themselves in their own words. Strategy variables involve knowledge about the relative merits of different approaches to the same cognitive task (Nickerson, Perkins, & Smith, 1985). Students who know about general strategies for thinking and problem solving are more likely to use them when confronting different classroom tasks (Bransford et al., 1999; Schneider & Pressley, 1997; Weinstein & Mayer, 1986). Metacognition directs the conscious use of strategies, including the monitoring of strategies. It also guides strategy shifts in the face of learning obstacles (Borkowski, Carr & Pressley, 1987). Cognitive strategies are used to help an individual achieve a particular goal, such as understanding a text, while metacognitive strategies help to ensure that the goal has been reached. Such strategies might include quizzing oneself to evaluate one's understanding of that text. (Livingston, 2003).

*Interaction of Variables.* Finally, Flavell (1979) pointed out that most metacognitive knowledge actually concerns the interactions among or combinations of two or three of these three types of variables. It includes knowledge of general strategies that might be used for different tasks; knowledge of the conditions under which these strategies might be used; knowledge of the extent to which the strategies are effective; and knowledge of self (Flavell, 1979; Pintrich, 2002; Schneider & Pressley, 1997). Metacognitive knowledge can play an important role in student learning and, by implication, in the ways students are taught and assessed in the classroom (Bransford et al., 1999). It refers to general knowledge about how human beings learn and process information, as well as to individual knowledge of one's own learning process. It can lead the individual to engage in or abandon a particular goal (Livingston, 2003).

### *Metacognitive Experiences*

Metacognitive experiences are any conscious cognitive or affective experiences that accompany and pertain to any intellectual enterprise (Flavell, 1979). In fact, some metacognitive experiences are items of metacognitive knowledge that have entered consciousness. For example, when thinking about the solution to a problem, an individual might suddenly recall another similar problem that was solved successfully. Thus, metacognitive knowledge and experiences form partially overlapping sets. These experiences include the subjective internal responses of an individual to his own metacognitive knowledge, goals, or strategies.

Metacognitive experiences can affect the metacognitive knowledge base by adding to it, deleting from it, or revising it. These metacognitive experiences can activate strategies aimed at two types of goals, cognitive or metacognitive, which include knowledge about learning and about oneself as a learner, and the skills of monitoring and regulating one's cognitive processes (Flavell, 1979).

Metacognitive experiences arise when they are explicitly demanded by a situation. Unfamiliar and novel situations and expectations also generate metacognitive experiences. In addition, if the outcome is very important, the individual is likely to monitor judgments and decisions more carefully (Flavell, 1987). Metacognitive experiences are especially likely to occur in situations that stimulate careful, highly conscious thinking. Also, they provide many opportunities for thinking about thoughts and feelings. Furthermore, only when students know the state of their own knowledge can they effectively self-direct learning to the unknown (Papaleontiou-Louca, 2003).

### *Cognitive Goals*

Cognitive goals (or tasks) refer to the objectives of a cognitive enterprise (Flavell, 1979). Flavell noted that an important aspect of this category concerns the information available to an individual during a cognitive enterprise. This information could be abundant or meager, familiar or unfamiliar, redundant or densely packed, well or poorly organized, interesting or dull, trustworthy or untrustworthy, delivered in a familiar or unfamiliar manner, presented in a new or familiar space, and so on. Thus, the metacognitive knowledge is an understanding of what such variations imply for how the cognitive enterprise should best be managed and how successful an individual is in achieving a goal. Furthermore, he stated that the child will come to know that some cognitive enterprises are more demanding and difficult than others (Flavell, 1979).

### *Cognitive Actions*

Flavell (1979) referred to cognitive actions (or strategies) as the cognitions or other behaviors employed to achieve a goal. He noted that there is a great deal of knowledge that could be acquired concerning what strategies are likely to be effective in achieving goals in various cognitive undertakings. Flavell stated that it is possible to acquire metacognitive strategies as well as cognitive ones. Cognitive strategies are invoked to make cognitive progress.

Metacognitive strategies monitor that progress.

### *Brown's Metacognitive Model*

The metacognitive framework initiated by Brown (1978) defines metacognition by its two components: knowledge of cognition and regulation of cognition. Knowledge of cognition refers to how much learners understand about their own memories and the way they learn. Regulation of cognition refers to how well learners can regulate their own memory and learning.

According to Brown (1978), knowledge of cognition and the regulation of cognition are closely related to each other.

### *Knowledge of Cognition*

Baker and Brown (1984) stated that knowledge of cognition is stationary over time, can be explained by the learner, may not be reliable, and is more cultivated in older learners. The knowledge about cognition is stable, fallible and often late-developing in human thinkers and learners (Baker & Brown, 1984). Further, knowledge about cognition includes three different kinds of metacognitive awareness: declarative, procedural, and conditional (Jacobs & Paris, 1987).

Declarative knowledge refers to an awareness and understanding of factual information. It is knowledge about one's general processing abilities. In other words, declarative knowledge includes knowledge about oneself as a learner and about what factors influence one's performance (Schraw, 1998).

Procedural knowledge refers to knowledge about how to perform an activity or operation. Jacobs and Paris (1987) stated: "Procedural metacognitive knowledge can be described as the awareness of processes of thinking or the knowledge of the methods for achieving goals and the knowledge of how skills work and how they are to be applied" (p. 259). Procedural knowledge is necessary to apply declarative knowledge efficaciously and to coordinate multiple cognitive and metacognitive problem solving (Montague, 1992). It is represented as heuristics and strategies and is used successfully to solve problems (Schraw, 1998).

Conditional or strategic metacognitive knowledge is considered to be the awareness of the conditions that influence learning, such as why strategies are effective, when they should be applied, and when they are appropriate (Jacobs & Paris, 1987). Conditional knowledge refers to

knowing when and why to use declarative and procedural knowledge (Gardner, 1991). It enables a learner to select appropriate strategies and to adjust behavior to changing task demands (Montague, 1992).

### *Regulation of Cognition*

Regulation of cognition refers to how well learners can regulate their own memory and learning (Brown, 1987). Research indicated significant improvement in learning when regulatory skills and understanding of how to use these skills were included as part of classroom instruction (Brown & Palincsar, 1989; Cross & Paris, 1988). King (1991) found that fifth-grade students who used a metacognitive regulatory checklist outperformed control students on a number of measures, including problem-solving, asking strategic questions, and elaborating upon information.

Regulation of cognition contains several different subcomponents, including planning, monitoring, and evaluating (Schraw, 1998). Planning is a process in which the sequence of activities is considered with attention before it takes place (Prawat, 1989). Planning refers to the discerning of the procedures and strategies to be used to reach specific goals (Pintrich, 1999; Viau, 1994; Winne, & Perry, 2000). Regulation of cognition is especially useful in complex tasks. It is needed to break down complex processes into steps that will be processed separately (Focant, Gregoire & Desoete, 2006). Monitoring refers to one's awareness of comprehension and task performance. The ability to engage in self-testing is a good example of monitoring. It is an observation of what is happening during the action. Monitoring points out problems not clearly defined (Focant, Gregoire, & Desoete, 2006). Evaluating refers to appraising the products and efficiency of one's learning (Schraw, 1998). It is a comparison with a goal (Bandura, 1986;

Zimmerman, 2000). It includes the control of the ongoing problem solving to prepare the next actions (Focant, Gregoire & Desoete, 2006).

Schraw (1998) emphasized two main points with regard to knowledge of cognition and regulation of cognition. First, knowledge of cognition and regulation of cognition are related to one another. For example, Swanson (1990) found that declarative knowledge of cognition facilitated regulation of problem solving among fifth- and sixth-grade students. Second, both components appear to span a wide variety of subject areas and domains; they are domain-general in nature (Schraw, 1998). Thus, metacognition consists of knowledge and regulatory skills that are used to control one's cognition (Schraw, 1998).

#### *Summary of Literature Review of Theoretical Foundations*

Metacognitive skills can be thought of as cognitive skills that are necessary or helpful to the acquisition, use, and control of knowledge and other cognitive skills. They include the ability to plan and regulate the effective use of one's own cognitive resources (Brown, 1978). Costa (1981) noted that if educators wish to develop intelligent behavior as a significant outcome of education, instructional strategies purposefully intended to develop children's metacognitive abilities must be infused into teaching methods, staff development, and supervisory processes (Costa, 1981).

Most people do not seem to develop the skills of thinking to the fullest. This is especially true among beginners, and less able persons. Researchers agree that with development, students become more aware of their own thinking and also more knowledgeable about cognition in general. As they act on this awareness, they tend to learn better (Bransford, Brown, & Cocking, 1999). Metacognitive awareness, therefore, serves a regulatory function and is essential to effective learning because it allows students to monitor numerous cognitive skills. Furthermore,

research showed that high levels of metacognitive self-regulation compensated for low overall abilities. Knowledge of cognition, objectivity, and problem representation were considered important self-regulatory variables for effective problem solving (Bruce et. al. 2001).

Students who know their own strengths and weaknesses can adjust their cognition and thinking to be more adaptive to diverse tasks and thus facilitate learning. Metacognitive knowledge is important in terms of how it is used by students to facilitate their own learning (Pintrich, 2002). It refers to higher-order thinking that involves active control over the cognitive processes engaged in learning (Livingston, 2003). Activities such as planning how to approach a given learning task, monitoring comprehension, and evaluating progress towards the completion of a task are metacognitive in nature (Livingston, 2003). The term metacognition has also been applied to numerous studies of children's cognition concerning comprehension, communication, language, perception, attention, and problem solving (Flavell, 2004).

#### *Overview of Metacognition and Mathematical Problem Solving*

Public concern about how well school children are learning mathematics is widespread and growing (Kilpatrick, 2001). Furthermore, metacognition seems involved, especially during the initial stage of mathematical problem-solving, when students build an appropriate representation of the problem and plan their problem-solving steps, as well as in the final stage of interpretation and checking the outcome of calculations (Desoete & Veenman, 2006).

This section of the Literature Review first discusses the mathematical problem-solving standards as outlined by the National Council of Teachers of Mathematics, because these standards serve as guidelines for curriculum and instruction in mathematics problem solving (NCTM, 2000). A discussion of metacognition and its effect on independence in problem-solving skills follows. Since accuracy and persistence in mathematical problem solving are two

of the variables researched in this study, a review of the literature regarding these constructs is included.

### *Mathematical Problem-Solving Standards*

In the Curriculum and Evaluations Standards for School Mathematics, National Council of Teachers of Mathematics (2000) has placed problem-solving as a major vision in mathematics education in addition to reasoning, communicating, and connecting. According to NCTM (2000), problem-solving means engaging in a task for which the solution method is not known in advance. To find a solution, students must draw on their knowledge; through this process, they will often develop new mathematical understandings. Solving problems is not only a goal of learning mathematics but also a significant means of doing so.

In addition, NCTM (2000) noted the importance of students having opportunities not only to learn conventional forms of representation but also to construct, refine, and use their own representations as tools to support learning and doing mathematics. Thus, problem-solving offers opportunities for students to personalize their solutions.

NCTM has also recognized that worthwhile problem-solving tasks should be intriguing, presented with a level of challenge that invites speculation and hard work. Such problems can promote the students' conceptual understanding, foster their ability to reason and communicate mathematically, and capture their interest and curiosity (NCTM, 2000). Mathematical problem-solving is a necessary skill for all students at all ages. Learning to become a problem solver is a life-long endeavor (Goldberg & Bush, 2003).

### *Metacognition and Independence in Mathematical Problem Solving*

Campione, Brown, and Connell (1988) stated that successful learners have powerful strategies for dealing with novel problems. They oversee and regulate those strategies effectively. They see themselves in control while weaker students are less aware of those strategies and do not use them flexibly. According to Davidson and Sternberg (1998), metacognition allows the solver to identify and work strategically with three parts of a problem. Specifically, metacognitive skills help the student: (a) strategically encode the nature of the problem and form a mental model or representation of its elements; (b) select appropriate plans and strategies for reaching the goal; and (c) identify and conquer obstacles that impede progress (Davidson & Sternberg, 1998). Knowledge about problem-solving in general and about their own mental processes in particular helps students become better problem solvers. Therefore, metacognition can be helpful in developing problem-solving skills.

More recently, Howard, McGee, Shia, and Hong (2000) identified five learning strategies that self-regulated learners use in a problem-solving context. The first is problem representation, in which learners seek to understand the nature of a research question before proceeding with an investigation. The second is knowledge of cognition, in which they are aware of the mental operations required to effectively engage in an investigation. The third is subtask monitoring, in which they break an investigation into subtasks and actively manage the completion of each one. The fourth is evaluation of subtasks, in which they evaluate the execution of each subtask to ensure that it has been done correctly. Finally, the fifth is objectivity, in which they reflect on the relative effectiveness of various learning strategies and take steps to improve them. These metacognitive components guide the cognitive actions.

In his research, Swanson (1990) indicated that metacognition was more important for problem-solving success than aptitude, and that students who had low aptitudes but high metacognition performed as well as students who had high aptitude. Schoenfeld (1992) found that children fell back on using the trial and error “discovery” technique that frequently lead nowhere, primarily because the children had no idea where to go.

Furthermore, metacognition allows students to use acquired knowledge in a flexible, strategic way (Lucangeli et al., 1998). One implication of the research completed by White and Fredriksen (1998) and Davis (1996; 1998) was that if it is possible to train students to utilize metacognitive strategies, then this training could help students to succeed despite their low ability levels, achievement, or aptitude. In fact, metacognitive skills were found to be trainable (Desoete & Roeyers, 2003). Even with a very brief metacognitive training process, students could learn to adopt a more self-judging learning approach, (Desoete, Roeyers & De Clercq, 2003). Students who were exposed to metacognitive training were expected to be better at reflecting on solution processes (general and specific) than students who were not exposed to such training (Kramarski & Mevarech, 2003). This metacognitive training improved pupil performance in mathematical problem-solving and was found to have a sustained effect on mathematical problem-solving (Desoete & Roeyers, 2006). In addition, metacognition prevents blind calculation or a superficial number-crunching approach and allows students to use the acquired knowledge in a flexible, strategic way (Desoete & Veenman, 2006). Mathematical problem-solving homework assignments can provide opportunity to train students in utilizing and improving these metacognitive strategies.

### *Accuracy in Mathematical Problem Solving*

An important component to successful problem-solving is accuracy. Students who do not monitor and evaluate their knowledge and solution procedures will have trouble correctly solving problems (Nickerson, Perkins, & Smith, 1985). In fact, students who have a limited repertoire of learning strategies may continue to use an ineffective strategy simply because they do not know an alternative strategy (Gall, Gall, Jacobsen & Bullock, 1990). As expected, this process of using ineffective strategies negatively impacts the accuracy of responses. However, it has been noted in a study by McVey (1993) that high metacognitive control is associated with a higher degree of accuracy.

McAfee and Leong (1994) stated that “[p]oor students may have the requisite knowledge and skills, but fail to use them correctly or at the appropriate time. These students lack flexibility and may stick to one strategy even when it does not lead to successful solutions” (p. 144). Costa and Kallick recognized the importance of striving for accuracy as a “habit of mind” (Costa & Kallick, 2000). Students who checked over their work, followed directions, reviewed models, used resources, and had a desire for reaching the highest possible standards took pride in their work. There was a sense of responsibility for demonstrating the best that they produced, even if it meant reworking and revising ideas. They were self-regulated learners. Students who were self-regulated produced quality work because they did not settle for mediocrity. They focused all their energies on accomplishing a task that reflected their commitment to excellence (Costa & Kallick, 2000).

Cunningham, Krull, Land, and Russell (2000) noted in their action research study that when students were aware of their thinking processes, accuracy in problem-solving activities improved by 14%. Also, Hohn and Frey (2002) reported that accuracy in problem-solving was

positively correlated with metacognitive processing. Including metacognitive processing activities in mathematical problem-solving assignments, such as homework, can be beneficial.

### *Persistence in Mathematical Problem-Solving*

Good learners tend to persist at a job or task until it is done to their satisfaction and to attribute their success to their own efforts. They are aware that they can do a great deal to control their own learning, and they constantly work to select appropriate strategies and to monitor strategy use throughout the learning process (Jones, Palincsar, Ogle, & Carr, 1987). Efficacious people stick to a task until it is completed. They do not give up easily. Lesh (1981), Pimm (1987) and Hiebert (1989), defined successful problem solvers as individuals who are able to accurately assess situations as being problematic, perceive situations in which their problem-solving capabilities can be applied, and devise effective strategies to resolve such dilemmas.

Researchers have found that students' perceptions of self-efficacy were positively related to such learning outcomes as task persistence (Zimmerman & Ringle, 1981), task choice (Bandura & Schunk, 1981; Zimmerman, 1985), effective study activities (Thomas, Iventosch & Rohwer, 1987), skill acquisition (Schunk, 1984), and academic achievement (Thomas et al., 1987). In fact, persistence was an important component of self-regulation (Pintrich & De Groot, 1990; Taplin, 1995; Zimmerman, Bandura, & Martinez-Pons, 1992). Persistent students have a repertoire of alternative strategies for problem-solving, and they employ a whole range of these strategies. They try alternative strategies when one does not work. They are able to sustain a problem-solving process over time so they are comfortable with ambiguous situations (Costa & Kallick, 2000). On the other hand, students who are not persistent often blurt out the first answer that comes to mind. Sometimes they start to work without fully understanding the direction. They lack an organized plan or strategy for approaching a problem, or they make immediate

value judgments about an idea before fully understanding it. They do not consider alternative possibilities or consequences (Costa & Kallick, 2000).

In the context of mathematical problem-solving, perseverance refers to the student's sense of when to continue with a chosen strategy or action and knowing when to abandon a particular strategy or action for a more effective or useful one. Furthermore, the development and effective use of students' self-questioning, self-regulatory techniques, and metacognitive skills is crucial to their success as problem posers and problem solvers (Thom & Pirie, 2002).

#### *Summary of Metacognitive Theory as it Relates to Mathematical Problem-Solving*

Problem-solving is pervasive in everyday experience and plays a major role in psychological theories of intelligence (Sternberg, 1985). It is a complex process that involves several cognitive operations such as collecting and selecting information, using heuristic strategies, and thinking metacognitively (Garofalo & Lester, 1985; Schoenfeld, 1994; and DeCorte, 1995). Metacognition has been identified as a key factor in the problem-solving domain (Schoenfeld, 1985). When solving problems, students need to be able to access a variety of thinking processes and ask questions about that thinking every step along the way.

To be successful problem solvers, Schoenfeld (1987) pointed out that students should wisely divide their time among: (a) understanding the problem, (b) planning to solve it, (c) making decisions on what to do, and (d) executing the decisions for a solution within the time frame. In the process of solving a problem, they should monitor and track the progress toward a solution. When the decisions seem not to work, they should try alternatives or make some adjustment. Schoenfeld (1987) indicated that this sequence of steps is unlike the behavior of most of his students, who never evaluate whether their calculated answers to problems made sense in the real world. In fact, one conclusion Lester, Garofalo, and Kroll, (1989.a.) drew was

that for the students' problem-solving performance to improve, they must attempt to solve a variety of types of problems on a regular basis and over a prolonged period.

In fact, research examining the relationship between metacognitive knowledge and achievement indicates that children who are aware of why, when, and how strategies should be used are more likely to be able to use those strategies successfully (Pressley, 1994). Desoete and Veenman (2006) stated that metacognition appeared to be a powerful predictor of mathematical problem-solving. Furthermore, the experimental base that grounds the importance and impact of metacognition in support of the mathematics learning process is vast and still growing.

### *Review of the Literature on Homework*

The third section of the literature review discusses homework because this study used homework assignments as a component of its data collection. A brief history of homework is presented to highlight the controversy surrounding this construct. This is followed by a discussion of the purposes of homework and its impact on achievement. To present a global view of homework, the review then focuses on international comparisons of homework policies. The topics of homework design, teacher preparation for designing homework activities, and homework expectations follow because this study recognizes that these are areas for future research. Finally, the review discusses the connection between metacognition, mathematical problem-solving, and homework since this is the intent of this investigation.

### *History of Homework*

Debates on homework have cycled through the years. From the end of the 19<sup>th</sup> century through the 1940s, homework was considered a threat to the health and well-being of the child (Nash, 1930). In the late 1950s, the trend changed as the nation watched the launching of Sputnik, a Russian satellite. Homework assignments were considered a necessary component for

a successful learning process (Goldstein, 1960). The American public worried that education lacked rigor and left children unprepared for complex technologies. Homework, it was believed, could accelerate knowledge acquisition (Gill & Schlossman, 2000). From the 1960s to the mid-1970s, the value of homework was again questioned. At that time, public opinion regarded homework as an example of the excessive pressure on students to achieve (Jones & Colvin, 1964). With the back-to-basics approach and the advent of the new math program in the 1970s, homework became an area of even more confusion and conflict among educators (Lee & Pruitt, 1979). Coulter (1979) in his review of the literature commented on the problematic nature of most of the previous research. He felt that a major weakness was that homework was studied in “quantitative rather than qualitative terms” (Coulter, 1979, p. 23). With the publication of *A Nation at Risk* (1983), a more positive view of homework was endorsed. This was especially true because of the concern for America’s declining achievement scores and declining ability to compete in the global marketplace (Cooper et al., 1998). In addition, with the onset of the No Child Left Behind Act (NCLB, 2003), accountability for learning has become paramount, and this accountability has an impact on homework assignments (Dudley-Marling, 2003). Today, the debate about the positive or negative effects of homework on improving student learning continues (Cooper, Robinson, & Patall, 2006).

