2016

Predictors of U.S. Teachers' Use of Metacognition in Mathematics Instruction

Regina Lewis
Walden University

Walden University

College of Education

This is to certify that the doctoral dissertation by

Regina Lewis

has been found to be complete and satisfactory in all respects,
and that any and all revisions required by
the review committee have been made.

Review Committee
Dr. Deanne Otto, Committee Chairperson, Education Faculty
Dr. Wade Smith, Committee Member, Education Faculty
Dr. Gerald Giraud, University Reviewer, Education Faculty

Chief Academic Officer
Eric Riedel, Ph.D.

Walden University
2016

Abstract

Predictors of U.S. Teachers' Use of Metacognition in Mathematics Instruction

By

Regina A. Lewis

MS, University of Scranton, 2007

BA, University of Maine at Augusta, 2002

Dissertation Submitted in Partial Fulfillment

of the Requirements for the Degree of

Doctor of Philosophy

Education

Walden University

July 2016

Abstract

American schools have been struggling with improving achievement in science, technology, engineering, and mathematics for decades. For the last four decades, the overall mathematics performance of 17 year-olds on the National Assessment of Educational Progress has not shown any significant improvement. Mathematics teachers can use metacognitive techniques to make immediate adjustments in instruction that may assist students in becoming more skillful problem solvers. The purpose of this study was to provide new knowledge about the potential predictors of mathematics teachers' use of the six subfactors of the Metacognitive Awareness Inventory for Teachers. The inventory was administered to 120 K-12 grade teachers from the membership list of the National Council of Teachers of Mathematics via an online survey. Multiple regression analysis indicates that there are significant differences among the participants in the influence of potential predictor variables for declarative knowledge, procedural knowledge, conditional knowledge, planning awareness, and monitoring awareness. The positive β coefficient indicates that the number of years of teaching experience plays a role in increasing the mathematics teachers' awareness of metacognition, $\beta=.207$, $p<.05$. The findings may help other researchers further explore the use of metacognition by mathematics teachers. Training in metacognitive skills may assist mathematics teachers with developing the expertise to make real time adjustments of instruction. Improvement in the teaching of mathematics may create positive social change by improving the numeracy skills of students and may decrease the number of students that need remediation in mathematics at the college and university level.

Predictors of U.S. Teachers' Use of Metacognition in Mathematics Instruction

by

Regina A. Lewis

MS, University of Scranton, 2007

BA, University of Maine at Augusta, 2002

Dissertation Submitted in Partial Fulfillment

of the Requirements for the Degree of

Doctor of Philosophy

Education

Walden University

July 2016

Dedication

To all those that understand that teaching and learning are inseparable, that the world is our classroom, that the human organism is a social being designed to learn throughout life's entirety and that spirituality cannot be overlooked as an essential need of the human organism.

Acknowledgments

First I want to thank the Lord our God for guiding me down this unfamiliar path and for carrying me when I was weary from the daunting and formidable journey.

My devoted husband, Jeffrey, who supported my venture into this unfamiliar territory. My children, who patiently understand my obsession for teaching and learning with the ‘world as my classroom’ and my grandchildren who demonstrate the complexity and gratification of mastering each newly learned task as an ultimate conquest on daily basis.

My first mentor, Vicky Eiben Ed.D.,who helped me take the first steps of this journey. Dr. Asoka Jayasena Ph.D., who inherited me and patiently helped me to evolve and develop a passion to understand and to explain phenomena beyond the realm of numbers. Dr. Paula Dawidowicz Ph.D. the reader for my final KAM, a fount of encouragement and support, and a highly knowledgeable resource.

My committee chair, Dr. Deanne Otto, and my methodologist, Dr. Wade Smith, who functioned as exemplars of patience while helping to form me as a scholar practitioner.

Monsignor Charles Murphy, whose eloquent compositions have helped me to understand the incompleteness of the educational experience in the current paradigm as it continues to ignore the importance of spirituality as a basic need of the human creature.

Table of Contents

List of Tables

Chapter 1: Introduction to the Study

Introduction

In “The Nation’s Report Card: Trends in Academic Progress 2012,” the U.S. Department of Education found that U.S. students at some age levels had shown improvement in mathematics while others had demonstrated little or no progress since 1973 (National Center for Education Statistics [NCES], 2013; National Science Foundation [NSF], 2016). All of the age groups that were tested demonstrated long-term improvement in their understanding of basic mathematical concepts from 1978-2012 except that of 17 year-olds. Overall since 1978, 9 year-olds have increased in mathematical performance across all age levels. The lower performing 13 year-olds also improved in mathematics performance during this period (NCES, 2013). Additionally, U.S. students average mathematical score on the Program for International Student Assessment (PISA) in 2012 was lower than the average score for all developed countries (NSF, 2016).