#### *Purposes for Assigning Homework*

Homework is assigned to serve different purposes. In 1985, Foyle utilized the Lee and Pruitt (1979) model which categorized the purpose of homework into four areas: preparation, practice, extension, and creativity. Walberg, Paschal, and Weinstein (1985) recognized the importance of teachers giving homework assignments that both reinforced what they were teaching in school and prompted students to reorganize and extend their learning to new and

richer areas. Homework assignments were usually an integral part of teachers' lesson plans (Leinhardt & Greeno, 1986). In fact, Begley (1998) suggested that homework in elementary school should serve the purpose of fostering a love of learning and honing study skills. Corno and Xu (1998) stated that like many aspects of education, the assignment of homework reflected an expert teacher's best judgment about his or her students' capabilities and needs and how these assignments related to clear teaching goals. Actually, homework and practice were ways of extending the school day and providing students with opportunities to refine and extend their knowledge. At the elementary level, Epstein (2001) noted that teachers and parents needed to work together with the goal of ensuring that children understood the increasing importance of their shared role in the homework process and how that process impacted achievement.

More recently, Van Voorhis (2004) discussed the three main functions of assigning homework as instructional, communicative, and political. Homework that is practice, preparation, participation in learning, or personal development is categorized as instructional. Communicative homework involves the key stakeholders--students, teachers, and families--in the learning process. These assignments are interactive and are designed to impact the home-school connection. The third function of homework in this model is political. Homework serves a political function when it is assigned to fulfill a policy mandate or satisfy public expectations. It signals parents and the public that a school has rigorous academic standards and expectations for student work (Van Voorhis, 2004).

Homework can also play a role in developing independent learners. Gall, Gall, Jacobsen, and Bullock (1990) referred to homework as a modified form of independent learning. They noted that students needed to be equipped with the tools that are necessary for successful learning in and out of the classroom (Gall, Gall, Jacobsen, & Bullock, 1990). In fact, Cooper et

al., (1998) attributed a greater degree of homework responsibility for sixth-grade students than second grade students as the result of a greater degree of self-regulation demonstrated in older students. In a 2000 survey, Muhlenbruck, Cooper, Nye, & Lindsey pointed out that for elementary level teachers, the content of homework was less important than the opportunity it provided to foster long-term time management skills, the effects of which would not be evident in younger children's school grades. Furthermore, Cooper and Valentine (2001) cited benefits of students' homework as enhancing their development as independent learners with better study skills, more positive academic attitudes, and greater responsibility toward learning.

The purpose and effects of doing homework have been both controversial and complex. Students, teachers, parents, and administrators each have had perspectives that influenced their understanding and appreciation for assigned learning activities which take place in the home (Marzano, Pickering, & Pollock, 2001).

Bempechat (2004) discussed the motivational benefits of homework from a social-cognitive perspective. She argued that homework played a critical long-term role in the development of children's achievement motivation. Homework assignments provided children with the time they needed to develop beliefs and study habits that were helpful to learning. She stated that skills such as these develop neither overnight, nor in a vacuum (Bempechat, 2004). At the elementary level, teachers and parents needed to work together with the goal of ensuring that children understood the increasing importance of their role in the homework process and how that process impacted achievement (Bempechat, 2004).

### *Homework and Achievement*

Cooper (1989 b.) conducted a review of nearly 120 empirical studies of the effects of homework and the ingredients of homework assignments. This review included three types of

studies. The first type compared the achievement of students given homework assignments to that of students not given homework. In twenty studies conducted between 1962 and 1986, fourteen produced effects favoring homework while six favored no homework. The influence of grade level was most interesting. These studies revealed that 69% of high school students in classes doing homework outperformed students in classes not doing homework, as measured by standardized tests or grades. In junior high, the average homework effect was half the magnitude. Most notably, in elementary school, homework had no association with achievement gains (Cooper, 1989 b.). In addition, when evidence compared homework with in-class supervised study in elementary schools, in-class study proved superior. Lastly, when the amount of time students spent on homework was correlated with a measure of achievement, students in elementary school had a correlation of nearly zero ( $r = 0$ ). Cooper (1989 b.) acknowledged that student characteristics, the subject matter, and especially the grade level influenced the value of homework.

In 1998, Cooper et al. conducted a study investigating the relationships between attitudes about homework, amount of homework assigned and completed, and student achievement. Cooper et al. noted that one weakness specific to research correlating homework to achievement was that no distinction had been made between how achievement related to (a) the amount of homework teachers assigned and (b) the proportion of assigned homework completed by students. Another weakness of many studies was that they typically measure achievement using a standardized achievement test or teacher-assigned grades. Rarely were both measures taken on the same students. Therefore, Cooper et al. conducted this correlational study which included measures of both the amount of homework assigned by the teacher and the amount of homework completed by the student. These measures were obtained from teachers, students, and their

parents. In addition, both standardized test scores and teacher-assigned grades were obtained as measures of achievement.

Cooper's sampling for this 1998 study was comprised of units of data referred to as triads. This included a teacher, at least one student in that teacher's class, and one parent of that student. A total of 103 teachers in Grades 2, 4, 6, 7, 8, 10, 11, and 12 initially agreed to take part in the study; and 82 returned at least one useable triad. The median number of complete triads per teacher was 9. The average response rate was 35%. Three school districts participated in the study: a large metropolitan public school district in Tennessee; a suburban school district adjacent to the urban district; and a rural school district. When the school district description was compared with the characteristics of the respondents, it was determined that the respondents were not a random sample drawn from the districts.

The instrument explicitly developed for this study was The Homework Process Inventory (HPI). The questionnaire is a multi-item survey that has six different versions, one each for lower and upper-grade students, their teacher, and their parents. The HPI was pilot-tested with small, heterogeneous samples of students, teachers, and parents. It was also examined by the Academic Resource Center at the University of Missouri. For Grades 2 through 5, the HPI was completed with reference to homework in general. At Grade 6 and above, the HPI was completed for the individual subject areas of mathematics or English homework.

With regard to homework and achievement, the study examined whether different relationships existed between the two types of achievement measures and behaviors reported by the different actors in the homework process, and whether relationships existed between teacher and student attitudes towards homework and achievement. The researchers developed their own standardized raw score measures of achievement. First, they formed an achievement measure for

each student on the basis of the Tennessee Comprehensive Assessment Program (TCAP) scores. For Grades 2 and 4, the total TCAP score was used. These scores were then standardized within each grade level, and the mean of the TCAP scores was set to 0 and the standard deviation to 1. The scores ranged from -3.68 to 2.10. For teacher-assigned grades, teachers provided a class grade for participating students on the day the HPI was completed. The mean grade given by all teachers was 88.74 (SD = 7.96). In all grade level groups, teacher assigned grades were moderately correlated with TCAP scores, for Grades 2 through 4,  $r(273) = .48, p < .0001$ .

For Grades 2 and 4, positive but nonsignificant relationships were found between the amount of homework teachers said they assigned and the average student achievement in their class; for the Tennessee Comprehensive Assessment Program (TCAP) scores,  $r(27) = .12, ns$ ; for teacher assigned grades,  $r(27) = .19, ns$ . Student reports of teacher assigned homework were negatively, but not significantly, correlated with TCAP scores,  $r(276) = -.04, ns$ , and significantly negatively correlated with grades.

$R(279) = -.22, p < .0002$ . Significant negative relations were also found in correlations involving parent reports of the amount of homework assigned by teachers and students' achievement; for TCAP scores,  $r(276) = -.12, p < .05$ ; for grades,  $r(279) = -.22, p < .0002$ .

Further, for Grades 2 and 4, students and parent reports of the portion of homework assignments completed by students were positively correlated with both measures of achievement. Student correlations did not reach significance for TCAP scores,  $r(274) = .07, ns$ ; for grades,  $r(274) = .10, p < .09$ . However, parent correlations did reach significance, for TAPC scores,  $r(277) = .22, p < .0003$ ; for grades,  $r(279) = .31, p < .0001$ .

The researchers also completed three hierarchical multiple regressions to examine further the relation between homework and achievement. When controlling for the variances of amount

of homework students reported completing, interaction of grade level and amount completed, and interaction of subject matter and amount completed, significant positive relations were found between the amount of homework students said they finished and both achievement measures: for TCAP  $F(1,583) = 6.88, p < .009$ ; for grades,  $F(1,624) = 40.22, p < .0001$ . These were the only significant effects.

In regard to the relationship between homework attitudes and achievement, for Grades 2 and 4, the study showed a sizable but not significant negative correlation, indicating that teachers who had more positive homework attitudes also had students who averaged poorer scores on the TACP,  $r(25) = -.24, ns$ . A significant negative correlation was found between homework attitudes and lower-grade students' TCAP scores  $r(273) = -.19, p < .002$ , along with a similar trend for grades  $r(276) = -.10, p < .09$ . A near zero correlation was found for teacher attitudes and teacher assigned grades,  $r(25) = -.01, ns$ .

The results of this study indicated that for Grade 2 and 4 students, composite measure of time spent on homework was correlated near zero with a standardized measure of achievement ( $r = -.04$ ), but was significantly negatively correlated with class grades ( $r = -.19$ ). Therefore, the study's results indicated a generally weak relation between the amount of homework teachers assigned and student achievement. Furthermore, the findings suggested positive relations between the portion of homework assignments students complete and their achievement. At the lower grades, students with poorer achievement test scores held more positive homework attitudes. In addition, these lower-grade teachers of less achieving students also expressed more positive attitudes towards homework but not significantly so. Lastly, the path diagrams of multiple regression proved to underscore the importance of completion of homework by students as a positive factor in achievement even when other influences were controlled.

In a meta-analysis, Cooper, Robinson and Patall (2006) conducted a synthesis of the research on homework from 1987 to 2003. One purpose of this analysis was to update the evidence on past conclusions about the effects of homework and determine if the conclusions from research needed modification. Cooper, Robinson and Patall noted that in a search of ERIC, PsycINFO, Sociological Abstracts, and Dissertation Abstracts between January 1987 and December 2003, there were more than 4,000 documents with homework as a key word added to these reference databases with 900 catalogued as empirical. Therefore, a reassessment of the research was necessary.

This analysis also looked for answers to previously unanswered questions. For example, even though the 1989 analysis showed a consistent influence of grade level, with elementary students nearly  $r = 0$ ; middle grades  $r = .07$ ; and high school students  $r = .25$  on the homework and achievement relationship, there were ambiguous results regarding the possible differential impact of homework on different subject matters and on different measures of achievement. Specifically, past research using different comparison groups such as no homework, supervised study, and correlations involving different reported amounts of homework, produced different orderings or magnitudes of the relation of homework to achievement for different subject matters and achievement measures. Also, Cooper's 1989(b.) study did not pay close attention to the ability of the cumulated evidence to establish a causal relationship between homework and achievement. Therefore, these areas became a focus for the 2006 study.

In addition, the 2006 analysis applied new research synthesis techniques. For example, more recent studies have employed structural equation modeling to test the fit of complex models of the relationship between the various factors and student achievement. Also, the more current studies demonstrated a greater understanding of meta-analytical error models involving

the use of fixed and random-error assumptions that add precision to statements about the generality of findings. Lastly, new tests have been developed to estimate the impact of data censoring research synthesis findings. Therefore, the 2006 synthesis included these designs.

For a study to be included in the synthesis, it needed to meet several criteria. The study had to have estimated in some way the relationship between a measure of homework activity on the part of the student and a measure of achievement. Also, the sampling was restricted to the population of students in kindergarten through grade 12 living in the United States. The study needed to have enough information to permit the calculation of the estimate of the homework-achievement relationship.

The researchers of this meta-analysis noted several different research designs. First, studies employed exogenous manipulations of homework, meaning that the presence or absence of homework assignments was manipulated expressly for the study. These studies were designed by either randomly assigning classrooms or students within classrooms to homework and no homework conditions, or these studies assigned homework to classrooms in a nonrandom manner but attempted statistical control of rival hypotheses. In addition, the researchers recorded information on: the number of students and classrooms included in the experiment from beginning to end: the grade level of students: the subject matter of homework: the number of assignments per week and their duration: the measure of achievement: and the magnitude of the relationship between homework and achievement. For this type, a standardized mean difference was used to estimate the effect of homework on measures of achievement. Calculations of effect sizes were based on the means and standard deviations of students' achievement indicators. The *d*-index measure was used to determine positive effect sizes.

A second type of design included studies that took naturalistic, cross-sectional measures of the amount of time the students spent on homework without any intervention on the part of the researchers, and related these to an achievement-related measure. This design also included an attempt to statistically equate students on other variables that might be confounded with homework and therefore might account for the homework achievement relationship. For these studies, the researchers also coded: the source of the data; the analytical strategy used to equate students; the grade level of students; the subject matter of homework; the amount of time each student spent doing homework as measured by the student or parent report; the measure of achievement; and the magnitude of the relationship between homework and achievement. For this design, the preferred measure of relationship strength was the standardized beta-weight. These were derived out of either multiple regressions or as path coefficients in structural equation models.

The third type of design involved the calculation of a correlation between the time the student spent on homework and the measure of achievement. In these studies where no attempt was made to equate students on other variables that might be confounded with homework, the calculation of a simple bivariate correlation between the time the students spent on homework and the measure of achievement was used. The researchers recorded the same variables coded for studies using statistical controls of other variables except the number and nature of controlled variables. In addition, several other variables were coded related to the sample of students. These were gender, socioeconomic status (SES), and student ability levels of gifted, average, at risk, underachieving/below grade level, learning disabled, overachieving/above grade level.

The literature search located six studies that employed a procedure in which the homework and no-homework conditions were imposed on students explicitly for the purpose of

studying the effects of homework. None of these studies was published. For studies involving the elementary school level, a study by Foyle et al. (1990) assigned four whole fifth-grade classrooms to conditions at random. However, the researchers noted that assigning only one classroom to each condition, even at random, cannot remove confounded classroom differences from the effect of homework. Also, the student, not the classroom, was used as the unit of statistical analysis, creating a concern that within-class dependencies among students were ignored. Analysis revealed that students differed significantly on a social studies pre-test and on a standard measure of intelligence, but it was not reported whether there were pre-existing classroom difference on these measures.

Finstad (1987) studied the effect of homework on mathematics achievement for 39 second-grade students in two intact classrooms. However, even though the same unit was taught, neither the frequency nor duration of assignments was reported. It was not reported how the classroom assignments were carried out, but it was reported that there were no pre-test differences between the classes. Data were analyzed on the student level without adjustment. The results indicated that students in the classroom doing homework performed significantly better on a post-test measure,  $d = .97$ .

Meloy (1987) studied the effects of homework on the English skills of third and fourth graders. Classes were matched on a shortened version of the Iowa Test of Basic Skills (ITBS) language subtest before the classes were randomly assigned to homework or no-homework conditions. A pre-test and post-test design was used to control for initial group differences, but pre-tests were used as a within-students factor rather than a covariant. In addition, students who scored above a threshold score on the pre-test were excluded for the post-test analysis. Thus, only 106 of the original sample of 186 were used in the analyses, and excluded students were not

evenly distributed across the homework or no-homework conditions. Grade levels were analyzed separately, and classrooms were a factor in the analyses. The class-within condition effect was not significant, so the student was used as the unit of analysis. The study monitored homework completion rates and set up reinforcement plans, different for each class to improve completion rates. The effects of homework were gauged by using a research modified version of the ITBS language subtest and a unit mastery test for the textbook. The author reported that the condition-by-time interactions indicated that homework had a significant negative effect on ITBS scores for third-graders and a significant positive effect on fourth-graders unit test scores.

Finally, Townsend (1995) examined the effects of homework on the acquisition of vocabulary knowledge and understanding among 40 third-grade students in two classes taught by the experimenter. Treatment was given to classes as a whole, and it was not stated how each class was assigned to the homework or no-homework condition. The student was used as the unit of analysis. A teacher-prepared posttest measure of vocabulary knowledge suggested that the homework group performed better,  $d = .71$ .

More recently, Cooper, Robinson and Patall (2006) noted that although the introduction of homework as an exogenous intervention was a positive feature of these studies, other methodological considerations made it difficult to draw strong causal inferences from their results. Nevertheless, Cooper, Robinson, and Patall felt the results were encouraging because of the consistency. The measurable effects of homework on unit tests varied between  $d = .39$  and  $d = .97$ . The small number of studies and their variety of methods and contexts precluded their use in any formal analyses investigating possible influences on the magnitude of the homework effect. Consequently, these analyses were limited to comparing studies that used random

assignment versus other means to create equivalent groups. In addition, the report noted that each of the studies had design flaws.

For studies using cross-sectional data and control of third variables to examine the relationship between homework and achievement, this literature search located nine reports that contained multivariate analyses of data collected as part of the National Education Longitudinal Study (NELS) of 1988 or in the NELS follow-ups of the same students in 1990, 1992, 1994, or 2000. However, as noted by Cooper, Robinson and Patall (2006), these studies referred only to high school students. Twelve additional studies were also reported that used data other than the NELS data. Of these twelve, three studies used elementary school students (Cooper et al., 1998; Olson, 1988; Wynn, 1996). These studies all revealed positive relationships between the homework measure and achievement. The Cooper et al. study (1998) calculated a beta weight of .22 for teacher-reported overall grades. In Olsen's study (1988) the beta weight was .10 for math, and .11 for reading. Wynn's (1996) study determined a beta weight of .04 for grade point average. In addition to using predictor variables in the regression models, these studies also included a variety of outcome measures, including standardized tests and teacher-assigned grades.

For structural equation-modeling studies using original data, the review noted one study for elementary students. For this study, a total of 214 second and fourth graders from an urban, suburban, and rural school district were participants. The researchers of this study (Cooper, Jackson, Nye, & Lindsay, 2001) used the MPlus program to predict grades assigned by teachers. The model also included student ability, homework norms, parent attitude, home environment, parent facilitation, presence of alternative activities and student attitudes. The path coefficient for the relationship between time on homework and class grade was .20,  $p < .01$ .

There were 32 studies correlating time spent on homework and a measure of academic achievement with nine studies relating to elementary-level students. Cooper et al. (2006) reported eight correlations separating out effects for elementary and secondary students on both class grades and standardized tests with time on homework reported by either students or parents. Bents-Hill (1988) studied students in grades three and six, and reported eight correlations for language arts, math, reading, and multiple subjects both for class grades and for a standardized test of achievement. Studies of elementary-level students by Epstein (1988), Olson (1988), and Walker (2002) reported two effect sizes, one for math and one for reading. Wynn (1996) reported two correlations, one involving class grades and one involving achievement test results.

In reviewing the results of analyses that examined whether the magnitude of the correlation between time spent on homework and achievement was moderated by the grade level of the student, Cooper, Robinson, and Patall (2006) reported that under fixed error assumptions that correlation was significantly higher for high school students ( $r = .25$  (95% CI = .25/.25) than for elementary school students ( $r = -.04$  (95% CI = -.06/-.02),  $Q(1) = 710.68$ ,  $p < .0001$ ). Under random error assumptions, the correlation between time spent on homework and achievement was also significantly higher for high school students ( $r = .20$  (95% CI = .17/.22) than for elementary school students ( $r = .05$  (95% CI = -.03/.13),  $Q(1) = 10.43$ ,  $p < .002$ ). The confidence intervals indicated that the mean correlation between time spent on homework and achievement was not significantly different from zero for elementary students.

Cooper et al. (2006) concluded the studies that randomly assigned classrooms or students within classrooms to homework or no-homework conditions were all flawed in some way that compromised their ability to draw strong causal inference. The researchers recommended that

future studies were needed to determine stronger conclusions establishing the productive impact of homework on achievement. Furthermore, the findings on manipulated homework study designs were consistent and encouraging, if not conclusive. They indicated a positive relationship between homework and achievement. The standardized mean difference on unit tests between students who did not do homework varied from  $d = .39$  to  $d = .97$ . The weighted mean *d-index* was .60 under both fixed and random error assumptions and was significantly different from zero when the student was used as the unit of analysis. When the effective sample size was substituted as the unit of analysis by adjusting for within-class dependency, the weighted mean *d-index* was .63 and was statistically significant up to an assumed intraclass correlation of .35. Similarly, the range of estimated regression coefficients derived from studies using multiple regression, path analysis, or structural equation modeling were nearly all positive and significant. However, Cooper et al. (2006) pointed out that estimates using naturalistic data and controlling for other variables were calculated primarily by using high school samples.

In reviewing the studies that correlated homework and achievement and moderator variables, Cooper et al. (2006) found 69 correlations between homework and achievement reported in 32 documents. Fifty correlations were in a positive direction, and 19, in a negative direction. The mean weighted correlation was  $r = .24$  using a fixed error model, and  $r = .16$  using a random error model, and both were significantly different from zero. Regarding the moderator variable of grade level of the student, there was strong evidence that homework and achievement were positively related for secondary school students. However, using fixed error assumptions, a significant, though small, negative relationship was found for elementary school students, but a nonsignificant positive relationship was found using random error assumptions. In addition, with

both error models, the difference between the mean correlations involving elementary versus secondary students was significant.

In their conclusions Cooper et al. (2006) offered possible explanations for the difference in the homework achievement relationship at different grade levels. These explanations included distractibility in younger students within the home environment, less effective study habits in younger students, and different amounts and purposes of homework assigned by teachers. As a result, Cooper et al. suggested that carefully controlled studies of the causal relationship between homework and achievement be a focus for future study, that these studies include students from a variety of grade levels, and that grade level be used as a moderating variable.

In support of this conclusion, Marzano (2007) stated that although homework is prevalent across the K-12 spectrum, there was still no clear-cut consensus on the benefits of homework at the lower levels. He said that the issue of grade level was still not resolved based on the Cooper, Robinson, Civey and Patall (2006) meta-analysis.

### *International Comparisons*

Past studies by Stigler, Lee, Lucker, and Stevenson (1982) reported that students in Japan spent considerably more time on homework activities than did students in the United States. In a study conducted by Sawada (1999), a typical fifth-grade lesson in Japan indicated that an emphasis was placed on the problem-solving processes used by students and errors were discussed in order to examine the breadth of strategies that were used. Also there was a considerable amount of time spent on a single problem in order to provide time for students to examine multiple approaches to problem-solving and to compare multiple solutions.

The Third International Mathematics and Science Study (TIMSS, 1995) indicated that although teachers often give students time to begin or review homework assignments in class,

homework is generally considered a method of extending the time spent on regular classroom lessons. Internationally, most fourth-grade students were assigned homework at least once or twice a week if not more. The pattern for the Netherlands differed substantially from other countries, with teachers reporting that 86% of the students were assigned homework less than once a week, and half of these were never assigned homework. Typically, these assignments were 30 minutes or fewer in length. In Hong Kong, Iran, Korea, Singapore, and Thailand, homework assignments were more than 30 minutes for about one third or more of students in these countries (Mullis, et al., 1997). In addition, the study reported that in all participating countries, teachers of at least 70% of the students reported they sometimes, if not always, corrected homework assignments and returned them to students. In general, for the TIMMS countries, teachers reported that mathematics homework assignments contributed only rarely or sometimes to students' grades or marks. In fact, teachers in the Czech Republic, Hong Kong, Japan, and Singapore reported that homework never or only rarely contributed to the grades for the majority of their students (Mullis, et al., 1997).

In addition, fourth-grade students reported averaging approximately an hour studying mathematics (Mullis, et al., 1997). Fourth-grade students in the Netherlands, Norway, and Scotland were at the lower end of the range, reporting an average of about one half hour of homework per school day. About one fourth of the students in Norway and Scotland and nearly half in the Netherlands reported that they normally spent no time outside of school studying mathematics. Those in Iran and Kuwait were at the top end, reporting two hours of mathematics homework per school day.

This study (TIMMS, 1995) also looked at the relationship between time spent studying mathematics outside of school and the students' average mathematics achievement. The

relationship was curvilinear in most countries, with the highest achievement being associated with less than one hour of homework per day. This pattern suggested that compared to their higher-achieving counterparts, the lower performing students may do less homework either because they choose not to do it or because their teachers do not assign more homework. In only Iran, Japan, and Korea did students who reported progressively more time studying mathematics outside of school have correspondingly higher average mathematics achievement scores. The only inverse relationship was noted for the Netherlands. As was reported, different countries clearly have different policies and practices about assigning homework and encouraging the study of mathematics outside of school (Mullis, et al., 1997).

More recently, Baker and LeTendre (2005) compared the United States to several East Asian nations. At the elementary school level, they saw little difference between the United States and the high-performing Asian nations in regard to homework. In fact, many countries where students scored highest on achievement tests, such as Japan, Denmark, and the Czech Republic, had teachers who assigned little homework (Baker & LeTendre, 2005). Baker and LeTendre's (2005) analyses of homework using the TIMSS (1995 & 2003) comparable data on homework measures showed a general multinational pattern. The overall correlations between national average student achievement and national averages in the frequency, total amount, and percentage of teachers who used homework in grading were all negative.

Baker and LeTendre (2005) concluded that most countries, teachers are not using homework in an effective manner. They suggested that educational policy makers and reformers needed to consider the overall quality of homework given in a nation as much as they needed to consider quantity. They recommended that the focus be on the type and usage of homework as well as on whether or not the students are actually doing the work (Baker & LeTendre, p. 130).

Furthermore, they noted that homework policies should be age-specific. They also reported that homework, perhaps more than any other aspect of schooling, highlights how critical it is for national policy makers, teachers, and law makers to understand the global patterns and forces that affect modern education (Baker & LeTendre, 2005).

### *Homework Design*

Homework activities are components of instruction, and students in most classrooms participate in these activities. Chuansheng and Stevenson (1989) proposed that if these assignments are interesting and children can see they are useful, this form of instructional practice can facilitate academic achievement. If the quality of homework assignments is poor and homework consists of repetitive problems and dull drill, an increase in the amount of homework is unlikely to have positive effects. They noted that a careful study of the content of homework can clarify this point (Chuansheng & Stevenson, 1989). The role of homework is also a link between home and school. Doyle & Barber (1990) reported that inappropriate or badly explained homework assignments, however, can just as readily serve as a source of antagonism between parent, teacher, and child. It is essential that classroom teachers make every effort to ensure that assignments are necessary and useful, appropriate to the ability and maturity level of the students, well explained and motivating, and clearly understood by both parent and child. Further, Kohn (1993) argued for expanding the role that students play in making decisions including the design of homework activities.

Margaret Nuzum, Director of Empire Educational Services, stated that homework success depended on the type and quality of the assignments given, the student's skills and understanding of the assignments, and parental expectations and participation (Nuzum, 1998). Examining why homework was not useful in elementary school, Begley found that many teachers at that level

assigned homework that was not relevant to the lessons taught. She concluded that good foundations and attitudes toward homework should be fostered in elementary school (Begley, 1998). Epstein (2001) noted that teachers have the responsibility to assign quality homework, and students have the responsibility to produce quality homework. Teachers needed to be informed educators and to be aware of what the research has stated about homework, especially research related to the level they teach.

Another homework design concern is tailoring homework to individual needs. Swanson (1990) investigated metacognition and problem-solving, and stated that high levels of metacognition substituted for an overall lack of ability by providing children with a domain-specific problem-solving aptitude. Furthermore, he stated that regardless of this speculation, the results do suggest that metacognition can be separated from general aptitude and that subjects with a high degree of metacognition do better in problem-solving than those with a lower degree of metacognition. Teachers need to be conscious of this when they assign tasks to students.

In a more specific example, students with learning disabilities are increasingly mainstreamed into general education classrooms. Special education teachers find themselves spending most of their time monitoring homework completion rather than developing the skills that would help students become capable of doing the homework independently (Hughes, Ruhl, Schumaker, & Deshler, 2002). In fact, Bryan (2004) referred to the impact of teachers' beliefs, values, and practices in the design of homework assignments for special education students. He referred to homework assignments being based on the preferences of individual teachers who may or may not set developmentally appropriate standards within and across grade levels. Furthermore, he stated that the amount and type of homework are influenced by community standards and teachers' perceptions of community expectations. Therefore, the impact of

teachers' beliefs about their students' abilities and about community standards and expectations may be reflected in the wide disparity of teachers' use of homework (Bryan, 2004).

In regard to students' beliefs, Bostrom and Lassen (2006) noted the effects for students, who were able to identify and define their own learning first, as the following: (a) They made more precise demands on teachers, their school and their education; (b) reflected on and understood their own learning, thus being enabled to do their homework, solve problems, and better sort through the flow of information; and (c) better understood the structure of the school system, thus having an easier time to participate actively.

In addition, Simplicio (2005) referred to the fact that many homework assignments were not accomplishing the educational goals they were designed to achieve. He cited an example of teachers assigning math homework that required students to solve a series of problems, the goal being to build on the basic skills learned in class and reinforcing these skills through repetition. He noted that the flaw in this process occurred when the student did not understand how to solve a problem; therefore, assigning more examples of the same problem was not an effective teaching tool. Conversely, completing several problems when a student grasps the math concept can lead to boredom and dislike for repetitious homework assignments. In addition, homework activities assigned to build or develop critical and cognitive thinking skills may be unclear and difficult for students to understand and require parental assistance, thus negatively impacting communication between students, families, and teachers (Simplicio, 2005). In fact, pupils' learning is more productive if it is reflective, intentional, and collaborative. These are goals that may not come naturally but can be taught and can lead pupils to take responsibility for their learning (Black et al., 2006). Consequently, students need to be accountable for learning from their homework (Willis, 2006).

### *Teacher Preparation*

To design quality homework assignments, teachers need education programs that address this area of instruction. In a 1988 study by Heller, Spooner, Anderson, and Mims, it was reported by the teachers surveyed that those with formal training in how to use homework had fewer obstacles to its implementation, viewed it as more important, and advocated for its more frequent use. Cooper and Nye (1994) noted that teachers benefited from training in the use of homework as a pedagogical strategy. Bryan and Burstein (2004) suggested that an area for research would be the impact of structured pre-service and in-service training to increase teacher knowledge and strategies for using homework. They added that teachers could systematically self-assess their practices, or explore teacher-student collaboration within and across grades. In addition, they noted as major issues getting teachers to adopt the strategies that research has demonstrated to be effective, to critically self-examine their own practices, to make changes based on these practices, and to establish school-wide teams to create developmentally appropriate homework assignments and methods for systematically evaluating the effect of homework assignments on students.

### *Homework Expectations*

Homework grows in frequency and difficulty as students move from elementary school to college, and teachers assume students' greater self-regulation as they advance through grade levels (Cooper, Lindsay, Nye, & Greathouse, 1998; Zimmerman, 2002). Therefore, it is expected that by the time students reach the end of the elementary level, they will have a strong sense of the importance of homework and will have developed the habits of mind, the self-efficacy, the

self-regulation, and the motivation to meet the challenges of the homework responsibilities of middle school, high school, and eventually college (Costa & Kallick, 2000). Homework and practice are ways of extending the school day and providing students with opportunities to refine and extend their knowledge. Teachers can use homework and practice as powerful instructional tools (Marzano, Pickering, & Pollock, 2001).

Consequently, homework must not merely be assigned activities (Cooper, 2001). From the start, there needs to be a step-by-step progression of learning for all stakeholders, beginning with the first experiences students have with the homework process. This progression of learning for teachers, students, and parents, requires commitment to a definitive goal if the homework process is to be successful. That goal would be to have the student become an independent, self-directed learner (Cooper, 2001). In addition, exposing individuals to metacognitive knowledge enables them to self-regulate their performance on a task (Eilam, 2001).

Marzano (2007, p. 71) referred to homework as an area of focus for practicing and deepening knowledge. However, he cautioned educators to be aware of six issues regarding homework:

1. Homework should be structured to ensure high completion rates.
2. The amount of time assigned as well as the grade levels should be carefully considered when assigning homework.
3. Homework should have a well-articulated purpose.
4. Homework should relate directly to identified learning goals.
5. Homework should be designed so that students can perform it independently.
6. Home work should involve parents and guardians in appropriate ways.

Therefore, educators need to design activities for our students that require rigorous and relevant practice of this type of thinking.

Marzano (2007) recommended three general types of homework. The first type is homework that helps students deepen their knowledge. The second is homework that enhances students' fluency with procedural knowledge. The third type of recommended homework introduces new content. Therefore, homework design needs to be purposeful to be effective.

#### *Metacognition, Problem Solving, and Homework*

Siegler and Jenkins (1989) and Kuhn, Schauble, and Garcia-Mila (1992) noted that extended practice and reflection played crucial roles in the construction of metacognitive knowledge and regulatory skills. This was especially true when students were given regular opportunities to reflect on their own successes and failures. In addition, students improved at problem solving when given practice and allowed time to work at problem-solving situations rather than simply finding a solution. Given multiple opportunities to practice, students learn to be more efficient in their choice and use of strategies, to generalize from one situation to another, and to discriminate relevant characteristics more quickly (Gartmann & Freiberg, 1994). In regard to homework, Corno (1995) and Corno and Xu (1998) stated that homework was mostly unsupervised and was, or should be, mostly self-regulated with learners determining and monitoring many aspects of its execution.

Furthermore, Carr and Biddlecomb (1998) stated that for many children, mathematics skills and knowledge appear to develop without the development of reflection. As a result, children are stymied in their attempts to transfer mathematics knowledge from the classroom to real-life activities. In addition, they recognized that metacognitive knowledge developed from children's interactions with peers and adults. Thus, mathematical problem-solving homework

assignments can provide opportunities for students to practice and improve their metacognitive skills.

### *Summary*

Homework is widely viewed as a useful supplement to classroom instruction; however, little is known about what kinds of homework to assign for learning to be optimal. The limited research on homework has been confined to investigations of the relation between quantity of homework assigned and students' achievement test scores. Neither the quality nor the function of homework has been considered. Students need to be able to perform procedures correctly before they undertake practice without supervision (Kilpatrick, 2001). With this in mind, this study was designed to focus on how homework can be designed to be more effective in improving student learning.

## CHAPTER 3: METHODOLOGY

The purpose of this study was to investigate whether or not mathematical problem-solving homework assignments that included metacognitive awareness practice would improve the development of mathematical problem-solving skills in fourth-grade students.

Five research questions guided the research in this study:

1. Is there a significant difference in mathematical problem-solving skills of fourth-grade students as measured by mathematics achievement when homework assignments include practice of metacognitive awareness as compared to when homework assignments do not include this practice after controlling for individual differences in mathematical problem-solving?
2. Is there a significant difference in the frequency of completed mathematical problem-solving homework responses for fourth-grade students when homework assignments include practice of metacognitive awareness compared to when homework assignments do not include this practice after controlling for individual differences in mathematical problem-solving?
3. Is there a significant difference in the frequency of accurate mathematical problem-solving homework responses for fourth-grade students when homework assignments include practice of metacognitive awareness compared to when homework assignments do not include this practice after controlling for individual differences in mathematical problem-solving?
4. Is there a significant difference in the frequency of independent mathematical problem-solving homework responses for fourth-grade students when homework assignments include practice of metacognitive awareness compared to when homework assignments

do not include this practice after controlling for individual differences in mathematical problem-solving?; and

5. Is there a significant difference in the quality of mathematical problem solving strategies of fourth-grade students as measured by a mathematical applications scoring rubric when homework assignments include practice of metacognitive awareness compared to when homework assignments do not include this practice after controlling for individual differences in mathematical problem-solving?

This chapter describes the setting, subjects, and sampling procedures and explains why this sampling was selected. It also includes a description of the processes determining the design and analyses used in this study, including details of the treatment. Furthermore, this chapter discusses the type of data and research design in reference to the research questions investigated in the study. The next subsection is a description of the instrumentation used, including reliability and validity data. In addition, justification of the selected procedures for analyzing the collective information including probability values and statistical formulas as well as an explanation of the relationship between the hypotheses and the employed statistics are discussed. This is followed by an explanation of the data-collection procedures, including permission forms and time frames. This chapter also identifies limitations of the study and then explains both internal and external threats. The chapter concludes with an ethics statement that is in compliance with the university's guidelines.

### Setting

The population for this study was an accessible sample of convenience selected from members of the fourth-grade classes in a school district in New England. This school district represented a white, suburban, upper-middle-class community. The two elementary schools

involved in the study had an average population of 550 students. Each school had four classrooms at the fourth-grade level. The sample included 45 students from School A and 67 students from School B. However, two students dropped out of the study, one from the control group and one from the treatment group, bringing the actual number of participants to  $n = 110$ . The students in the sample were from the eight heterogeneously grouped, self-contained fourth-grade classrooms with class sizes ranging from seventeen to twenty-four students.

Schools A and B had similar demographics. According to the *Strategic School Profile 2006-2007* (Connecticut State Department of Education, 2007), School A had an enrollment of 487 students, and School B had an enrollment of 616 students. School A is an elementary school that includes grades Kindergarten through Grade 5, and School B is an elementary school that includes grades Pre-kindergarten through Grade 5. In School A, 2.7% of students received free or reduced-price lunch; at School B, 1.8%. Among the student body of School A, there were five students who were non-English speaking. School B had seven students in this category. Most students at School A and School B attended some form of pre-school education, 91.8% and 84.8%, respectively. Neither School A nor B had any students identified as gifted and talented. School A had a special education population of 8.6%; this population was 19.6% at School B. Both schools provided 978 hours of instructional time and delivered the same instructional mathematics curriculum, Math Trailblazers (Becker & Morgenthaler, 1998). The percentage of professional staff members with a Master's Degree or above was very similar in both schools with School A having 83% and School B having 82.5%. Both schools provided the same types of remedial instructional services to students lacking basic skills, pull-out instruction, and in-class tutorial.

For the school year 2006-2007, 77.2% of students in School A and 87.5% of students in School B reached the grade-level goal in mathematics on the Grade Four Connecticut Mastery Test. As of October 1, 2006, School A had a 97.4%, and School B had a 99.0% attendance rate.

### Subjects

This target accessible sample was representative of the school population in gender makeup and ethnicity. Initially, the sample was comprised of 18 male students and 27 female students in School A and 36 male students and 31 female students in School B, for a total of  $n = 112$ . There were 12 females and 11 males in the treatment group in School A, and 13 females and 19 males in the treatment group in School B for a total of 25 females and 30 males in the treatment group. There were 15 females and 7 males in the control group in School A, and 18 females and 17 males in the control group in School B for a total of 33 females and 24 males in the control group. However, two students, one from School A in the control group, and one from School B, in the treatment group, dropped out of the study bringing the actual number of total participants to  $n = 110$ . The student participants had an ethnic diversity consistent with the school population.

### Sampling Procedures

In February of 2006, the researcher received permission from the Institutional Review Board (IRB) to conduct the study (see Appendix C). All students enrolled in the fourth-grade classes at School A and school B were eligible to participate. In May of 2007, for each of the eight fourth-grade classroom in school A and school B, letters of consent were sent to the parents and guardians of potential student participants in the study (see Appendix D). After all consent forms were received, the researcher randomly selected four classrooms for the control group and four classrooms for the treatment group. The results of the random selection

determined that two classrooms in School A and two classrooms in school B were in the control group, and two classrooms in school A and two classrooms in school B were in the treatment group.

### Design and Analysis

This study was quantitative, using a quasi-experimental design. The categorical independent variable tested was homework assignments with the two levels of students who practiced metacognitive awareness and students who did not practice metacognitive awareness. The interval-level-dependent variable was the gain in mathematical problem-solving skills as measured by the Applications content area total standard scores of the KeyMath-3 DA, Forms A and B, as pre- and post-tests (Connolly, 2007). The total standard scores for the Applications content area was determined by calculating the total raw scores for the two subtests, Foundations of Problem Solving and Applied Problem Solving.

For seven weeks, seven mathematical problem-solving homework assignments were collected from each participant. These assignments were selected from the mathematics application sample practice problems of the Connecticut Mastery Test, Fourth Generation (see Appendix E). Participants in the study were given identical mathematical problem-solving homework assignments one day per week. Four classrooms were randomly assigned to a control group and four classrooms were randomly assigned to a treatment group. Treatment groups also responded to the Thinking about Thinking Inventory for Fourth-Grade Students (TAT-4) attached to the first, fourth, and seventh mathematics problem-solving homework assignment (see Appendix B). The assignment sheet included a direction section that asked all students to sign off as to whether or not they did the homework independently. There was also a place to indicate the amount of time it took to finish the assignment. Each week, the

homework assignments were delivered by the researcher in envelopes to the teachers in school A and school B. At the end of the week, the researcher collected the assignments in these same envelopes from the teachers in school A and school B. These assignments were scored by the researcher for number and frequency of completed, accurate, and independent responses. Using the *Connecticut Mastery Test Scoring Rubric for Scoring 3-Point Extended-Task Mathematical Items*, the researcher scored the quality of problem-solving strategies and solutions (see Appendix A). A qualified teacher checked a random sample of the scoring results of these data throughout the data collection process. Descriptive statistics were reported from these data.

#### *Treatment*

All eight fourth-grade classroom teachers in Schools A and B agreed to be part of the study. By random selection, two classrooms from each of the schools were placed in the treatment group. A total of 54 students were in the treatment group. To assess general mathematical problem-solving skills, all participants were administered the Foundations of Problem Solving and the Applications of Problem Solving subtests of the KeyMath-3 DA, Form A. These two subtest scores were combined to determine a total standard score for the Application content area of the KeyMath-3 DA, Form A. Upon completion of the pre-test, students in the treatment group were given a math problem to solve for homework once a week for seven weeks. The homework assignments were sample mathematics application practice problems (see Appendix E) from the Connecticut Mastery Test. These assignments were the math homework for Tuesday nights. The classroom teachers were not shown the problem-solving assignments or the responses to those assignments, and therefore did not provide specific assistance that interfered with the outcome of this research project. In addition, at no point during this study was mathematics instruction using Math Trailblazers materials

interrupted. The assignment sheet included a place for students to indicate whether or not they did the assignment independently. There also was a place to indicate the amount of time it took to finish the assignment. In addition to responding to the homework assignment, students in the treatment group also responded to the Thinking About Thinking Inventory for Fourth Grade Students, TAT-4 (see Appendix B), attached to the mathematics problem-solving homework assignment. This was an activity that students completed to reflect on their mathematical problem-solving behaviors. Each homework assignment was analyzed for the dependent variables of completion of responses, accuracy of responses, and independence of responses. The TAT-4 appeared three times during the testing period attached to the first assignment, the fourth assignment, and the seventh assignment. Assignments for both treatment and control groups were coded so the information remained confidential. All homework assignments were delivered and collected by the researcher each week.