The overall average of mathematical performance on the National Assessment of Educational Progress (NAEP) for 17 year-olds did not improve significantly. Lower and middle performing 17 year-old students improved in mathematics performance over the long-term, however the overall performance of this age group did not change. This uneven performance of this age group is surprising because the number of 17 year-old students who are enrolled in calculus courses has increased (NCES, 2013). In addition, the number of Grade 12 students performing at the level of proficiency remained at 26% from 2000 to 20013, while the percentages of Grade 4 and Grade 8 students performing at a level of proficiency rose to 42% and 36% respectively (NSF, 2016). While the number of students enrolled in Advanced Placement (AP) course in mathematics and science courses continued to rise, a decreasing percentage of these students have earned a passing score of 3 or better on the AP Exam from 2003 to 2013 (College Board, 2014; NSF, 2016).

According to some experts in mathematics and science (NCES, 2013; NSF, 2016), changes in the racial and ethnic composition of this age group as well as an increase in the number of students in the lower performance levels may account for the uneven performance. In 1978, the percentage of 9 year-old, 13 year-old, and 17 year-old white students that took the NAEP was 79%, 80%, and 83%, respectively. Black students made up 14%, 13%, and 12% of these same age groups. Asian and Pacific Island students only made up 1% of the of the students that took the NAEP in 1978. These numbers changed drastically over the next 34 years. In 2012, the percentage of 9-year-old, 13 year-old, and 17 year-old white students that took the NAEP was 52%, 56%, and 56% respectively (NCES, 2013). Another factor is that an increasing number of pupils are now attending lower grades for their age. To illustrate this point, the number of 13-year-olds in 7th grade or below was 28% in 1978 but increased to 39% in 2012, while the number of 13-year-olds in the 8th grade decreased from 72% in 1978 to 60% in 2012. The 17-year-olds and 9-year-olds also revealed a similar pattern (NCES, 2013).

The quality of instruction plays a major role in student achievement in mathematics (Boonen, Van Damme, and Onghena 2014; Jackson, Rockoff, and Staiger 2014). Teacher qualifications, knowledge of the content, and access to professional development and professional coaching are among the factors that impact the quality of instruction. A major finding noted by the National Science Foundation (2016) was that there are fewer highly qualified mathematics and science teachers at schools with higher levels of minority students and higher levels of impoverished students. It is difficult to evaluate the differences in instructional techniques that exist among the teachers of the students evaluated by the NAEP and the PISA (NSF, 2016). Examples of teacher attributes that are difficult to evaluate include the ability of a teacher to motivate students and the ability of a teacher to identify students' difficulties with learning (NSF, 2016). In addition, Jackson (2012; 2014) described the complexity of determining the impact of teacher effectiveness due to confounding variables such as student tracking. Tracking can impact a student's ability to access mathematics courses with greater rigor or more difficult level of content.

Metacognition is the ability of a person to understand, reflect, and control one's learning based upon reflection and understanding of one's thinking (Schraw & Dennison, 1994). Metacognitive techniques can have a great impact upon classroom instruction (Clark & Peterson, 1986; Doganay & Demir, 2011; Shavelson & Stern, 1981; Wilson & Bai, 2010). Through the use of metacognitive skills teachers can act as effective interventionists during classroom instruction (Barton, Freeman, Lewis, & Thompson, 2001; Marzano et al., 2012). The teacher must be aware of the individual needs of each student and provide scaffolding to assist the students as necessary. By using metacognitive practices, mathematics teachers can take advantage of classroom opportunities to adjust instruction that may assist students in becoming more skillful problem solvers (Veenman, VanHout-Wolters, & Afflerbach, 2006).

Some researchers suggest that learners in classrooms with teachers who are more metacognitively aware have higher academic achievement that learners in other classrooms (Schraw & Dennison, 1994; Smith, 2013). Other researchers suggest that students must also be proficient at applying their knowledge in order to be successful (Pressley & Ghatala, 1990). The strategies used for problem solving are considered to be metacognitive because they serve as a guide for the problem solving process (Silver 1982, 1987). These strategies help the student monitor the steps to the problem solving process. By using metacognitive strategies, the student can monitor whether each step is moving toward the goal and whether the answer attained during calculations makes sense within the context of the problem.