### *Control*

The control group participants were determined following the same procedure as the treatment group. There were 56 participants in the control group. Upon completion of the pre-test, students in control group classrooms were given the same math problems as the treatment group to solve for homework each week for a period of seven weeks. The mathematical homework assignment included the same directions asking for the students to indicate whether or not they did the homework independently. Students also noted the amount of time it took to complete the assignment. As with the treatment group, the classroom teachers for the control group were not shown the problem-solving assignments or the responses to those assignments, and therefore did not provide specific assistance that interfered with the outcome of this research project. In addition, at no point during this study was mathematics instruction using

Math Trailblazers materials interrupted. The scores on these assignments were not included in the students' grades.

Upon completion of the homework data collection process, students in both the treatment and control groups were administered the Applications content area of the KeyMath-3 DA, Form B as a post-test. Test statistics on general mathematical problem-solving ability as well as test statistics for completion, accuracy, independence, and quality of mathematical problem-solving homework responses were then determined.

### Type of Data and Research Design

#### *Research Question One: Hypothesis, Design, and Analysis*

The first research question asked: Is there a significant difference in mathematical problem-solving skills of fourth-grade students as measured by mathematics achievement when homework assignments include practice of metacognitive awareness compared to when homework assignments do not include this practice after controlling for individual differences in mathematical problem-solving?

The first hypothesis states: There will be a significant positive effect on mathematical problem-solving skills for fourth-grade students as measured by mathematics problem-solving achievement when the practice of metacognitive awareness is included in mathematical problem-solving homework assignments compared to when there is no practice of metacognitive awareness after controlling for individual differences in mathematical problem-solving.

The design for this first research question was quasi-experimental with a pre- and post-test, using a treatment and a control group. In October 2007, participants were assigned to either the treatment or the control group by random assignment of classroom, and the Applications content area of the KeyMath-3 DA, Form A, was administered as a pre-test. The dependent

variables were the scores on two subscales of the standardized test, Foundations of Problem Solving and Applied Problem Solving. The scores on these two subtests were totaled to determine a total standard score for the Applications content area of the KeyMath-3DA. In February 2008, the Foundations of Problem Solving and Applied Problem Solving subtests were administered to determine a total standard score for the Applications content area of the KeyMath-3 DA, Form B, as a post-test. The independent variable was a homework assignment with two levels, students who practiced metacognitive awareness using the TAT-4 and students who did not practice metacognitive awareness using the TAT-4.

The post-test data from the Applications content area of the KeyMath-3 DA, Form B, determined homogeneity of groups in regard to mathematical problem-solving ability. A one-way analysis of covariance (ANCOVA) was used to analyze these data, controlling for post-test differences using pre-test scores, to determine the between groups mean values of the dependent variables of math scores and for each level of the independent variable of homework assignment, with a significance level of less than or equal to 0.01 (SPSS, 1999).

#### *Research Question Two: Hypothesis, Design, and Analysis*

The second research question asked: Is there a significant difference in the frequency of completed mathematical problem-solving homework responses for fourth-grade students when homework assignments include practice of metacognitive awareness compared to when homework assignments do not include this practice after controlling for individual differences in mathematical problem-solving?

The second hypothesis stated: There will be a significant positive effect on the frequency of completed mathematical problem-solving homework responses for fourth-grade students when the practice of metacognitive awareness is included in mathematical problem-solving

homework assignments compared to when there is no practice of metacognitive awareness after controlling for individual differences in mathematical problem-solving.

The design for the second research question was post-test only with a treatment and control group. The treatment and control group were randomly assigned by classroom. The dependent variable was completed mathematical problem-solving responses in homework assignments. The independent variable was homework assignments with two levels, students who practiced metacognitive awareness using the TAT-4 and students who did not practice metacognitive awareness using the TAT-4.

Over seven weeks in November and December 2007, weekly mathematical problem-solving homework assignments were collected from the control and treatment groups. These homework assignments were taken from the CMT Mathematics Application sample items. The researcher determined the frequency of completed responses for these data.

At the end of the data collection period, the researcher computed an ANCOVA, using pre-test total standard scores on the Applications content area of the KeyMath-3 DA as a covariate, to determine the between-groups mean values of the dependent variable of completion of responses and for each level of the independent variable of homework assignment, with a significance level of less than or equal to 0.01 (SPSS, 1999).

### *Research Question Three: Hypothesis, Design, and Analysis*

The third research question asked: Is there a significant difference in the frequency of accurate mathematical problem-solving homework responses for fourth-grade students when homework assignments include practice of metacognitive awareness compared to when homework assignments do not include this practice after controlling for individual differences in mathematical problem-solving?

The third hypothesis stated: There will be a significant positive effect on the frequency of accurate mathematical problem-solving homework responses for fourth-grade students when the practice of metacognitive awareness is included in mathematical problem-solving homework assignments compared to when there is no practice of metacognitive awareness after controlling for individual differences in mathematical problem-solving.

The design for the third research question was post-test only with a treatment and control group. The treatment and control group were randomly assigned by classroom. The dependent variable was accurate mathematical problem-solving responses in homework assignments. The independent variable was homework assignment with two levels, students who practiced metacognitive awareness using the TAT-4 and students who did not practice metacognitive awareness using the TAT-4.

In November and December 2007, seven weekly mathematical problem-solving homework assignments were collected from the control and treatment groups. These homework assignments were taken from the CMT Mathematics Application sample items. The researcher determined the frequency of accurate responses for these data.

At the end of the data collection period, the researcher computed an ANCOVA, using pre-test total standard scores on the Applications content area of the KeyMath-3 DA as a covariate, to determine the between-groups mean values for the dependent variable of accuracy of responses and for each level of the independent variable of homework assignment, with a significance level of less than or equal to 0.01 (SPSS, 1999).

#### *Research Question Four: Hypothesis, Design, and Analysis*

The fourth research question asked: Is there a significant difference in the frequency of independent mathematical problem-solving homework responses for fourth-grade students when

homework assignments include practice of metacognitive awareness compared to when homework assignments do not include this practice after controlling for individual differences in mathematical problem-solving?

The fourth hypothesis stated: There will be a significant positive effect on the frequency of independent mathematical problem-solving homework responses for fourth-grade students when the practice of metacognitive awareness is included in mathematical problem-solving homework assignments compared to when there is no practice of metacognitive awareness after controlling for individual differences in mathematical problem-solving.

The design for the fourth research question was post-test only with a treatment and control group. The treatment and control group were randomly assigned by classroom. The dependent variable was independence in mathematical problem-solving responses in homework assignments. The independent variable was homework assignment with two levels, students who practiced metacognitive awareness using the TAT-4 and students who did not practice metacognitive awareness using the TAT-4.

In November and December 2007, seven weekly mathematical problem-solving homework assignments were collected from the control and treatment groups. These homework assignments were taken from the CMT Mathematics Application sample items. The researcher determined the frequency of independent responses for these data.

At the end of the data collection period, the researcher computed an ANCOVA, using pre-test total standard scores on the Applications content area of the KeyMath-3 DA as a covariate, to determine the between-groups mean values for the dependent variable of independence of responses and for each level of the independent variable of homework assignment, with a significance level of less than or equal to 0.01 (SPSS, 1999).

*Research Question Five: Hypothesis, Design, and Analysis*

The fifth research question asked: Is there a significant difference in the quality of mathematical problem-solving strategies of fourth-grade students as measured by a mathematical applications scoring rubric when homework assignments include practice of metacognitive awareness compared to when homework assignments do not include this practice after controlling for individual differences in mathematical problem-solving?

The fifth hypothesis stated: There will be a significant positive effect on the quality of mathematical problem-solving strategies and solutions of fourth-grade students as measured by a mathematical applications scoring rubric when the practice of metacognitive awareness is included in mathematical problem-solving homework assignments compared to when there is no practice of metacognitive awareness after controlling for individual differences in mathematical problem-solving.

To answer the fifth research question, a design of post-test only with treatment and control group was employed. The treatment and control group were randomly assigned by classroom. The dependent variable was quality of mathematical problem-solving responses in homework assignments. The independent variable was homework assignment with two levels of students who practiced metacognitive awareness using the TAT-4 and students who did not practice metacognitive awareness using the TAT-4.

In November and December 2007, seven weekly mathematical problem-solving homework assignments were collected from the control and treatment groups. These homework assignments were taken from the CMT Mathematics Application sample items. The researcher

computed a simple repeated-measures ANCOVA, using pre-test total standard scores on the Applications content area of the KeyMath-3 DA as a covariate, to determine the variation among individuals, variation among treatment occasions, and residual variation with a significance level of less than or equal to 0.01 (SPSS, 1999).

### Instrumentation

#### *KeyMath-3 Diagnostic Assessment (KeyMath-3 DA)*

The KeyMath-3 Diagnostic Assessment (KeyMath-3 DA) is a comprehensive, norm-referenced measure of essential mathematical concepts and skills (Connolly, 2007). The KeyMath-3 DA can be used with individuals from age 4 1/2 through 21 years who are functioning at these instructional levels. It is not timed, and it is individually administered. The KeyMath-3 DA reflects the content and process standards described in the National Council of Teachers of Mathematics (NCTM) *Principals and Standards for School Mathematics* (NCTM, 2000). The five subtests corresponding to the basic Concepts content area correspond directly to the five NCTM content standards. The KeyMath-3 DA item content also represents the five NCTM process standards. The KeyMath-3 DA Applications content area is composed of two subtests that mirror problem solving and learning with understanding: The Foundations of Problem Solving subtest addresses the requisite skills for successful problem solving, and the Applied Problem Solving subtest addresses the application of those skills, as well as conceptual knowledge and facility with the operations to solve problems.

The KeyMath-3 DA standardized assessment consists of 10 subtests spanning three general areas (Basic Concepts, Operations, and Applications). The assessment includes two parallel versions (Form A and Form B). These were developed concurrently, matched statistically and by content. For the purposes of this study, participants were administered only

the Applications content section of the test. This included the subtests of Numeration, Foundations of Problem Solving, and Applied Problem Solving (Connolly, 2007).

The Numeration subtest measures an individual's understanding of whole and rational numbers. It measures mathematical concepts that serve as a foundation for estimation and computation, measurement, data interpretation, and problem solving.

The Foundations of Problem Solving subtest assesses the "readiness" for applied problem-solving. It measures an individual's ability to identify the necessary elements, operations, and strategies required to solve math problems. It also places emphasis on the individual's ability to explore the procedural elements that facilitate solutions. Components of this subtest include analysis of problems, word problems, and problem-solving strategies.

The Applied Problem Solving subtest measures an individual's ability to interpret problems set in a context and to apply computational skills and conceptual knowledge to produce a solution. Components of this subtest include numeration, algebra, geometry, measurement, and data analysis and probability.

Test reliability refers to the consistency of scores obtained from repeated testing of a student with the same or a similar test under comparable testing conditions. This incorporates the dependability or reproducibility of test scores.

The KeyMath-3 DA uses the split-half method. The correlation between the scores on the halves is adjusted by the Spearman-Brown formula. With the split-half method, the participant's performance on each half is converted to an ability score, using the item difficulties from the Rasch calibration of the subtest. These ability scores are correlated and adjusted using the Spearman-Brown formula. The adjustment method is to calculate the standard error of measurement (SEM) for each form in ability-score units; to compute the SD

of ability scores for the entire norm sample at that season, grade, or age; and to insert those values into the reliability formula ( $r_{xx} = 1 - (\text{SEM}^2) / (\text{SD}^2)$ ), (Connolly, 2007). Median subtest test-retest reliabilities are .86 for the younger examinees and .88 for the older examinees, all area score reliabilities are in the mid-.90s, and the test-retest reliability of the total test score is .97 for both grade levels (Connolly, 2007).

Validity refers to the degree to which accumulated data substantiate the inferences drawn from the test results. Content validity, construct validity, and correlations with other tests provide evidence of the KeyMath-3 DA's validity. Content validity refers to the degree that the KeyMath-3 DA's test items represent the content of the mathematics curricula at the national level based on the test takers' age range from 4 1/2 through 21 years. State math standards and the National Council of Teachers of Mathematics (NCTM) publications were reviewed (Connolly, 2007). Input was also obtained from more than 400 educational practitioners and consultants with mathematic curriculum expertise. Construct validity refers to the extent to which a test measures the developmentally sequenced progression of fundamental knowledge and skills in mathematics. Intercorrelation among subtests areas and total test for grades three through five vary from .63 to .92 (Connolly, 2007).

#### *Schraw & Denison's Metacognitive Awareness Inventory (MAI)*

The *Schraw & Denison's Metacognitive Awareness Inventory (MAI)* is a 52-item inventory designed to measure the metacognitive awareness of adults (Schraw & Dennison, 1994). Items are classified into eight subcomponents under the two broader categories of Knowledge of Cognition and Regulation of Cognition. The knowledge component includes statements of declarative, procedural, and conditional knowledge. The regulation component includes statements of planning, information management, comprehension monitoring,

debugging, and evaluation. The internal consistency of these two scales ranged from 0.93 to 0.88. Baker and Cerro (2000) conducted factor analysis on the MAI. This analysis demonstrated that the instrument has good internal consistency for two factors, the individual's knowledge about cognition and regulation of cognition. The MAI factors were reliable (i.e., probability  $\alpha = .90$  and inter-correlated ( $r = .54$ ) (Schraw & Dennison, 1994).

*Thinking about Thinking Inventory for Fourth-Grade Students (TAT-4)*

This inventory is designed by the researcher is based on Schraw and Dennison's Metacognitive Awareness Inventory (MAI, 1994). Permission to modify the MAI was given to the researcher by Dr. Schraw (see Appendix F).

The TAT-4 is a 26-item metacognitive awareness inventory. The items are classified into five subcomponents under the two broader categories of knowledge of cognition and regulation of cognition. The knowledge component included statements of declarative and procedural knowledge. Conditional knowledge and evaluation were grouped together because of the overlapping nature of these two subcomponents. The regulation of knowledge includes planning and a subcategory comprised of monitoring, information management, and debugging.

Content validity was obtained by distributing a survey about the definition of subscales for the instrument to twelve content experts in elementary school mathematics. The experts were asked to relate each item to one of the five subscales and to indicate how strongly he or she felt about that selection. The results indicated that participants in the survey agreed that items referring to conditional knowledge and evaluation could be grouped into one subscale. In addition, results supported the collapsing of monitoring, information management, and debugging into a single subscale. An initial pilot of the TAT-4 indicated that the internal

consistency reliability for the overall instrument was .917. The reliability calculations of the main subscales of knowledge of cognition and regulation of cognition were .747 and .896, respectively.

*Connecticut Mastery Test Scoring Rubric for Scoring*

*3-Point Extended-Task Mathematical Items*

*Connecticut Mastery Test Scoring Rubric for Scoring 3-Point Extended-Task*

*Mathematical Items* is used to score open-ended student responses on the Fourth Generation CMT. The 4-point rubric, ranging from 0-3, is only used for Strand 25, Integrated Understanding questions and Mathematical Applications (see Appendix A). In this strand students solve extended numerical and statistical problems (CMT, 2006).

Another part of assessing the quality and validity of inferences made from an instrument is to assess the equality of the items on the test. For item specifications, the CMT employs Standards for Educational and Psychological Testing (AERA, APA, NCME, 1999) as a primary source of guidance in the construction, field testing, and documentation of the tests. The target reliability coefficients of .90 (or higher) are set for the cut points of each test. Item statistics also include item difficulty, item discrimination, and differential item functioning.

For Constructed-Response items, there were multiple score categories. CMT employed the simple Mantel-Haenszel chi-square value. Chi-square values with probabilities less than .05 were deemed significant, indicating differential item functioning (Dr. M. Dirir, personal communication, January 12, 2007)

### *Completion*

For this study, the dependent variable of completion of responses was calculated by counting the number of completed responses on each homework assignment for both the treatment and the control group participants. Completion was determined based on the definition previously listed. A percentage of completion for seven homework assignments was determined.

### *Accuracy*

Also, the dependent variable of accuracy of responses was calculated by counting the number of accurate responses on each homework assignment for both the treatment and the control group participants. Accuracy was determined based on the definition previously listed. A percentage of accuracy for seven homework assignments was determined.

### *Independence*

The dependent variable of independence of responses was calculated by counting the number of independent responses on each homework assignment for both the treatment and the control group participants. Independence was determined based on the definition previously listed. A percentage of independent responses for seven homework assignments was determined.

### *Quality*

The dependent variable of quality was calculated by counting the number of 0-3 responses on each homework assignment for both the treatment and the control group participants. The variation among individuals, treatment occasions, and the residual variation was determined.

## Data Collection

In April 2006, the researcher conducted a pilot study of 47 fourth-grade students. One area of focus for this study was the percentage of completed and accurate responses on 10 homework assignments in mathematics. The results of this study showed that only 15% of the students had a 100% completion rate for homework assignments. Also, there were no students with 100% accuracy on these homework assignments. The researcher also related these percentages to report-card letter grades. There were eight female students and six male students who had a letter grade of A. For thirteen students in this group, the completion percentage was higher than the accuracy percentage. For students with a B letter grade, all nineteen students had a completion percentage higher than an accuracy percentage. Similarly, there were fourteen students with a letter grade of C, and all fourteen students had a completion percentage higher than an accuracy percentage. As a result of this study, the researcher concluded that students were persistent in completing their homework, but the work they completed was not equally accurate (Shaw, 2006). The participants in this pilot study were not the same participants in the current study.

A pilot study with 40 fourth-grade students was conducted by the researcher in April 2007 to field test the developmental appropriateness of the TAT-4. The participants in this pilot study were not the same participants as in the present study.

The researcher presented an overview of the study to any interested stakeholders, such as parents, administrators, teachers, community members, and students, in May 2007. In September of the 2007 school year, an informational letter along with consent forms were sent home with students who were members of the classrooms participating in the study (see Appendix D).

Throughout the month of October 2007, pre-testing of the Applications content area of the KeyMath-3 DA, Form A was individually administered by certified staff to all participants in the study. When all pre-testing was completed, the homework data collection began each Tuesday from November 6, 2007 until December 17, 2007. For these seven Tuesday nights between November 6, 2007 and December 17, 2007, every student in the class was given the same problem-solving assignment for that night's homework. This was appropriate since the problems assigned for homework in the study were sample CMT mathematical application problems designed for use with fourth-grade students. The researcher designed the assignment sheets with codes for those in the study. (see Appendix E). In addition, to make the process of distributing homework not complicated for the teacher and since all students received the same homework assignment, the researcher included assignment sheets without codes for those students not in the study. The classroom teachers were aware of which students were in the study and those students' corresponding code numbers. The following day, teachers collected all the homework assignments and placed them in the designated envelopes for collection by researcher. The researcher scored all of the assignments in the envelope and, at the end of each week, returned the assignments to the students not in the study. This process made the homework assignments given on these seven consecutive Tuesdays more manageable for teachers, students, and parents in these classrooms. Teachers, students, or parents did not report any specific concerns to the researcher about this process throughout the data collection process.

In February 2008, the Applications content area of the KeyMath-3 DA Form B, post-test was administered. This allowed for the KeyMath-3 DA recommended three-month waiting

period between pre-and post-testing (Connolly, 2007). The researcher then computed the statistics for the study based on these data.

### Limitations

One external threat to this study was its population validity. This study is limited in its generalizability to fourth-grade classrooms in different school communities with different demographics. Ecological validity concerns the extent to which the results of an experiment can be generalized from the set of environmental conditions created by the researcher to different environmental conditions (Gall, Gall, & Borg, 2003). As a result, there exists the possibility of the threats of explicit description, as well as the Hawthorne effect and pre-and post-test sensitivity. The latter was controlled for in the dependent variable of the Key Math by having alternate test forms.

Since this was a study of homework assignments completed outside the school environment, the researcher was cognizant of the fact that the internal threats of experimental treatment diffusion and compensatory rivalry by the control group were possible. In order to address these threats, the researcher made available to the control group members the opportunity to participate in the treatment at a future date.

Also, this study was limited to metacognitive awareness and mathematics homework. Other subject areas were not investigated. Methods of data collection also threaten validity. Finally, since the TAT-4 is a modification of the MAI, the reliability and validity of this instrument may be slightly less rigorous than the original; therefore, only descriptive statistics were reported in this study.

### Statement of Ethics and Confidentiality

Permission to participate in this research was sought from each district's superintendent, each school principal, and all parents of students. To assure confidentiality, each participant was assigned a confidential identification number. All data were stored in a locked filing cabinet in the researcher's office and will be maintained there until the findings have been published. These data are accessible only to other researchers for whom the data would prove useful in further comparative analyses and who are enrolled in Western Connecticut State University's Doctor of Education in Instructional Leadership Program.

## CHAPTER FOUR: ANALYSIS OF THE DATA AND FINDINGS

This chapter includes a review of the research questions, the hypotheses, a description of the analyses, and the findings of the study. The purpose of this study was to investigate the effect of metacognitive awareness on the development of mathematical problem-solving skills in fourth-grade students' homework assignments. This chapter is organized into two sections. First, the research questions and hypotheses are restated. Second, there are analyses of the statistical results related to each research question.

The independent variable for this study was homework assignments with two levels, students who practiced metacognitive awareness and students who did not practice metacognitive awareness. The study investigated the effect of the independent variable on the dependent variable, mathematical problem-solving achievement. The study also investigated the effect of homework assignments on the frequency of completion, accuracy, and independence in mathematical problem-solving homework assignments. Lastly, the study examined the effect of homework assignments on the quality of mathematical problem-solving homework assignments.