Very little research, however, exists regarding the role of the teacher as a demonstrator of thinking and learning processes in mathematics (Veenman et al., 2006). Cognitive research on student thinking has encouraged the development of reform mathematics curricula for secondary and middle school mathematics (Edwards, A. R., Esmonde, I., & Wagner, J. F., 2011). Based on research focused on the enhancement of students' mathematical thinking, the Cognitively Guided Instruction program for teacher professional development was created to impact teachers' principles and understanding that guide their instructional practices (Fennema et al., 1996; Fennema, Franke, Carpenter, & Carey, 1993). These changes in teachers' instructional practices were in turn reflected in students' learning (Fennema et al. 1993; Fennema et al. 1996). The classroom discussions mediated by the teachers acknowledge students' contributions and assist the student in aligning their contributions with the mathematical content. These contributions by the students could then be further refined into more conventional forms of mathematical thinking and integrated into their learning practices (Cobb et al., 1997; Edwards, A. R., Esmonde, I., & Wagner, J. F., 2011). Forman, Larreamendy-Joerns, Stein, and Brown (1998) contributed to the knowledge of how cognitive models of classroom instructional practices can impact student learning and support student acquisition of mathematical processes. These methods include the connection of metacognition and mathematical procedures through instruction and feedback provided by teachers (Veenman et al., 2006).

The mathematics teacher plays a crucial role in the classroom by acknowledging the contributions of students through feedback. In addition, the teacher can guide future or supplemental instruction based on the students' contributions (Yackel, 2002). The role of the teacher concerning modeling by example and then providing formative feedback for guidance has not been highly investigated. Teachers need the tools for implementing metacognition as a part of their instructional practices and for assisting students in becoming aware of their metacognitive activities (Veenman et al., 2006). The National Mathematics Advisory Panel (NMAP, 2008) stated that none of the studies examined by the panel investigated how elementary and middle school teachers' mathematics knowledge impacted their instructional quality or student learning of mathematics.

In this study, I sought to investigate the predictors of metacognitive awareness among U.S. mathematics teachers. New knowledge and insight could enhance training programs for current and preservice teachers to assist with improving the development of their expertise in the use of metacognition to adjust student instruction. Improvement in the teaching and learning of mathematics may create positive social change by improving the quantitative literacy and numeracy skills of students. Stronger numeracy skills will improve the quality of the workers entering the workforce. In addition, improving the numeracy skills of students may lead to a decrease in the number of students that need remediation in mathematics at the post secondary level.

The content of the first chapter provides an overview of this research study. The background section of this chapter describes how metacognition is related to the teaching and learning of mathematics is discussed in the first section of the chapter. The problem statement clearly explains the problem created when students did not attain a level of mathematics literacy that is necessary to function as a student, problem-solver, and active member of the community. The purpose statement describes how metacognition can be a part of the improvement of the teaching and learning of mathematics. In the fourth section the research questions that are the focus of this quantitative study are presented with their associated hypotheses. A theoretical framework for the importance of metacognition in the teaching and learning is provided that emphasizes the importance of the use of metacognition for the improvement in teaching and learning mathematics. After the presentation of the framework, the nature of the study is described. Definitions were provided to assist the reader in attaining the minimum of a basic comprehension of the study. The assumptions of this quantitative survey research study are discussed in the eighth section of this chapter. A section on the scope and delimitations of the study is also provided. Following these sections, the limitations of the study are described. In the scope and delimitations section, the intent of this study and the delimitations of this study are presented. Then, the limitations of this critical investigation are discussed. The last section of this chapter discussed the significance and potential application of the results of this research study. The significance of the study is presented just prior to the summary of this first chapter.

Background

A learner's experiences in elementary and secondary education can provide strong foundational skills for future lifelong experiences of learning. The purpose of these educational experiences is to assist students in the development of the skills needed to acquire, learn, and apply new knowledge and solve problems efficiently (Farrell, 2010; Zimmerman, 2008). Balcikanli (2011) stated that one goal of education is to help learners assume responsibility for their learning. He emphasized that students need to be capable of planning, monitoring and evaluating their learning. Balcikanli specified that metacognitive awareness is required for students to be able to accomplish this task. Metacognition is the awareness and regulations of one's thoughts and actions (Ebdon, Coakley, & Legnard, 2003).

As noted by Bransford, Brown, and Cocking (2000), metacognition plays a critical role in successful learning. This success can be accounted for by both the teacher and the learner. A teacher uses reflection and self evaluation to monitor the effectiveness of instruction and student learning (Barton, Freeman, Lewis, & Thompson, 2001; Doganay & Demir, 2011; Marzano, 2012). Through modeling, teachers can assist students in learning how to monitoring their learning and understanding (Bransford et al., 2000). Teachers can assist students with the transfer of new learning into their repertoire of procedures for learning and problem solving through feedback. According to Bransford et al. (2000), researchers have found that these practices improve student learning by increasing the transfer and application of knowledge to other appropriate situations.