### Research Questions

This study investigated the following five research questions:

1. Is there a significant difference in mathematical problem-solving skills of fourth-grade students as measured by mathematics achievement when homework assignments include the practice of metacognitive awareness compared to when homework assignments do not include this practice after controlling for individual differences in mathematical problem-solving?
2. Is there a significant difference in the frequency of completed mathematical problem-solving homework responses for fourth-grade students when homework assignments

include the practice of metacognitive awareness compared to when homework assignments do not include this practice after controlling for individual differences in mathematical problem-solving?

3. Is there a significant difference in the frequency of accurate mathematical problem-solving homework responses for fourth-grade students when homework assignments include the practice of metacognitive awareness compared to when homework assignments do not include this practice after controlling for individual differences in mathematical problem-solving?
4. Is there a significant difference in the frequency of independent mathematical problem-solving homework responses for fourth-grade students when homework assignments include the practice of metacognitive awareness compared to when homework assignments do not include this practice after controlling for individual differences in mathematical problem-solving?; and
5. Is there a significant difference in the quality of mathematical problem-solving strategies of fourth-grade students as measured by a mathematical applications scoring rubric when homework assignments include the practice of metacognitive awareness compared to when homework assignments do not include this practice after controlling for individual differences in mathematical problem-solving?

#### Hypotheses

The first hypothesis stated that there will be a significant positive effect on mathematical problem-solving skills for fourth-grade students as measured by mathematics problem-solving achievement when the practice of metacognitive awareness is included in mathematical problem-

solving homework assignments compared to when there is no practice of metacognitive awareness after controlling for individual differences in mathematical problem-solving.

The second hypothesis stated that there will be a significant positive effect on the frequency of completed mathematical problem-solving homework responses for fourth-grade students when the practice of metacognitive awareness is included in mathematical problem-solving homework assignments compared to when there is no practice of metacognitive awareness after controlling for individual differences in mathematical problem-solving.

The third hypothesis stated that there will be a significant positive effect on the frequency of accurate mathematical problem-solving homework responses for fourth-grade students when the practice of metacognitive awareness is included in mathematical problem-solving homework assignments compared to when there is no practice of metacognitive awareness after controlling for individual differences in mathematical problem-solving.

The fourth hypothesis stated that there will be a significant positive effect on the frequency of independent mathematical problem-solving homework responses for fourth-grade students when the practice of metacognitive awareness is included in mathematical problem-solving homework assignments compared to when there is no practice of metacognitive awareness after controlling for individual differences in mathematical problem-solving.

The fifth hypothesis stated that there will be a significant positive effect on the quality of mathematical problem-solving strategies and solutions of fourth-grade students as measured by a mathematical applications scoring rubric when the practice of metacognitive awareness is included in mathematical problem-solving homework assignments compared to when there is no practice of metacognitive awareness after controlling for individual differences in mathematical problem-solving.

## Assumptions Underlying a One-way ANCOVA

To perform the statistical procedure of an analysis of covariance (ANCOVA), four assumptions needed to be maintained (Green & Salkind, 2005). An explanation of how these four assumptions were addressed is discussed in this section. A description of the ANCOVA results is included in the review of the data related to each research question.

1. Assumption 1: The dependent variable is normally distributed in the population for any specific value of the covariate and for any one level of a factor (Green & Salkind, 2005). With regard to this assumption, outliers, which are cases with extreme or unusual values on a single variable or on a combination of variables, were identified (Meyers, Gamst, & Guarino, 2006). These outliers needed to be addressed before proceeding with the statistical analysis. Stem and leaf plots and box plots were calculated for the dependent variable, post-test total standard scores. The stems in the stem and leaf plot are the leading digits of each score, and the leaves are the trailing digits of each score (Green & Salkind, 2005). Tables 1 and 2 show the data for the stem and leaf plots, and Figure 1 shows the data for the box plot. The three outliers in the control group, homework assignments without the practice of metacognitive awareness, and the one outlier in the treatment group, homework with the practice of metacognitive awareness, were removed from the study.

Table 1

Stem and leaf plot: For the post-test total standard scores on the Applications content area for students who completed homework with metacognitive awareness assignments

Frequency		Stem and leaf
1	9	0
2	9	88
7	10	0011113
14	10	55556666669999
11	11	11112224444
4	11	5999
6	12	113444
5	12	66699
2	13	33
1	1.	7

*Note.* Stem width is 10.00. Each leaf is equal to one case.

Table 2

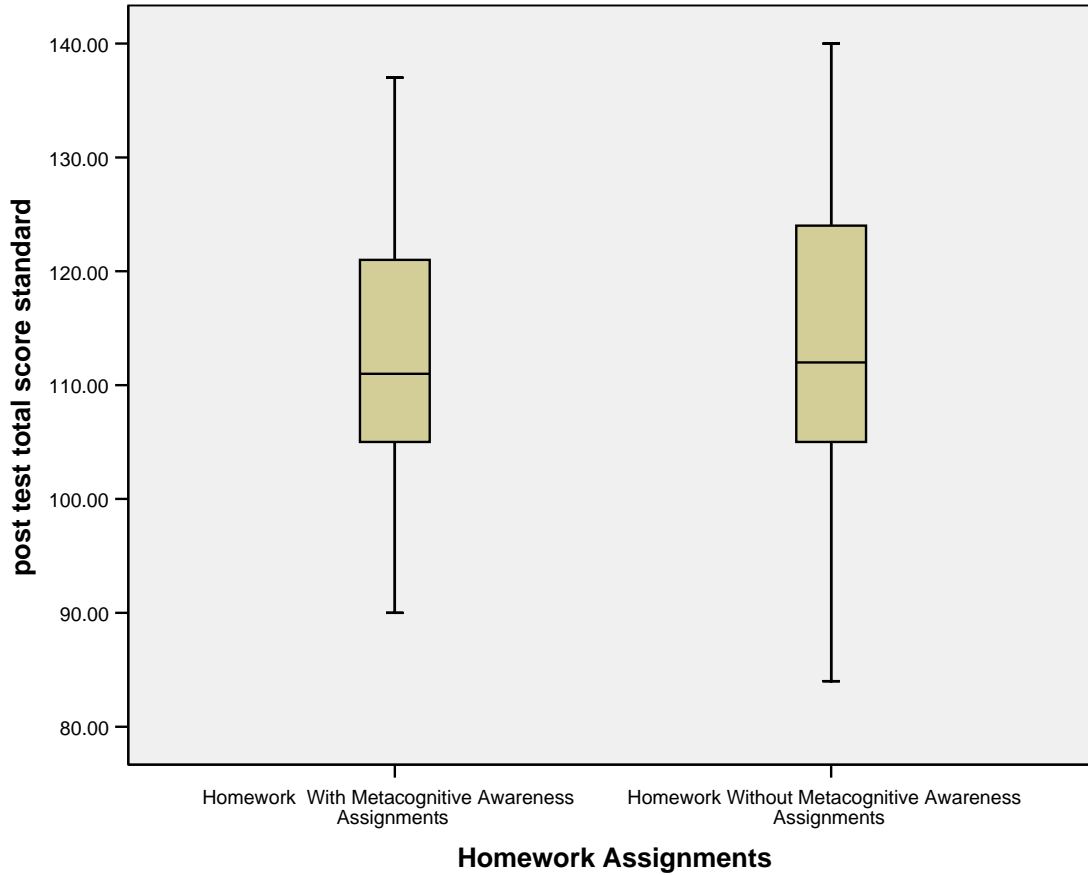
Stem and leaf plot: For the post-test total standard scores on the Applications content area for students who completed homework without metacognitive awareness assignments

Frequency		Stem and leaf
2	8	47
7	9	0115688
12	10	113355566999
15	11	111112222445559
11	12	11344466999
5	13	11555
1	14	0

*Note.* Stem width is 10.00. Each leaf is equal to one case.

Both Table 1 and 2 visually demonstrate normal distribution, which is a prerequisite for ANCOVA assumptions. Table 1 demonstrates slight bimodal distribution, however even assuming a conservative threshold of plus or minus 0.5 for skewness and kurtosis the data still does not depart from normalcy (Hair, Anderson, Tatham, & Black, 1998) for total standard scores. The standard scores range from 9.0 to 13.7 for the group with metacognitive awareness assignments, and from 8.7 to 14.0 for the group without metacognitive awareness assignments.

The Key Math 3-DA (Connelly, 2007) test manual provided a conversion chart for computing standard scores from raw scores. Standard scores represented an equal interval data measurement. Standard scores are based on student grade level and the semester (fall and spring), therefore assuming growth over a school year. Standard scores at each grade level have a mean of 100 with a standard deviation of 15.



*Figure 1.* Box and whisker plot of distribution of post-test total standard scores on the Applications content area for treatment students (with metacognitive awareness assignments) and control students (without metacognitive awareness assignments).

Table 3 presents the data on skewness and kurtosis for the five dependent variables in the study. As Table 3 indicates, the skewness score for independence and the kurtosis score for quality are the only two scores above 1 (-1.020 and 1.141, respectively). However, since there were only two scores in this range and one of the scores was only slightly above 1, (-1.020), it was determined that no additional outliers would be removed from the study. Therefore the sample size would remain the same.

Table 3

*Skewness and Kurtosis of the Dependent Variables of Post-test Total Standard Scores, Completion, Accuracy, Independence, and Quality*

Dependent Variable	Skewness	Kurtosis
Posttest total standard scores	.099	-.421
Completion	-.897	.624
Accuracy	-.504	-.761
Independence	-1.020	.484
Quality	-.985	1.141

2. Assumption 2: The variances of the dependent variable for the conditional distributions described in Assumption 1 are equal (Green & Salkind, 2005). Using a series of Levene's Tests of Equality of Error Variances (see Tables 4 and 5), the statistical hypothesis of equal variances across the two levels of the independent variable, homework assignments with the practice of metacognitive awareness and homework assignments without the practice of metacognitive awareness, was determined for each of the dependent variables, post-test total standard scores, completion, accuracy, independence, and quality. The pre-test total standard scores on the Applications content area of the KeyMath-3 DA were used as the covariate in this test. All values pass homogeneity of variance ( $p > .05$ )

Table 4

*Levene's Test of Equal Variances for the Dependent Variables of Posttest Total Standard Scores, Completion, Accuracy, and Independence*

Dependent variable	F	df1	df2	Sig.
Post-test total				
standard scores	3.832	1	104	.053
Completion	.948	1	104	.332
Accuracy	.181	1	104	.671
Independence	.686	1	104	.410

Table 5

## Levene's Test of Equality of Error Variances for Quality of Homework Responses

Date	F	df1	df2	Sig.
Nov 6	1.366	1	102	.245
Nov 13	2.344	1	102	.129
Nov 20	.440	1	102	.509
Nov 27	.246	1	102	.621
Dec 3	.007	1	102	.934
Dec 10	.357	1	102	.552
Dec 17	7.405	1	102	.008

3. Assumption 3 states that the cases represent a random sample from the population, and the scores on the dependent variable are independent of each other (Green & Salkind, 2005). The accessible population for this study was the eight heterogeneous fourth-grade classrooms in School A and School B. All parents of the students in this accessible population were sent letters of consent for participation in the study. Of the 77 students in the accessible population in School A, 45 students, 58%, participated in the study; and of the 94 students in the accessible population in School B, 67 students, 71%, participated in the study. Overall, 65% of the accessible population consented to participate in the study.
4. Assumption 4 states that the covariate is linearly related to the dependent variable within all levels of the factor, and the weights or slopes relating the covariate to the dependent variable are equal across all levels of the factor (Green & Salkind, 2005).

To maintain the integrity of Assumption 4, the homogeneity-of-slopes assumption was tested. This test evaluated the interaction between the covariate and the factor in the prediction of each of the dependent variables. The pre-test total standard scores on the Applications content area of the KeyMath-3 DA were used as the covariate. The results of the homogeneity-of-slopes assumption on the interaction between the dependent variables were not significant (see Table 6).

Table 6

*Test Results for Homogeneity of Slopes for Dependent Variables of Posttest Total Standard Scores, Completion, Accuracy, Independence, and Quality of Homework Responses*

Dependent Variable	F	Sig.
Posttest total standard score	.098	.755
Completion	.256	.614
Accuracy	1.269	.263
Independence	2.981	.087
Quality	.473	.493

*Relationships Among the Dependent Variables*

Table 7 indicates an intercorrelation matrix between the six variables used in this study. Correlations are described according to direction, magnitude, and significance as well as the relationship between the trait and method of the responses. For example, in Table 7, the correlation between the mean pre-test total standard scores and the mean post-test total standard scores was in the moderate positive range with significance at the  $p = .001$  level (.653). Since these scores were based on alternate forms of the Key Math instrument, both of these variables tested for the same trait, mathematical problem-solving, and with the same method, oral assessment. Also, the correlation between mean percentages of accuracy and mean percentages of quality for these responses was in the high positive range with significance at the  $p = .001$  level (.848). These similar variables of quality and accuracy were assessed with like methods using paper and pencil. The correlation between mean percentages of completion and mean percentages of quality was in the moderately positive range with significance at the  $p = .001$  level (.645), meaning that students who completed their homework, were likely to have accurate responses of high quality but completion alone did not guarantee that students had the correct answers. In addition, the variables of completion and quality were assessed with the like methods using paper and pencil. Lastly, the correlation between mean percentages of independence and mean post-test total standard scores was in the low positive range with significance at the  $p = .001$  level (.458). This correlation indicated that students who independently pursued their mathematical problem-solving homework tended to have higher standardized test scores.

Table 7

*Correlations Between the Dependent Variables of Posttest Total Standard Scores, Pretest Total Standard Scores, Completion, Accuracy, Quality, and Independence*

	2.	3.	4.	5.	6.
1. Mean posttest total standard score	.653***	.147	.152	.214*	.458***
2. Mean pretest total standard score		.172*	.190*	.237**	.384***
3. Mean percentages of completion			.380***	.645***	-.092
4. Mean percentages of accuracy				.848***	-.206*
5. Mean quality scores					-.206*
6. Mean independence values					

\*\*\*  $p < .001$ . \*\*  $p < .01$ .  $p < .05$ .

Note: The dichotomous Independence variable was scored using a “1” for independence in pursuing a problem-solving homework assignment and a “0” for getting help to pursue a problem-solving assignment.

#### Analysis and Findings of Research Question One

Is there a significant difference in the mathematical problem-solving skills of fourth-grade students as measured by mathematics achievement when homework assignments include the practice of metacognitive awareness as compared to when homework assignments do not include this practice after controlling for individual differences in mathematical problem-solving?

The design for this first research question was quasi-experimental with a pre- and post-test treatment and control group. The dependent variable was the mean total standard score on the Applications content area of the KeyMath-3 DA standardized test (Connolly, 2007). The

independent variable was homework assignments with two levels, students who practiced metacognitive awareness using the TAT-4 and students who did not practice metacognitive awareness using the TAT-4. Descriptive data for the dependent variable and the independent variable appear in Table 8.

Table 8

Descriptive Statistics for Post-test Total Standard Scores of the Applications content area of KeyMath-3 DA of Homework Assignment Distribution

	Unweighted	Standard	Weighted	Standard	
Homework	Mean	deviation	Mean	deviation	N
With	112.1111	11.0482	112.6226	10.4885	53
metacognitive awareness assignments					
Without	113.0714	15.3431	112.6415	13.5137	53
metacognitive awareness assignments					
Total	112.6000	13.3555	112.6321	12.0383	106

A one-way (ANCOVA) was computed using pre-test total standard scores on the Applications content area of the KeyMath-3 DA as a covariate. The ANCOVA (see Table 9) was used to analyze the between groups mean values of the dependent variable, math scores, for each level of the independent variable, homework assignments with two levels, those assignments with the practice of metacognitive awareness and those assignments without the practice of metacognitive awareness, at a significance level of less than or equal to 0.01 (SPSS, 1999).

The usual practice is to administer the post-test immediately after the research participants have completed the experimental treatment (Gall, Gall, and Borg, 2003). However, in order to allow for the three month testing window between pre and post-testing as recommended by the KeyMath-3 DA (Connelly, 2007), post-testing was completed one month after the data collection ended. Therefore, conclusions about treatment effectiveness could be impacted by the requisite delay in post-test administration.

Table 9

*ANCOVA of the Between-groups Mean Values of the Dependent Variable, Total Standard Scores on the Applications Content Area for Each Level of the Independent Variable, Homework Assignments with the Practice of Metacognitive Awareness and without the Practice of Metacognitive Awareness*

Source	Type III sum of squares	df	Mean square	F	Sig.	Partial Eta squared
Corrected model	6567.09 <sup>a</sup>	2	3283.548	39.101	.000	.432
Intercept	1241.335	1	1241.335	14.782	.000	.126
Pre-test total standard score (covariate)	6567.087	1	6567.087	78.202	.000	.432
Group <sup>b</sup>	171.611	1	171.611	2.044	.156	.019
Error	8649.555	103	83.976			
Total	1359931.000	106				
Corrected Total	15216.651	105				

<sup>a</sup>R Squared = .432; (Adjusted R Squared = .421). <sup>b</sup>Independent variable group levels are students with metacognitive awareness assignments and students without metacognitive awareness.

The findings from the between-subject effects indicated that there was no significant difference between groups ( $p = .156$ ). In other words, there was no significant difference in the post-test total standard scores of the Applications content area of the KeyMath-3 DA standardized test (Connolly, 2007) for those students whose homework assignments included the practice of metacognitive awareness and those students whose homework assignments did not include the practice of metacognitive awareness. Therefore, the null hypothesis for this research question was not rejected but accepted.

#### Analysis and Findings of Research Question Two

Is there a significant difference in the frequency of completed mathematical problem-solving homework responses for fourth-grade students when the practice of metacognitive awareness was included in mathematical problem-solving homework assignments compared to when homework assignments do not include this practice after controlling for individual differences?

The design for the second research question was post-test only with treatment and control group. The dependent variable was the mean for all seven completed mathematical problem-solving responses in homework assignments. The independent variable was homework assignments with two levels, students who practiced metacognitive awareness using the TAT-4 and students who did not practice metacognitive awareness using the TAT-4.

First, the frequency of completed responses for these data was determined, and the mean was calculated. Then, an ANCOVA was computed to determine the between-groups mean values of the dependent variable, completion of responses for each level of the independent variable, homework assignments, with a significance level of less than or equal to 0.01 (SPSS, 1999). The pre-test total standard scores on the Applications content area of the KeyMath-3 DA were used

as the covariate in this test. Table 10 and Figure 2 show the frequency and percentage results, respectively, of completed or not-completed assignments for the seven homework assignment dates. For each date, homework was completed by approximately 50% of the students in the study. On all other dates, the percentage of homework completion was between 75% to 99%. For all seven dates, the completion percentage exceeded the non-completion percentage. These data also indicated that only 3 out of a possible 742 assignments were not submitted.

Table 10

## Frequencies and Percentages of Completed and Not-completed Homework Assignments

Date	Individuals with completed assignments	Individuals with assignments not completed	Total number of individuals	Percentage of assignments completed	Percentage of assignments not completed	Total percent
November 6, 2007	105	1	106	99.1	0.9	100.0
November 13, 2007	55	51	106	51.9	48.1	100.0
November 20, 2007	101	4	105 <sup>a</sup>	96.2	3.8	100.0
November 27, 2007	99	7	106	93.4	6.6	100.0
December 3, 2007	80	26	106	75.5	24.5	100.0
December 10, 2007	84	22	106	79.2	20.8	100.0
December 17, 2007	90	14	104 <sup>a</sup>	86.5	13.5	100.0

<sup>a</sup>Data excluded because assignments were not submitted.

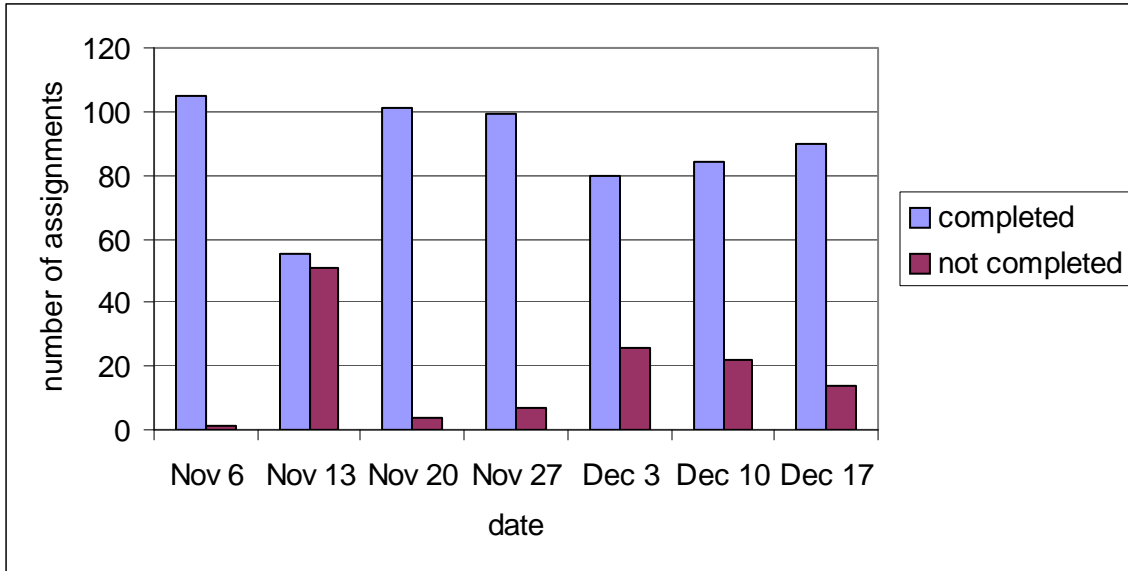


Figure 2. Distribution of completed and non-completed assignments by date.