Learners who experience a greater degree of metacognitive awareness show more significant academic achievement (Schraw & Dennison, 1994; Smith, 2013). Schraw and Dennison (1994) found that students with a higher degree of knowledge of cognition answered a greater number of test questions correctly. Smith (2013) noted that many researchers have demonstrated a positive relationship between metacognition and academic performance. However, in her research study of students in a differential equation mathematics course, student metacognitive awareness was not a predictor of the course grade earned. Smith proposed that the complexity of the higher order concept of differential equations requires more than just an awareness of one's cognitive knowledge. Her conclusion was that metacognition was not an appropriate predictor of student performance in the context of her research study (Smith, 2013). The majority of these students began the course with a moderate level of declarative, procedural, and conditional knowledge of the content. Based on these findings, Bransford et al. (2000) contend that curricula of teacher training programs and schools of education should include an integrated focus on the development of metacognitive strategies and how to instruct using those strategies .

Many students experience challenges to learning mathematics that lead to experiencing frustration and anxiety while performing mathematical tasks. The fearful or negative attitudes that they develop interfere with their potential and ability to perform mathematical tasks (Geist 2010; Hembree, 1990). Geist (2010) noted that many students struggle to complete mathematics tasks and experience feelings of discouragement and anxiety as a result. Hembree (1990) demonstrated that cognitive-behavioral interventions offered promise to improve student performance through the reduction of the anxiety experienced by the student. Cognitive-behavioral interventions may reduce the frustration of students who struggle learn mathematics concepts and allow them to improve in math achievement (Hembree, 1990; Rubinsten & Tannock, 2010).

However, despite a multitude of efforts to improve mathematics performance of students in the United States, very little improvement has been achieved (NCES, 2013; NSF; 2016, Stigler, 2009). In comparison to other developed countries, the United States produces far fewer students with the highest levels of mathematics performance and achievement (NSF, 2016). On the Trends in International Mathematics and Science Study tests in 2011, U.S. students were not among the highest performing groups. However, students in the United States did outperform student from many other countries.

Student performance can be improved through the teachers' awareness of and making adjustments to the classroom environment. Teaching involves a process of thinking and adjusting while instructing. Constant monitoring and evaluation of the interactions between the teacher and the learner, as well as, the learning environment within the classroom is continuously performed. Multiple factors of metacognition are a part of the thought processes carried out by teachers. Their awareness, monitoring, and evaluation of these interactions are subfactors of metacognition. These elements of metacognition are conducted throughout the different stages of a teacher's instructional practices (Clark & Peterson, 1986; Shavelson & Stern, 1981). Modification of instruction based on taking into account the needs and learning style of the student can provide the opportunity for a greater number of students to demonstrate an increase in academic perform performance (Tomlinson & Allan, 2000).

Improvement in metacognitive skills can assist teachers and learners with increasing student performance. Many researchers and practitioners emphasize the vital role of metacognition in the improvement of teaching and learning practices (Sperling, Richmond, Ramsay, & Klapp, 2012). Teachers use metacognitive strategies for teaching metacognition to their students, as well as, for monitoring their thinking and learning (Doganay & Demir, 2011). Metacognitive skills may play a more significant role than intellectual capacity during the early stages of the mathematics problem solving process (Veenman et al., 2006). Sperling et al. (2012) noted that metacognitive learners recognized when their learning strategies are effective and when the learning strategies are mismatched resulting in misunderstandings and struggles. These students were able to select and apply additional strategies to assist with learning or to monitor better and control their motivation.

In addition to content knowledge and its required procedures, math teachers must be aware of their cognitive processes. Metacognition is a critical element in the reflective practices required for the improvement of teaching and learning (Barton, Freeman, Lewis, & Thompson, 2001; Marzano et al., 2012). The metacognitive mathematics teacher monitors the attempts of the student to learn, provide scaffolds, and adapt the learning environment or methodology when necessary. Through this constant state of monitoring, evaluating, and adjusting, the mathematics teacher designs or selects learning activities that are appropriately challenging for students (Lester, 2013; 2010).

Problem Statement

The ability of a person to understand, reflect, and control one's learning based upon reflection and understanding of one's thinking is referred to as metacognition (Schraw & Dennison, 1994). Metacognition was among five prominent dimensions of thinking recognized by Marzano et al. (1988) as those that are highly noted in research. The five dimensions identified by Marzano et al. are (a) Metacognition, (b) Critical and creative thinking, (c) Thinking processes, (d) Core thinking skills, and (e) The relationship of content area knowledge to thinking (p. 4). All of these dimensions of thinking have a place in teaching and learning. The scope of these five dimensions is far too broad to address within the confines of this study. Thus only the first dimension, metacognition, will be addressed in the context of its application to the adjustment of instruction by the mathematics teacher that takes place within the classroom.