Data results with regard to homework completion for the treatment and control groups were also determined. On the three dates of November 6, November 27, and December 17, 2007, the TAT-4 was given to the treatment group along with the group's homework assignment. On the other four dates, only a problem-solving assignment was given. When analyzing the results of homework completion in reference to the treatment group and the control group, these descriptive data indicated several points to consider. First, the assignment with the highest percentage of completion was the initial assignment in the study. This also was one of the three dates that the TAT-4 was given to the treatment group. In fact, on the three dates when the TAT-4 was included with the homework assignments, the control group had a higher mean for homework completion than the treatment group. Only on November 13 and December 10, 2007, did the treatment group have a higher mean score than did the control group.

Table 11

Descriptive Statistics for the Seven Data Collection Dates of Total Mean Scores for Completed Homework Assignments by Group

Date	Homework group	Number		Mean Score	S.D.
		completed	Total		
November 6, 2007	With metacognitive awareness assignments	52	53	.9811	.1360
	Without metacognitive awareness assignments	53	53	1.0000	.0000
	Total	103	106	.9904	.0981
November 13, 2007	With metacognitive awareness assignments	29	53	.5472	.4978
	Without metacognitive awareness assignments	26	53	.4906	.5047
	Total	54	106	.5192	.5021
November 20, 2007	With metacognitive awareness assignments	50	52	.9615	.1923
	Without metacognitive awareness assignments	51	53	.9623	.1924
	Total	100	105	.9615	.1932
November 27, 2007	With metacognitive awareness assignments	47	53	.8868	.3168
	Without metacognitive awareness assignments	52	53	.9811	.1374
	Total	97	106	.9327	.2518

Table 11 (continued).

Date	Homework group	Number		Mean Score	S.D.
		completed	Total		
December 3, 2007	With metacognitive awareness assignments	40	53	.7547	.4303
	Without metacognitive awareness assignments	40	53	.7547	.4344
	Total	78	106	.7500	.4351
December 10, 2007	With metacognitive awareness assignments	43	53	.8113	.3913
	Without metacognitive awareness assignments	41	53	.7736	.4225
	Total	82	106	.7885	.4104
December 17, 2007	With metacognitive awareness assignments	40	51	.7843	.4154
	Without metacognitive awareness assignments	50	53	.9434	.2333
	Total	90	104	.8654	.3430

Table 12

Descriptive Statistics for the Seven Data Collection Dates of Total Percentages for Completed Homework Assignments by Group

Homework group	Number			
	completed	Total	Percentage	S.D.
With metacognitive awareness assignments	301	368	81.8	17.2
Without metacognitive awareness assignments	272	371	73.3	14.4
Total	573	739	77.5	15.8

Table 13 displays the results of the ANCOVA at significance level of 0.01. The findings from the between-subject effects indicated that there was no significant difference between groups ( $p = .178$ ). In other words, there was no significant difference in the completion of homework assignments between those students whose homework assignments included practice of metacognitive awareness and those students whose homework assignments did not include the practice of metacognitive awareness. Therefore, the null hypothesis for this research question was accepted.

Table 13

*ANCOVA between Group Effects of Homework Completion for Students with or without*

*Metacognitive Awareness*

Source	Type III sum of squares	df	Mean square	F	Sig.	Partial Eta squared
Corrected model						
Intercept	1174.005 <sup>a</sup>	2	587.002	2.395	.096	.044
Pretest total standard score (covariate)	3060.989	1	3060.989	12.491	.001	.108
Group <sup>b</sup>	896.789	1	896.789	3.660	.059	.034
Error	451.118	1	451.118	1.841	.178	.018
Total	25240.168	103	245.050			
Corrected Total	752219.389	106				
	26414.173	105				

<sup>a</sup>R Squared = .044; (Adjusted R Squared = .026). <sup>b</sup>Independent variable group levels are students with metacognitive awareness assignments and students without metacognitive awareness assignments.

### Analysis and Findings of Research Question Three

Is there a significant difference in the frequency of accurate mathematical problem-solving homework responses for fourth-grade students when homework assignments include the practice of metacognitive awareness compared to when homework assignments do not include this practice after controlling for individual differences in mathematical problem-solving?

The design for the third research question was post-test only with treatment and control group. The dependent variable was accurate mathematical problem-solving responses in homework assignments. The independent variable was homework assignments with two levels, students who practiced metacognitive awareness using the TAT-4 and students who did not practice metacognitive awareness using the TAT-4.

First, the frequency of accurate responses for these data was determined and the mean was calculated. Then, an ANCOVA was computed to determine the between-groups mean values of the dependent variable, completion of responses for each level of the independent variable, and homework assignments with a significance level of less than or equal to 0.01 (SPSS, 1999). The pre-test total standard scores on the Applications content area of the KeyMath-3 DA were used as the covariate in this test.

The following table shows the frequency and percentage results of accurate or not-accurate assignments for the seven homework assignment dates. As these data indicated, in every homework assignment the percentage of accurate responses was lower than the percentage of completed responses. This is most evident in the November 6, 20, and 27, 2007, assignments, for which the completion rate was 90% or above, but the corresponding accuracy rate was 67.9%, 24.5 %, and 41.5 %, respectively. On November 6 and 27, 2007, the treatment group completed

the TAT-4 as well as the problem-solving assignment. Refer to Table 14 for the descriptive data for this research question.

Table 14

## Frequencies and Percentages of Accuracy of Homework Assignments

Date	Individuals with accurate assignments	Individuals with assignments not accurate	Total number of individuals	Percentage of accurate assignments	Percentage of assignments not accurate	Total percent
November 6, 2007	72	34	106	67.9	32.1	100.0
November 13, 2007	48	62	106	43.6	56.4	100.0
November 20, 2007	26	79	105 <sup>a</sup>	24.8	75.2	100.0
November 27, 2007	44	62	106	41.5	58.5	100.0
December 3, 2007	78	28	106	73.6	26.4	100.0
December 10, 2007	67	39	106	63.2	36.8	100.0
December 17, 2007	87	17	104 <sup>a</sup>	83.7	16.3	100.0

<sup>a</sup>Data excluded because assignments were not submitted.

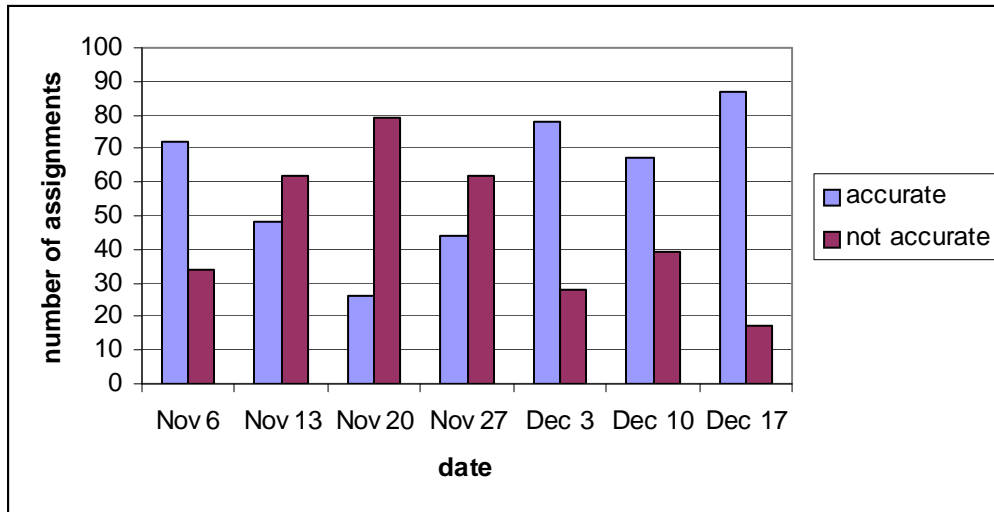


Figure 3. Distribution of accurate and non-accurate assignments by date.

As was previously stated, on November 6 and 27 and December 17, 2007, the TAT-4 was given to the treatment group along with their homework assignment. On the other four dates, only a problem-solving assignment was given. When analyzing the results of homework accuracy in reference to the treatment group, whose members completed homework with metacognitive awareness, and the control group, whose members completed homework without metacognitive awareness, these descriptive data indicated several points to consider. First, there were two dates, November 6 and December 17, 2007 when the means were higher for the treatment group than the control group. On November 6, 2007, the mean score for the treatment group, homework assignments with metacognitive awareness practice, was .7255 while the mean score for the control group, homework assignments without metacognitive awareness practice, was .6604. Also on December 17, 2007 the mean score for the treatment group was .8431 while the mean score for the control group was .8302. These dates also corresponded to the dates when the students in the treatment group completed the TAT-4 along with their problem-solving assignment. However, this relationship of mean scores was not demonstrated on November 27, 2007 when the TAT-4 was also included in the homework assignment. On this date the mean

score for the treatment group was .3333 while the mean score for the control group was .4906.

Overall, the total mean score for all the assignments showed a higher value for the control group (mean = 63.0719) than the treatment group (mean = 57.9831). These data are listed in Tables 15 and 16.

Table 15

## Descriptive Statistics for the Seven Data Collection Dates of Total Mean Scores for Accurate Homework Assignments by Group

Date	Homework group	Number		Mean score	S.D.
		completed	Total		
November 6, 2007	With metacognitive awareness assignments	37	51	.6981	.4507
	Without metacognitive awareness assignments	35	53	.6604	.4781
	Total	72	106	.6923	.4638
November 13, 2007	With metacognitive awareness assignments	35	53	.6604	.4736
	Without metacognitive awareness assignments	35	53	.6604	.4781
	Total	69	106	.6635	.4748
November 20, 2007	With metacognitive awareness assignments	12	52	.2308	.4213
	Without metacognitive awareness assignments	14	53	.2642	.4451
	Total	25	105	.2404	.4294
November 27, 2007	With metacognitive awareness assignments	18	51	.3396	.4736
	Without metacognitive awareness assignments	26	53	.4906	.5047
	Total	43	106	.4135	.4948

Table 15 (continued).

Date	Homework group	Number		Mean score	S.D.
		completed	Total		
December 3, 2007	With metacognitive awareness assignments	38	53	.7170	.4505
	Without metacognitive awareness assignments	40	53	.7547	.4344
	Total	77	106	.7404	.4406
December 10, 2007	With metacognitive awareness assignments	28	53	.5283	.4992
	Without metacognitive awareness assignments	39	53	.7358	.4451
	Total	67	106	.6442	.4811
December 17, 2007	With metacognitive awareness assignments	43	51	.8431	.3637
	Without metacognitive awareness assignments	44	53	.8302	.3791
	Total	87	104	.8365	.3716

Table 16

Descriptive statistics for the seven data collection dates of total percentages for accurate homework assignments by group

Homework group	Number			
	completed	Total	Percentage	S.D.
With metacognitive awareness assignments	211	368	57.3	23.3
Without metacognitive awareness assignments	233	371	62.8	22.7
Total	440	739	59.5	23.0

Table 17 displays the results of the ANCOVA. The findings from the between-subject effects indicated that there was no significant difference between groups ( $p = .086$ ). In other words, there was no significant difference in the accuracy of homework assignments between those students whose homework assignments included practice of metacognitive awareness and those students whose homework assignments did not include practice of metacognitive awareness. Therefore, the null hypothesis for this research question was accepted.

Table 17

*ANCOVA between-group effects of homework accuracy for students with or without metacognitive awareness*

Source	Type III					Partial Eta squared
	sum of squares	df	Mean square	F	Sig.	
Corrected model	3433.982 <sup>a</sup>	2	1716.991	3.333	.040	.061
Intercept	163.568	1	163.568	.318	.574	.003
Pretest total standard score (covariate)	2415.756	1	2415.756	4.690	.033	.044
Group <sup>b</sup>	1551.045	1	1551.045	3.011	.086	.028
Error	53055.465	103	515.102			
Total	437740.328	106				
Corrected total	56489.448	105				

<sup>a</sup>R Squared = .061; (Adjusted R Squared = .043). <sup>b</sup>Independent variable group levels are students with metacognitive awareness assignments and students without metacognitive awareness assignments.

#### Analysis and Findings of Research Question Four

Is there a significant difference in the frequency of independent mathematical problem-solving homework responses for fourth-grade students when homework assignments include the practice of metacognitive awareness as compared to when homework assignments do not include this practice after controlling for individual differences in mathematical problem-solving?

The design for the fourth research question was post-test only with treatment and control group. The dependent variable was independent mathematical problem-solving responses in homework assignments. The independent variable was homework assignments with two levels, students who practiced metacognitive awareness using the TAT-4 and students who did not practice metacognitive awareness using the TAT-4.

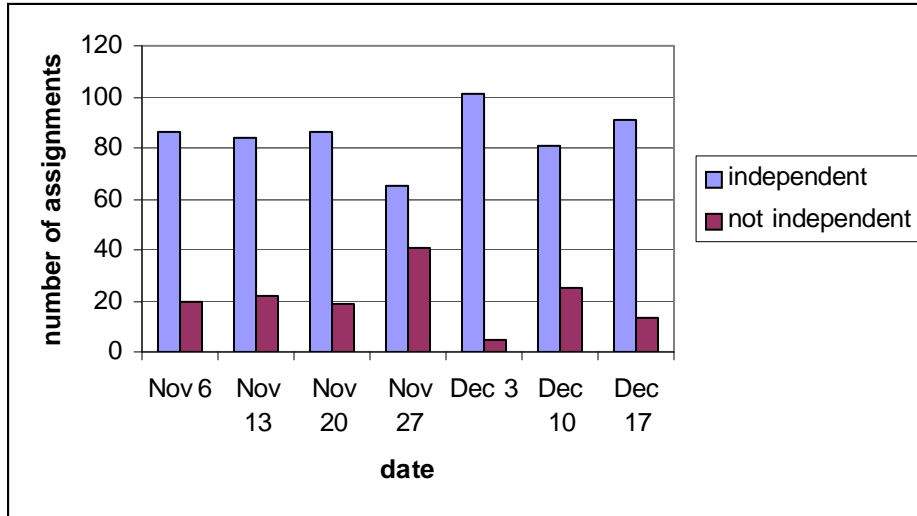
First, the frequency of independent responses for these data was determined, and the mean was calculated. Then, an ANCOVA was computed to determine the between-groups mean values of the dependent variable of completion of responses and for each level of the independent variable of homework assignments with a significance level of less than or equal to 0.01 (SPSS, 1999). The pre-test total standard Analysis and Findings of Research Question One scores on the Applications content area of the KeyMath-3 DA were used as the covariate in this test. Table 18 and Figure 4 show the frequency and percentage results of independent or not-independent assignments for the seven homework assignment dates.

Table 18

## Frequencies and Percentages of Independence of Homework Assignments

Date	Individuals			Percentage of independent assignments	Percentage of assignments not independent	Total percentage
	Individuals with independent assignments	with assignments not independent	Total number of individuals			
November 6, 2007	86	20	106	81.1	18.9	100.0
November 13, 2007	84	22	106	79.2	20.8	100.0
November 20, 2007	86	19	105 <sup>a</sup>	81.1	17.9	100.0
November 27, 2007	65	41	106	61.3	38.7	100.0
December 3, 2007	101	5	106	95.3	4.7	100.0
December 10, 2007	81	25	106	76.4	23.6	100.0
December 17, 2007	91	13	104 <sup>a</sup>	85.8	12.3	100.0

<sup>a</sup>Data excluded because assignments were not submitted.



*Figure 4.* Distribution of independent and not independent assignments by date.

As these data indicated, in every homework assignment the percentage of independent responses was higher than the percentage of non-independent responses. This is most evident on December 3, 2007, when the independence rate was greater than 95%. In fact, for every data collection date, the percentage of independence was greater than 60%.

On the first date, November 6, 2007, when the TAT-4 was attached to the homework assignments of the treatment group, the mean scores were the same for the treatment group as they were for the control group (see Table 19). On all remaining dates, including November 27 and December 17, 2007, when the TAT-4 was also attached to the homework assignments of the treatment group, the mean scores were higher for the treatment group than for the control group (see Table 19). Overall, more students independently completed their assignment.

Table 19

## Descriptive Statistics for the Seven Data Collection Dates of Total Mean Scores for Independent Homework Assignments by Group

Date	Homework group	Number		Mean score	S.D.
		completed	Total		
November 6, 2007	With metacognitive awareness assignments	43	53	.8113	.395
	Without metacognitive awareness assignments	43	53	.8113	.395
	Total	86	106	.8113	.395
November 13, 2007	With metacognitive awareness assignments	44	53	.8302	.3791
	Without metacognitive awareness assignments	40	53	.7543	.4344
	Total	84	106	.7923	.4068
November 20, 2007	With metacognitive awareness assignments	42	52	.8077	.3980
	Without metacognitive awareness assignments	44	53	.8302	.3791
	Total	86	105	.8190	.3886

Table 19 (continued).

Date	Homework group	Number		Mean	S.D.
		completed	Total	score	
November 27, 2007	With metacognitive				
	awareness assignments	36	53	.6792	.4712
	Without metacognitive				
	awareness assignments	29	53	.5472	.5025
	Total	65	106	.6132	.4869
December 3, 2007	With metacognitive				
	awareness assignments	51	53	.9623	.1924
	Without metacognitive				
	awareness assignments	50	53	.9434	.2333
	Total	101	106	.9529	.2129
December 10, 2007	With metacognitive				
	awareness assignments	45	53	.8491	.3614
	Without metacognitive				
	awareness assignments	36	53	.6792	.4712
	Total	81	106	.7641	.4163
December 17, 2007	With metacognitive				
	awareness assignments	48	51	.9412	.2376
	Without metacognitive				
	awareness assignments	43	53	.8113	.3950
	Total	91	104	.8763	.3163

Table 20

Descriptive Statistics for the Seven Data Collection Dates of Total Percentages for Independent Homework Assignments by Group

Homework group	Number			
	completed	Total	Percentage	S.D.
With metacognitive awareness assignments	309	368	83.9	17.5
Without metacognitive awareness assignments	285	371	76.8	22.8
Total	594	739	80.3	20.2

Table 21 displays the results of the ANCOVA. The findings from the between subject effects indicated that there was no significant difference between groups ( $p = .250$ ). In other words, there was no significant difference in the independence of homework assignments between those students whose homework assignments included the practice of metacognitive awareness and those students whose homework assignments did not include the practice of metacognitive awareness. Therefore, the null hypothesis for this research question was accepted.

Table 21

*ANCOVA Between-group Effects of Homework Independence for Students with or without Metacognitive Awareness*

Source	Type III					Partial Eta squared
	sum of squares	df	Mean square	F	Sig.	
Corrected model	.723	2	.361	10.042	.000	.163
Intercept	.003	1	.003	.090	.764	.001
Pretest total standard score (covariate)	.590	1	.590	16.394	.000	.137
Group <sup>b</sup>	.048	1	.048	1.340	.250	.013
Error	3.707	103	.036			
Total	72.880	106				
Corrected Total	4.429	105				

<sup>a</sup>R Squared = .061; (Adjusted R Squared = .043). <sup>b</sup>Independent variable group levels are students with metacognitive awareness assignments and students without metacognitive awareness assignments.

### Analysis and Findings of Research Question Five

Is there a significant difference in the quality of mathematical problem-solving strategies of fourth-grade students as measured by a mathematical applications scoring rubric when homework assignments include the practice of metacognitive awareness compared to when homework assignments do not include this practice after controlling for individual differences in mathematical problem-solving?

The design for the fifth research question was a post-test only with treatment and control group. The dependent variable was quality of mathematical problem-solving responses in homework assignments. The independent variable was homework assignments with two levels, students who practiced metacognitive awareness using the TAT-4 and students who did not practice metacognitive awareness using the TAT-4. The researcher computed a repeated-measures ANCOVA to determine the variation among individuals and variation among treatment occasions as well as residual variation (SPSS, 1999). The pre-test total standard scores on the Applications content area of the KeyMath-3 DA were used as the covariant in this test.

Table 22

Descriptive Statistics of Quality of Mathematical Problem-solving Responses Based on Rubric Scores of Homework Assignments with Metacognitive Awareness and Homework Assignments without Metacognitive Awareness

Date	Homework group	Rubric score <sup>a</sup>				Mean	S.D.	N
		0	1	2	3			
Nov. 6, 2007	With metacognitive awareness assignments	6	12	29	6	1.66	.83	53
	Without metacognitive awareness assignments	4	15	24	10	1.75	.85	53
	Total	10	27	53	16			
Nov. 13, 2007	With metacognitive awareness assignments	7	7	20	19	1.96	1.01	53
	Without metacognitive awareness assignments	5	15	14	19	0.86	1.01	53
	Total	12	22	34	38			

<sup>a</sup>Scores are based on the Connecticut Mastery Test Application Strand 25 Rubric on a scale of 0-3. <sup>b</sup>There were 106 students in the sample. On November 20, only 105 of the 106 were graded due to assignments not being not submitted.

Table 22 (continued).

Date	Homework group	Rubric score <sup>a</sup>				Mean	S.D.	N
		0	1	2	3			
Nov. 20, 2007	With metacognitive							
	awareness assignments	3	13	27	9	1.81	0.79	53
	Without metacognitive							
	awareness assignments	2	15	27	9	1.81	0.76	53
	Total <sup>b</sup>	5	28	54	18			
Nov. 27, 2007	With metacognitive	2	18	15	18	1.92	0.91	53
	awareness assignments							
	Without metacognitive	1	8	18	26	2.30	0.80	53
	awareness assignments							
	Total	3	26	33	44			

<sup>a</sup>Scores are based on the Connecticut Mastery Test Application Strand 25 Rubric on a scale of 0-3. <sup>b</sup>There were 106 students in the sample. On November 20, only 105 of the 106 were graded due to assignments not being not submitted.

Table 22 (continued).

Date	Homework group	Rubric score <sup>a</sup>				Mean	S.D.	N
		0	1	2	3			
Dec. 3, 2007	With metacognitive awareness assignments	0	3	21	29	2.49	0.61	53
	Without metacognitive awareness assignments	2	4	15	32	2.45	0.80	53
	Total	2	7	36	61			
Dec. 10, 2007	With metacognitive awareness assignments	3	13	13	24	2.09	0.97	53
	Without metacognitive awareness assignments	2	7	12	32	2.40	0.86	53
	Total	5	20	25	56			

Table 22 (continued).

Date	Homework group	Rubric score <sup>a</sup>				Mean	S.D.	N
		0	1	2	3			
Dec 17, 2007	With metacognitive awareness assignments	2	12	7	30	2.27	0.96	53
	Without metacognitive awareness assignments	0	4	13	36	2.60	0.63	53
	Total <sup>a</sup>	2	16	20	66			

<sup>a</sup>Scores are based on the Connecticut Mastery Test Application Strand 25 Rubric on a scale of 0-3. <sup>b</sup>There were 106 students in the sample. On November 20, only 105 of the 106 were graded due to assignments not being submitted.

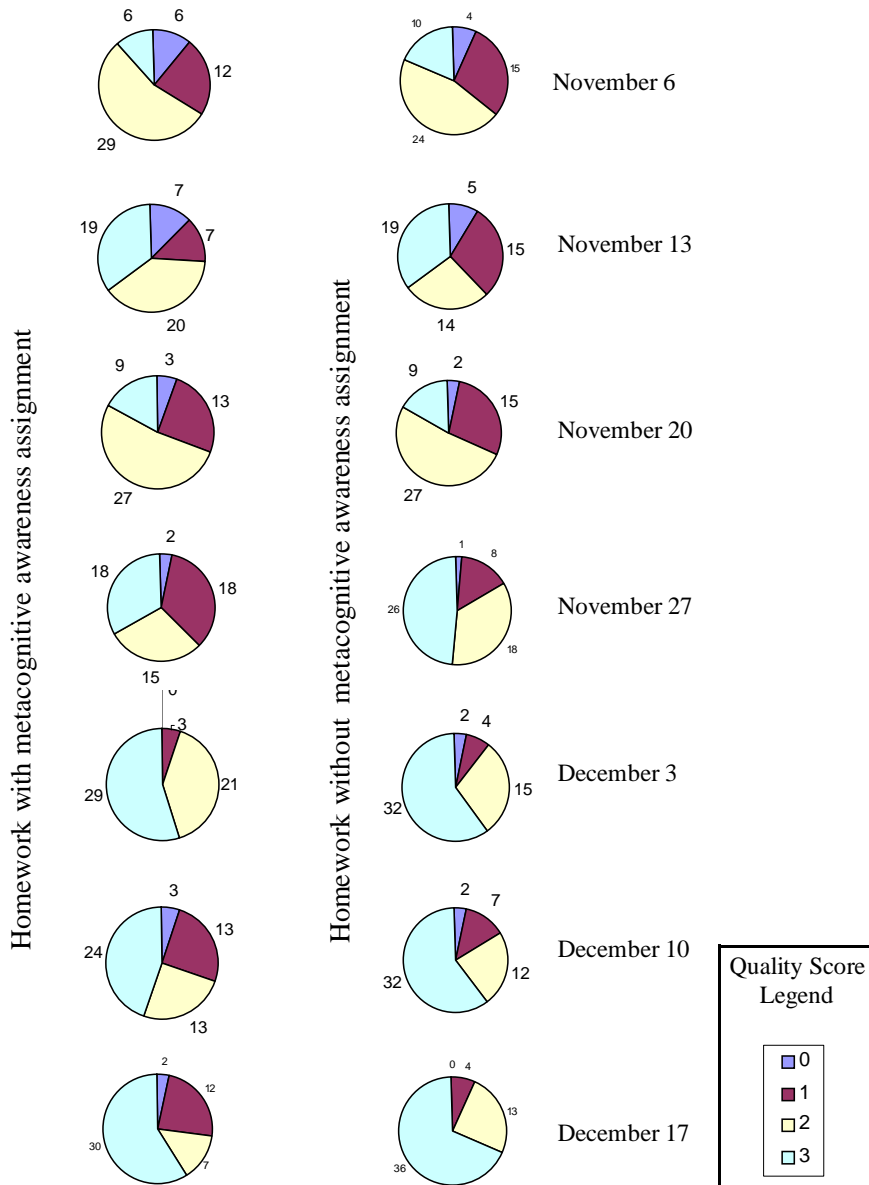


Figure 5. Distribution of quality scores based on group and date.

Box's M Test was conducted to test that the observed covariance matrices of the dependent variables were equal across groups. The design allowed for repeated measures by date for the within-subjects factor. The data, reported in Table 23, indicated that there was homogeneity within subjects because  $p = .190$  which is greater than the  $\alpha$  of 0.01.

Table 23

*Box's Test of Equality of Covariance Matrices*

Factor	Value
Box's M	34.953
F	1.152
df1	28
df2	27088.573
Sig.	.264

A repeated-measures ANCOVA was conducted to determine whether or not there was a difference between group with metacognitive awareness assignments and the group without metacognitive awareness assignments. These data were reported in Table 24. Although there were significant differences ( $p < .01$ ) across dates, there was no significant difference in quality of homework assignments between those students whose homework assignments included the practice of metacognitive awareness and those students whose homework assignments did not include the practice of metacognitive awareness. Therefore, the null hypothesis for this research question was accepted.

Table 24

*Repeated Measures ANCOVA of Quality of Homework between Assignments with or without Metacognitive Awareness*

		Type III		Mean		
Source		sum of squares	df	square	F	Sig.
Dates	Sphericity					
	assumed	1.690	6.000	.282	.490	.816
	Greenhouse-					
	Geisser	1.690	5.489	.308	.490	.800
	Huynh-Feldt	1.690	5.956	.284	.490	.814
	Lower-bound	1.690	1.000	1.690	.490	.485
Dates *	Sphericity					
Group	assumed	1.265	6.000	.211	.367	.900
	Greenhouse-					
	Geisser	1.265	5.489	.230	.367	.886
	Huynh-Feldt	1.265	5.956	.212	.367	.899
	Lower-bound	1.265	1.000	1.265	.367	.546
	Error	Sphericity				
(Dates)	assumed	3.250	6.000	.542	.943	.463
	Greenhouse-					
	Geisser	3.250	5.489	.592	.943	.458
	Huynh-Feldt	3.250	5.956	.546	.943	.463
	Lower-bound	3.250	1.000	3.250	.943	.334

## CHAPTER FIVE: SUMMARY AND CONCLUSIONS

The purpose of this study was to examine the development of mathematical problem-solving skills when the practice of metacognitive awareness was included in fourth-grade mathematical problem-solving homework assignments. The theoretical and research literature reviewed in chapter two discussed the effect of metacognition on the development of problem-solving skills as well as the impact of grade level on the relationship between homework and achievement. Therefore, the researcher hypothesized that fourth-grade mathematical problem-solving homework assignments designed to include metacognitive awareness practice would have a more significant positive effect on the development of mathematical problem-solving skills as compared to those fourth-grade homework assignments that did not include metacognitive awareness practice.

In addition, it was hypothesized that the fourth-grade mathematical problem-solving homework assignments designed to include metacognitive awareness practice would have a more significant positive effect on the dependent variables of completion, accuracy, independence, and quality of mathematical homework assignments as compared to those fourth-grade assignments that did not include metacognitive awareness practice. This chapter restates the research questions and hypotheses, a review of the results, the conclusions drawn, and implications for educators. The chapter concludes with limitations of the study and recommendations for future research.

### Review of the Findings

#### *Research Question One*

The first research question asked: Is there a significant difference in mathematical problem-solving skills of fourth-grade students as measured by mathematics achievement when

homework assignments include the practice of metacognitive awareness compared to when homework assignments do not include this practice after controlling for individual differences in mathematical problem-solving? With regard to this research question, the researcher hypothesized that there would be a significant positive effect on mathematical problem-solving skills for fourth-grade students as measured by mathematics problem-solving achievement when the practice of metacognitive awareness was included in mathematical problem-solving homework assignments as compared to when there was no practice of metacognitive awareness. The results based on this first research question and hypothesis indicated that there was no significant difference in the mathematical problem-solving skills of fourth-grade students, as measured by post-test total standard scores, when the homework assignments included metacognitive awareness practice and when the homework assignments did not include metacognitive awareness practice. Therefore, the null hypothesis for this research question was accepted.

The value of homework, especially at the elementary level, is a controversial issue. As the research has shown, there is no conclusive evidence that homework at this grade level impacts achievement (Cooper, Robinson & Patall, 2006), but there were suggestions in the literature that the upper-elementary level should be investigated in order to find out the age level when metacognitive activities should be placed in the homework curriculum. The results of this current study supported the inconclusiveness of the effects of homework on mathematical problem-solving achievement at the elementary level, specifically fourth-grade, even when metacognitive awareness practice was included in homework assignments.

Flavell (1979) discussed the fact that metacognition may be activated consciously for an effective strategy or unintentionally and automatically by retrieval cues in the task situation, and

it can lead an individual to select, evaluate, revise, and abandon cognitive tasks, goals, and strategies in light of their relationships with one another and with abilities and interests with respect to that enterprise. As the literature noted, metacognition, or thinking about thinking, enables students to be cognizant about themselves, the task, and the strategies available to them as they approach a learning activity. It is important for students to understand the need to monitor and adjust this metacognitive process with each new activity they encounter. However, from the results of this study at the fourth-grade level, there is still a question about how metacognitive awareness can be monitored and how it can be productive to students in a homework environment. Hall and Esposito (1984) noted that there was real potential for teachers adopting metacognitive knowledge in direct instructional programs and that teachers could help students learn about their own capabilities. In light of this current research, an implication of this study is that educators need to determine how this potential can be developed outside the classroom setting. If metacognitive awareness practice is to be a valuable component in the improvement of student achievement, educators need to research methods of practicing metacognitive awareness that students can effectively apply not only in school but also at home over an extended period of time.

#### *Research Question Two*

The second research question asked: Is there a significant difference in the frequency of completed mathematical problem-solving homework responses for fourth-grade students when homework assignments include the practice of metacognitive awareness compared to when homework assignments do not include this practice after controlling for individual differences in mathematical problem-solving? The researcher hypothesized that there would be a significant positive effect on homework completion for fourth-grade students when the practice of

metacognitive awareness was included in mathematical problem-solving homework assignments compared to when there was no practice of metacognitive awareness. The results based on this second research question and hypothesis indicated that there was no significant positive difference on the mathematical problem-solving skills of fourth-grade students, as measured by completion of responses when the homework assignments included metacognitive awareness practice and when the homework assignments did not include metacognitive awareness practice. Therefore, the null hypothesis for this research question was accepted.

As the research has shown, good learners tend to persist at a job or task until it is done to their satisfaction, and they attribute their success to their own efforts. They are aware that they can do a great deal to control their own learning, and they constantly work to select appropriate strategies and to monitor strategy use throughout the learning process (Jones, Palincsar, Ogle, & Carr, 1987). Efficacious people do not give up easily. From the results of this current study, it can be concluded that the student participants demonstrated the importance of completing their assignments. This is evident in the fact that for 6 of the 7 homework assignments, the completion percentage was more than 50% for both the control and treatment groups. Also, for 3 of the 7 assignments, the completion percentage was 90% or greater. An implication for teachers is the fact that when teachers assign homework, students complete that homework for the most part. However, this research also pointed to the fact that some students do not complete their homework. Therefore, as educators guiding instruction, teachers need to ensure that the time students spend on homework assignments will not only result in the completion of those assignments, but also in responses resulting in learning that is beneficial.

### *Research Question Three*

The third research question asked: Is there a significant difference in the frequency of accurate mathematical problem-solving homework responses for fourth-grade students when homework assignments include the practice of metacognitive awareness as compared to when homework assignments do not include this practice after controlling for individual differences in mathematical problem-solving? The researcher hypothesized that there would be a significant positive effect on homework accuracy for fourth-grade students when the practice of metacognitive awareness was included in mathematical problem-solving homework assignments compared to when there was no practice of metacognitive awareness. The results based on this third research question and hypothesis indicated that there was no significant positive difference on the mathematical problem-solving skills of fourth-grade students, as measured by accuracy of responses when the homework assignments included metacognitive awareness practice and when the homework assignments did not include metacognitive awareness practice. Therefore, the null hypothesis for this research question was accepted.

An important component to successful problem-solving is accuracy. Students who do not monitor and evaluate their knowledge and problem-solving procedures will have trouble correctly solving problems (Nickerson, Perkins, & Smith, 1985). However, the results of this study indicated that in a homework situation, students who were given the opportunity to practice metacognitive awareness did not demonstrate a higher percentage of accurate responses than those students who did not have the opportunity to practice metacognitive awareness.

Costa and Kallick recognized the importance of striving for accuracy as a “habit of mind” (Costa & Kallick, 2000). Furthermore, Hohn and Frey (2002) reported that accuracy in problem solving was positively correlated with metacognitive processing. However, these data implied

that homework accuracy was a component of homework that educators need to address. This is especially apparent when comparing the data of homework completion to homework accuracy. Overall, students completed their homework, but it was not always accurate among all students. Since metacognitive skills were found to be trainable (Desoete & Roeyers, 2003), and high metacognitive control was associated with a higher degree of accuracy (McVey, 1993) for homework to be valuable, educators need to work towards having students more successfully use homework as an avenue to practice the application of metacognitive awareness skills resulting in responses that are not only complete but also accurate.

#### *Research Question Four*

The fourth research question asked: Is there a significant difference in the frequency of independent mathematical problem-solving homework responses for fourth-grade students when homework assignments include the practice of metacognitive awareness compared to when homework assignments do not include this practice after controlling for individual differences in mathematical problem-solving?

The researcher hypothesized that there would be a significant positive effect on homework independence for fourth-grade students when the practice of metacognitive awareness was included in mathematical problem-solving homework assignments compared to when there was no practice of metacognitive awareness. The results based on this fourth research question and hypothesis indicated that there was no significant difference in the mathematical problem-solving skills of grade four students, as measured by independence of responses when the homework assignments included metacognitive awareness practice and when the homework assignments did not include metacognitive awareness practice. Therefore, the null hypothesis for this research question was accepted.

Gall, Gall, Jacobsen, and Bullock (1990) referred to homework as a modified form of independent learning. They noted that students needed to be equipped with the tools that are necessary for successful learning in and out of the classroom (Gall, Gall, Jacobsen, & Bullock, 1990). Furthermore, Cooper and Valentine (2001) cited benefits of students' homework as enhancing students' development as independent learners with better study skills, more positive academic attitudes, and greater responsibility toward learning.

Homework can also play a role in developing independent learners. In this current study, the data indicated that there were more students who were independent in responding to their homework assignments than who were non-independent. In fact when comparing the treatment group to the control group for every data collection date except November 20, 2007, the treatment group had a higher percentage of independent responses than non-independent responses.

When analyzing the correlation between independence, accuracy, and completion rates and mathematical problem-solving scores in responding to homework, an important conclusion can be noted. Students who received more help with their homework (non-independent) had higher accuracy and completion rates related to their homework than those students who worked independently. In other words, help with homework improves performance on an assignment for the short term in terms of accuracy and completion of responses. This help, however, does not necessarily carry over for the long-term and improve students' standard scores in mathematical problem-solving. Fortunately, students who were independent in responding to their homework assignments did have higher total standard scores in mathematical problem-solving. Therefore, these data imply that educators need to explore how to design homework effectively so that it will transfer over time and positively influence achievement. In addition, investigators need to

examine the types of homework assistance that can lead to students to become independent learners.

#### *Research Question Five*

The fifth research question asked: Is there a significant difference in the quality of mathematical problem-solving strategies of fourth-grade students as measured by a mathematical applications scoring rubric when homework assignments included the practice of metacognitive awareness compared to when homework assignments did not include this practice after controlling for individual differences in mathematical problem-solving?

The design for the fifth research question was a pre-and post-test control group. The researcher hypothesized that there would be a significant positive effect on the quality of homework responses when the practice of metacognitive awareness was included in mathematical problem-solving homework assignments compared to when there was no practice of metacognitive awareness. The results based on this fifth research question and hypothesis indicated that there was no significant difference in the mathematical problem-solving skills of grade four students as measured by quality of responses when the homework assignments included metacognitive awareness practice or when the homework assignments did not include metacognitive awareness practice. Therefore, the null hypothesis for this research question was accepted.

It is important for students to produce quality work whether they are in school or outside of school. Research has shown that students who are successful problem solvers are also metacognitively aware. In the process of solving a problem, they should monitor and track their progress toward a solution. When the decisions seem not to work, they should try alternatives or make some adjustment (Schoenfeld, 1987). In fact, Lester, Garofalo, and Kroll (1989) concluded

that for students' problem-solving performance to improve, they must attempt to solve a variety of types of problems on a regular basis and over a prolonged period. Also, students who have a limited repertoire of learning strategies may continue to use an ineffective strategy simply because they do not know an alternative strategy (Gall, Gall, Jacobsen & Bullock, 1990).

The results of this current study demonstrated that, overall, the majority of students' responses were either a score of three (full and complete) or a score of two (reasonable). In other words, the majority of the students in the study were able to solve problems understanding what was reasonable or full and complete. Their responses indicated a sound mathematical approach. They were able to effectively identify and apply strategies that were of quality. The data demonstrated that 299 students in the study received a rubric score of three, and 255 students received a rubric score of two. Whereas, 146 received a rubric score of one (partial), and 39 received a rubric score of zero (merely an acquaintance). In general, many students in the study were capable problem solvers on these assignments.

However, when analyzing the correlation between independence, quality, and total standard scores in mathematical problem-solving, a similar conclusion in regard to the correlation between independence, accuracy, and total standard scores in mathematical problem-solving was realized. That similar conclusion was students who received help with their homework (non-independent) improved the quality of their responses; however, students who did not have help with their homework (independent) had higher total standard scores in mathematical problem-solving. In other words, as was true with the dependent variable of accuracy, help with homework improved the quality of performance on a homework assignment for the short term—in this case quality of responses—but this help does not always carry over for the long term to improve students' standard scores in mathematical problem-solving.

As noted by Costa (2008), learning to think begins with recognizing how one is thinking. Students need to be able to consciously use metacognitive awareness in all learning situations. Educators need to explore ways that metacognitive awareness and homework can be integrated to provide an enduring effect on student achievement.

#### Limitations

One external threat to this study was its population validity. This study may be limited by its generalizability to fourth-grade classrooms in different school communities with different demographics. However, since the homework assignments included in the study were taken from Connecticut Mastery Test Mathematical Applications sample items, these items should be generalizable to all fourth-grade students in Connecticut. In addition, when several teachers are involved in a study, the possibility exists that personal variables, such as instructional techniques, may interact with resulting data. To address this threat, the researcher planned the data collection window before Connecticut Mastery Test mathematical application problem-solving practice was a focus in these fourth-grade classrooms.

Also, students responded to the independent variable, homework assignments with two levels, outside the classroom environment. Ecological validity concerns the extent to which the results of an experiment can be generalized from the set of environmental conditions created by the researcher to different environmental conditions (Gall, Gall, & Borg, 2003). As a result, there exists the possibility of the threats of explicit description as well as the Hawthorne Effect and pre- and posttest sensitivity.

Since this was a study of homework assignments completed outside the school environment, the researcher was cognizant of the fact that the internal threats of experimental treatment diffusion and compensatory rivalry by the control group were possible. In order to

address these threats, the researcher made available to the control group members the opportunity to participate in the treatment at a future date.

Also, this study was limited to metacognitive awareness and mathematics homework. Other subject areas were not investigated. Methods of data collection also threaten validity. Since the TAT-4 is a modification of the MAI, the reliability and validity of this instrument may be slightly less rigorous than the original; therefore, only descriptive statistics were reported in this study.

### Suggestions for Future Research

In general, there is a need for more research exploring the relationship between achievement and homework design. The following are recommendations based upon the consideration of the data from this study:

1. Replication of this study at multiple grade levels is recommended to determine a more significant homework design for the elementary level student that incorporates metacognitive awareness. It is recommended that a mixed design (quantitative with qualitative follow-up) would improve the understanding of the metacognitive processes and their relationship to homework responses.
2. Research to field test and standardize the TAT-4 would determine its significance as an instrument to measure metacognitive awareness.
3. Research to investigate the process of developing independent learners at home through a gradual release of responsibility from teacher to student.

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## Appendix A

### Connecticut Mastery Test Scoring Rubric for Scoring 3-point Extended-Tasks

## Rubric for Scoring 3-Point Extended-Task Mathematics Items (Strand 25 Only)

### Score Point 3

In an appropriate response, the student has demonstrated a **full and complete** understanding of all concepts and processes embodied in this application. The student has addressed the task in a mathematically sound manner. The response contains evidence of the student's competence in problem solving and reasoning, computing and estimating, and communicating to the full extent that these processes apply to the specified task. The response may, however, contain minor arithmetic errors that do not detract from a demonstration of full understanding.

### Score Point 2

The student has demonstrated a **reasonable** understanding of the essential mathematical concepts and processes embodied in this application. The student's response contains most of the attributes of an appropriate response, including a mathematically sound approach and evidence of competence with applicable mathematical processes, but contains flaws that do not diminish countervailing evidence that the student comprehends the essential mathematical ideas addressed by this task. Such flaws include errors ascribable to faulty reading, writing or drawing skills; errors ascribable to insufficient, nonmathematical knowledge; and errors ascribable to negligent or inattentive execution of mathematical ideas or algorithms.

### Score Point 1

The student has demonstrated a **partial** understanding of some of the concepts and processes embodied in this application. The student's response contains some of the attributes of an appropriate response but lacks convincing evidence that the student fully comprehends the essential mathematical ideas addressed by this task. Such deficits include evidence of insufficient mathematical knowledge; errors in fundamental mathematical procedures; and other omissions or anomalies that bring into question the extent of the student's ability to solve problems of this general type.

### Score Point 0

The student has demonstrated **merely an acquaintance** with the topic. The student's response is associated with the task in the item, but contains few attributes of an appropriate response. There are significant omissions or anomalies that indicate a basic lack of comprehension in regard to the mathematical ideas and procedures necessary to adequately address the specified task. No evidence is present to suggest that the student has the ability to solve problems of this general type.

Appendix B

Thinking about Thinking Inventory for Fourth-Grade TAT-4

Code #

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**“Thinking About Thinking” Inventory 4**

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**Circle Always, Usually, Sometimes, Never to the following statements about your math problem solving homework.**

**1. I am good at organizing information to solve a math problem.**

Always                      Usually                      Sometimes                      Never

**2. I try to use math strategies that have worked for me in the past.**

Always                      Usually                      Sometimes                      Never

**3. I learn best when I know something about the topic of the math problem I am solving.**

Always                      Usually                      Sometimes                      Never

**4. I think about what I need to learn before I begin solving a math problem.**

Always                      Usually                      Sometimes                      Never

**5. I slow down if I come upon new information when solving a math problem.**

Always                      Usually                      Sometimes                      Never

**6. I think about different strategies to solve a math problem before I begin.**

Always                      Usually                      Sometimes                      Never

**7. I ask others for help if I get stuck in the middle of a math problem.**

Always                      Usually                      Sometimes                      Never

**8. I know how well I did when I finish a math problem.**

Always                      Usually                      Sometimes                      Never

**9. I have control over how well I learn math.**

Always                      Usually                      Sometimes                      Never

**10. I choose a strategy to match the math problem.**

Always                      Usually                      Sometimes                      Never

**11. I use different strategies depending upon the type of math problem I am solving.**

Always                      Usually                      Sometimes                      Never

**12. I ask myself questions about the math problem before I begin.**

Always                      Usually                      Sometimes                      Never

**13. I create my own examples to help me understand how to solve a math problem.**

Always                      Usually                      Sometimes                      Never

**14. I stop regularly to make sure I understand how I am solving a math problem.**

Always                      Usually                      Sometimes                      Never

**15. I stop and reread a math problem when I am confused.**

Always                      Usually                      Sometimes                      Never

**16. I review what I learned when I finish solving a math problem.**

Always                      Usually                      Sometimes                      Never

**17. I am a good judge of how well I understand math.**

Always                      Usually                      Sometimes                      Never

**18. I know when each strategy I use is helpful.**

Always                      Usually                      Sometimes                      Never

**19. I think of several ways to solve a math problem and then choose the best one.**

Always                      Usually                      Sometimes                      Never

**20. I draw pictures or diagrams to help me solve a math problem.**

Always                      Usually                      Sometimes                      Never

**21. I ask myself questions about how well I am doing when I am solving a math problem.**

Always                      Usually                      Sometimes                      Never

**22. I ask myself if there are any other solutions when I finish solving a math problem.**

Always                      Usually                      Sometimes                      Never

**23. I understand better when I am interested about the topic of a math problem.**

Always                      Usually                      Sometimes                      Never

**24. I read directions carefully before I solve a math problem.**

Always                      Usually                      Sometimes                      Never

**25. I ask myself if the math problem is connected to something I already know.**

Always                      Usually                      Sometimes                      Never

**26. I try to break down the math problem into smaller steps.**

Always                      Usually                      Sometimes                      Never



**Thank You**

Appendix C

Institutional Review Board

Human Subjects Research Review Form

Defense Proposal Acceptance Form

Protocol # \_\_\_\_\_ +HUM-1

WESTERN CONNECTICUT STATE UNIVERSITY  
Human Subjects Research Review Form

Principal Investigator Susan C. Shaw

Department Doctoral Student – Instructional Leadership

Address signed form should be sent to 67 Bruce Street Watertown, CT 06795

E-mail sueshaw46@hotmail.com Phone number: (203) 217-0359

New research project  Continuation  Modification  Teaching

Exempt Review (attach a completed copy of the “Application for Exemption”)

Expedited/Full Review

To complete this form, please follow the instructions in sections A and B.

**CHECKLIST FOR ATTACHMENTS:**

Completed Application for Exemption (if claiming exemption)

Answers to A1 through A6

Survey or questionnaire

Informed consent form

Student’s current NIH training certificate

on file Instructor’s current NIH training certificate

on file Chair’s current NIH training certificate

The **department chair** and the **principal investigator (PI)** must sign this form. If the PI is a student, his/her faculty supervisor must also sign.

**Assurance of continued compliance with regulations regarding the use of human subjects.** I certify that the information provided for this project is accurate. If procedures for obtaining consent of subjects change, or if the risk of physical, psychological, or social injury increases, or if there should arise unanticipated problems involving risk to subjects or others, I shall promptly report such changes to the Institutional Review Board. I shall report promptly unanticipated injury of a subject to my department chair and to the Institutional Review Board.

Principal Investigator’s Signature Date \_\_\_\_\_

Faculty Supervisor’s Signature (if PI is a student) Date \_\_\_\_\_

Department Chair’s signature Date \_\_\_\_\_

**Committee Action:**

Approved through exempt review  Approved by full committee review

Approved through expedited review  Not approved; clarification modification required

IRB Chair’s Signature Date \_\_\_\_\_

**A. Instructions for completing the HUM-1 Form (attach answers):**

1. Describe the characteristics of the subject population (anticipated number, age ranges, gender, ethnic background, and health status.)

Subjects are approximately 100 fourth grade students in four classrooms at two suburban elementary schools in an upper middle class school system in Connecticut. Students are relatively evenly mixed in terms of gender. The students are primarily white, with less than 10% of the district's population being minority. Approximately 3-5 students in each of the classrooms are identified as special education students. All students with informed consent will be included in the study. There will be approximately 50 students receiving the treatment, while another 50 students will be part of the control group.

2. Explain the rationale for use of special classes of subjects (children, mentally disabled, elderly, prisoners, or others).

The purpose of this study is to examine the effect of metacognition on the development of problem solving skills in mathematical homework assignments. Research has shown that metacognition was more important for problem-solving success than aptitude. In situations where students had low aptitudes but high metacognition, they performed as well as students who had high aptitude. The purpose of this study is to determine if incorporating metacognition as a part of the homework process will help to improve the completion, accuracy, and quality of the responses in these problem solving homework assignments. While the subjects are children, there are no other special classes of subjects.

3. Identify the records or data to be obtained for individually identifiable living human subjects.

The KeyMath-R, standardized test will be used as a pre-post testing instrument to measure general math aptitude. This test will be administered and scored by qualified teachers other than the researcher. As part of the study's data collection, ten homework assignments for each participant in the study will be distributed and collected by classroom teachers in sealed envelopes. These assignments will then be scored by the researcher for completion and accuracy. In addition, these assignments will be scored for quality of problem solving strategies and solutions using the Connecticut Mastery Test Mathematical Applications Scoring Rubric.

4. Describe plans for recruitment of subjects and the consent procedures to be followed, or explain why consent is not needed.

Subjects will be recruited from four classrooms from two of the four elementary schools in the region. Consent forms will be sent home to parents and guardians. Participants will be randomly assigned by classroom to either the treatment or control group.

5. Describe safeguards to assure anonymity and voluntary participation of subjects. In the case of student subjects, indicate that failure to participate in or withdrawal from the project will not affect class grade.

Information provided by subjects will remain confidential. A code will be assigned to each subject, by an objective researcher. The classroom teacher will not know the scores of students during the study. Failure to participate in the study or withdrawal from the study will not impact the student's grade.

6. "Subject at risk" means any individual who may be exposed to the possibility of injury, including physical, psychological, or social injury, as a consequence of participation as a subject in any research, development, or related activity that departs from the application of

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those established and accepted methods. [45CFR 46.3(b)]

No subject will be at risk for any physical, psychological, or social injury. If the instructional curriculum researched is found to be effective, it will be shared with the participants in the control group.

**B. Answer the following (if you answer yes to either question, the protocol requires full review):**

- Does your project involve **risk of physical injury** to subjects?

Yes  No

(If yes, describe the nature of the risk, the justification for undertaking the risk, and the procedures used to obtain the subject's informed consent to take the risk.)

- Does your project involve **risk of psychological or social injury** to human subjects?

Yes  No

(If yes, describe the nature of the risk, the justification for undertaking the risk, and the procedures used to obtain the subject's informed consent to take the risk.)

**NOTE:** If participation in the research involves physical, psychological, and/or social risk to the subject, the informed consent form **must say so in bold type.**

**Please send the completed form (if the protocol requires full review, send 12 copies) to: Director of Grant Programs, 321 Warner Hall. If you have questions, call 7-8281.**

6/26/06



**Proposal Approval  
for  
Doctoral Dissertation**

**Degree: Doctor of Education**

Name: Susan C. Shaw

Date: February 1, 2007

Title of Approved Proposal: *The Effects of Practicing Metacognitive Awareness on the Development of Mathematical Problem Solving Skills in Grade Four Homework Assignments*

Edward Duncanson, EdD Major Advisor	<i>Edward Duncanson</i> Signature	<i>Feb 1, 07</i> Date
Marjorie Ancil, EdD Secondary Advisor Committee Member	<i>Marjorie Ancil</i> Signature	<i>2/1/07</i> Date
Laurel Halloran, PhD Secondary Advisor Committee Member	<i>Laurel Halloran</i> Signature	<i>2/1/07</i> Date
Marcia A. B. Delcourt, PhD Program Coordinator	<i>Marcia Delcourt</i> Signature	<i>2/1/07</i> Date
Kathryn Campbell, PhD Department Chairperson	<i>Kathryn Campbell</i> Signature	<i>2/1/07</i> Date
Lynne W. Clark, PhD Dean of The School of Professional Studies	<i>Lynne W. Clark</i> Signature	<i>5/22/07</i> Date
Ellen D. Durmin, PhD Dean of Graduate Studies	<i>Ellen Durmin</i> Signature	<i>6/19/07</i> Date

Note: Any change in the committee must be approved by the Program Coordinator.  
c.c.: Dean's Office, Program Coordinator, Major Advisor, Dept. Chairperson, Doctoral Candidate

## Appendix D

### Consent Letter and Forms

Consent to Participate in Doctoral Dissertation Research Study  
The Effects of Metacognition on the Development of Mathematical Problem Solving in  
Grade Four Homework Assignments

May 2007

Dear Parent or Guardian,

My name is Susan Shaw and I am a fourth grade teacher at Long Meadow Elementary School. I am also enrolled in the doctoral program for Instructional Leadership at Western Connecticut State University. A requirement of the program includes research study dissertation work. I have chosen to research the effect of metacognition, thinking about your thinking, on the development of mathematical problem solving skills in homework assignments. I will examine the impact of metacognitive awareness on the completion, accuracy, and quality of problem solving responses in homework assignments.

I have chosen this research topic because of our region's dedication as a community that strives for excellence in education. It is important for us to continue to ensure that homework assignments are designed to reflect this commitment.

My research will consist of administering the *KeyMath-R Standardized Test* to all participants as a pre and post test. This is an individualized math test that takes about forty-five minutes to complete. This test will be administered by qualified teachers to determine general math aptitude. This test will not affect your child's grades in any way. In addition, for a 5-week period, each participant will be given one mathematical problem solving homework assignment on Monday and one on Thursday nights, for a total of ten assignments. These assignments will be the math homework for those nights. The assignments will come from the fourth grade *Math Trailblazers* program and from fourth grade sample problems on the *Connecticut Mastery Mathematical Applications Test*. They will be delivered and collected in sealed envelopes. Students in the experimental group will also receive a metacognitive awareness inventory to complete along with their math problem solving homework. The information provided by these data will remain confidential and will not affect your child's grade. A code will be assigned to each student, by an objective researcher. The classroom teacher will not know the responses to the problem solving assignments. At no point of this research will mathematics instruction using Math Trailblazers materials be interrupted. No school data will be collected on your child during this project.

This project has been approved by Regional School District #15; including Dr. Frank Sippy, Mr. Richard Gusenburg, and Mr. John Mudry. I will hold all information received in strict confidence. All data will be reported in group form. At no time will names be reported for the data I have collected. It is my hope that my research will be able to provide insight on homework design that benefits students and their learning, and upon request, I will share the results of the research. Your participation in the study is totally voluntary, and you are free to remove your child from the study at any time.

If you have any questions, or would like to speak with me further about the project, please contact me at Long Meadow Elementary School (203-758-1144) or via email at [sshaw@region15.org](mailto:sshaw@region15.org). If you agree to have your child participate in the research, please complete the attached form, and return it to your child's teacher by May 30, 2007. Thank you for your support.

Sincerely yours,

Susan C. Shaw

Western Connecticut State University  
Institutional Review Board

Consent to Participate in Research Study  
The Effects of Metacognition on the Development of Mathematical Problem Solving in  
Grade Four Homework Assignments

I, \_\_\_\_\_, the parent/legal guardian of the minor named below, acknowledge that the researcher has explained to me the purpose of this research, identified any risks involved and offered to answer any questions I may have about the nature of my child's participation. I freely and voluntarily consent to my child's participation. I understand all information gathered during this project will be completely confidential. I also understand that a copy of this consent form has been provided for my files.

Name of Minor: \_\_\_\_\_

School \_\_\_\_\_

\_\_\_\_\_  
Signature of Parent/Legal Guardian Date

Appendix E

Connecticut Mastery Test Sample Problem Homework Assignments

Code: \_\_\_\_\_

Time \_\_\_\_\_

By Myself: Y or N

Please solve the problem.

E-1 Marla and Janie are on the same basketball team. In the first 4 games of the season, Marla scored a total of 24 points and Janie scored a total of 21 points as shown in the table below.

Player	1st Game	2nd Game	3rd Game	4th Game	Total Points
Marla					24
Janie					21

- In the 1st game, Marla and Janie together scored 11 points
- In the 2nd game, together they scored fewer than 10 points
- In the 3rd game, together they scored more than 12 points
- In the 4th game, they each scored at least 3 points

Complete the table above to show how Marla and Janie could have scored their points in the 4 games. Show your work or explain how you found your answers.

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Code: \_\_\_\_\_

Time \_\_\_\_\_  
By Myself: Y or N

The school store sells pencils, pens and erasers. The chart below shows the cost of each of these items:

ITEM	COST
Pencils	15¢
Pens	25¢
Erasers	40¢

Allyson purchased several items in the store and spent 95¢. Show three DIFFERENT ways that she could have purchased some pencils, pens and erasers and spent exactly 95¢.

Pens _____	Pens _____	Pens _____
Pencils _____	Pencils _____	Pencils _____
Erasers _____	Erasers _____	Erasers _____
Total Cost _____	Total Cost _____	Total Cost _____

Show your work here:

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Code: \_\_\_\_\_

Time \_\_\_\_\_  
By Myself: Y or N

**You estimate that you'll need 40 buns for a class picnic.**

**Hot dog buns are sold in packages of 8 and packages of 12.**

**The package of 8 costs \$1.00**

**The package of 12 costs \$1.20**

**a. Show three different ways you could buy packages to get at least 40 buns.**

**b. Which packages would you buy if you wanted to spend the least money? Show or explain how you arrived at your answer.**

**c. Which packages would you buy if you wanted exactly 40 buns?**

Code: \_\_\_\_\_

Time \_\_\_\_\_  
By Myself: Y or N

**Samantha has the following types of food:**

- 6 donuts that cost 20¢ each**
- 3 bagels that cost 30¢ each**
- 7 pastries that cost 40¢ each**
- 4 granola bars that cost 50¢ each**

**To make breakfast bags for 5 groups of students, Samantha needs to sort ALL 20 of the food items into 5 bags.**

- Each bag must contain the same total number of items.**
- Each bag must contain at least three different types of items.**
- No two bags can be filled exactly like another bag.**

**Show how Samantha can put the items into each bag and then find the total cost of each bag.**

**BAG 1**

**BAG 2**

**BAG 3**

**BAG 4**

**BAG 5**

**Cost:**

**Cost:**

**Cost:**

**Cost:**

**Cost:**

Code: \_\_\_\_\_

Time \_\_\_\_\_  
By Myself: Y or N

A set of cards for a new game contains 25 cards.

Sixteen cards are labeled A  
Eight cards are labeled B  
One card is labeled C.

In the game, points are awarded in this way:

A cards are worth 2 points  
B cards are worth 5 points  
C cards are worth 10 points

Bill could have ended up with all 16 A cards for a total of 32 points.

Show **THREE** other ways that Bill could have gotten a total of 32 points and show how these combinations add up to 32 points.

Code: \_\_\_\_\_

Time \_\_\_\_\_  
By Myself: Y or N

The owner of a nut store packages nuts into 2 different sizes of packages. The prices for the two sizes are:

Weight	Cost
2 pound bag	\$2.00
5 pound bag	\$5.00

This morning, she needs to package 50 pounds of nuts and needs at least 5 bags of each size. Complete the table below to show

- how many 2 pound bags and how many 5 pound bags she could package
- the total weight of these bags, and
- how much money these bags will sell for.

In the space below the chart, show how you arrived at your answers.

Bag size	Number of bags packaged	Total weight of packaged nuts	Total value of the bags
2 pounds			\$ _____
5 pounds			\$ _____
	Total number of bags packaged: _____	Total weight of the packaged bags: _____	Total value of the bags of nuts: _____

Show your work here:

Code: \_\_\_\_\_

Time \_\_\_\_\_  
By Myself: Y or N

You and your classmates must provide music for a puppet show that will last 30 minutes.

The table below shows the songs that you can use and the number of minutes long each song is:

Song Title	Length in Minutes
Do Re Me	2
Sara's Waltz	5
Puppet Polka	8
Whispering Leaves	6
General March	4
Bells of Billings	4
Trumpet Tune	6
Spring and Fall	3

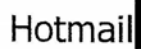
Use the information in the table to complete the schedule below that shows which songs you will use and the time each song will begin so that you will have exactly 30 minutes of music beginning at 2:00.

Time that Song Begins	Song Title
2:00	
2:30	

Appendix F

Metacognitive Awareness Inventory

Permission to Modify



sueshaw46@hotmail.com Messenger: Online

Reply | Reply All | Forward | Delete | Junk | Put in Folder | Print View | Save Address

From : Gregory Schraw <gschraw@unlv.nevada.edu>
Sent : Friday, December 1, 2006 4:37 PM
To : Susan Shaw <sueshaw46@hotmail.com>, gs <gschraw@unlv.nevada.edu>
Subject : Re: metacognitive awareness inventory

Attachment : MAI.doc (0.04 MB), MAI.doc (0.14 MB)

Susan,

Please feel free to adapt the MAI to suit your needs. I'm attaching some cites that might be helpful.

Gregg

Susan Shaw wrote:

Dr. Schraw, The date for me to defend my dissertation is December 21, 2006. Please let me know, as soon as possible, if permission is granted to modify the Metacognitive Awareness Inventory for use with fourth grade students. Thank you very much.

## Sue Shaw

From: gschraw@unlv.nevada.edu
To: susan shaw <sueshaw46@hotmail.com>
Subject: Re: metacognitive awareness inventory
Date: Sat, 11 Nov 2006 11:36:46 -0800

>Susan,
>
>I'm traveling through next Thursday, but will forward some info then.
>
>Gregg
>
>
>Quoting susan shaw <sueshaw46@hotmail.com>:
>
>> Dear Dr. Schraw, I am a doctoral student in the Instructional Leadership
>> Program at Western Connecticut State University. I am presently writing the
>> proposal for my dissertation on the effects of metacognition on problem
>> solving homework assignments for fourth grade students. I am very interested
>> in using the MAI in my study. Since I am working with younger students, I
>> would like to ask your permission to adapt the MAI in order to use it with my
>> sample. Also, if you could give me direction about purchasing the MAI or the
>> Jr. version, I would be most appreciative. Thank you very much.
>> Sincerely,
>> Susan Shaw sueshaw46@hotmail.com
>>
>>
>>

### Author Note

Thank you everyone: Family who stood by me throughout the journey; special friends who understood me, encouraged me, and laughed with me from start to finish; colleagues, professors, and students who supported and inspired me to achieve this goal. I congratulate all of you. For this dissertation represents our efforts to improve learning for all.