Flavell (1976; 1979) described metacognition as one's knowledge of cognition and its necessity for comprehension and learning. He emphasized that metacognition included the monitoring and regulation of one's thought processes. Wen (2012) described metacognition as the knowledge and control of one's cognition. Wilson and Bai (2010) stated that metacognition is more than a selection of specific strategies but also includes the knowledge required for the choice of an appropriate strategy for a particular situation and conditions.

Teaching involves a process of thinking and adjusting while instructing. Within the classroom environment, there exists a constant monitoring and evaluation of the interactions between the teacher and the learner, as well as, the learning environment. Multiple components of metacognition have an impact on the thought processes of teachers. The teacher’s awareness, monitoring, and evaluation of these interactions are components of metacognition. These components of metacognition are conducted throughout the different stages of a teacher’s instructional practices (Clark & Peterson, 1986; Shavelson & Stern, 1981). Modification of instruction based upon the needs of the student while taking into account the learning style of the student will provide the opportunity for a greater number of pupils to demonstrate an increase in academic performance (Tomlinson & Allan, 2000).

Some researchers have proposed that learners that experience a greater degree of metacognitive awareness demonstrate more significant academic achievement (Schraw & Dennison, 1994; Smith, 2013). Veenman et al. (2006) suggested that at the beginning of the mathematics problem solving process, metacognitive skills may play a more significant role than intellectual capacity. Magno (2010) noted that when a teacher provided explicit instruction and guidelines for metacognition to learn materials effectively, critical thinking was encouraged among the students in the classroom. Through increased awareness of metacognition and its impact, interventions can be more readily available and more quickly administered to struggling students. Investigation of the influence of metacognitive development in formal academic settings and its connection with other contexts, such as mathematics, is needed.

Math teachers must be aware of their cognitive processes, as well as, the content and its required procedures. As emphasized by Doganay and Demir (2011), metacognition is interconnected with all of the dimensions of the thought process as demonstrated by the learner's attentiveness and responsiveness to their thoughts and in controlling their actions. Using prior experiences and prior knowledge, as well as, innovation and imagination to acquire new skills also demonstrates the interconnection of metacognition with the thought process (Doganay & Demir, 2011). The metacognitive mathematics teacher must monitor the attempts of the student to learn, provide scaffolds, and adapt the learning environment or methodology when necessary. Metacognition is a critical element in the reflective practices required for the improvement of teaching and learning (Barton, Freeman, Lewis, & Thompson, 2001; Marzano et al., 2012). Veenman et al., (2006) noted that very little research exists regarding the role of the teacher as a demonstrator of thinking, process, and communicator of the processes of thinking and learning of mathematics. As previously indicated, the NMAP (2008) stated that no studies examined by the panel investigated how elementary and middle school teachers' mathematics knowledge impacted instructional quality, student achievement, and the students' opportunities for the learning of mathematics.

Purpose of the Study

The purpose of this survey study was to provide new knowledge and insight about the relationship and impact of the nine independent variables of: age, gender, type of teacher preparation, grade level of mathematics instruction, number of years of education, degrees earned, age when entered the teaching profession, years of teaching experience, and any interruptions in teachers' years of experience six dependent variable subfactors of metacognition examined. This quantitative survey study critically examined the impact of the potential predictor variables upon the six subfactors of teacher metacognitive awareness in a sample of mathematics for the purpose of improving teaching and learning. The sample of participants included teachers that differed in the number of years of teaching experience, from preservice to multiple decades, as well as teachers that that instruct students from kindergarten through grade 12.

This study investigated the predictors of teacher metacognitive awareness and focused on six subfactors of metacognition used by mathematics teachers for the adjustment of instruction of students and the learning of mathematics. The results of this study provide insight into the metacognitive processes of mathematics teachers as identified and as validated by this study using the survey the Metacognitive Awareness Inventory for Teachers (MAIT). These methods are used by mathematics teachers to adjust their instruction for the purposes of meeting the learning needs of their students and for providing the students' with opportunities for the thinking and learning of mathematics noted by Veenman et al. (2006). Unlike the study conducted by Balcikanli (2011) in which the MAIT was administered only to student teachers of English Language Teaching (ELT) Programs, this study investigated how the metacognitive knowledge and practices of mathematics teachers of differ. The level of teacher experience and knowledge impacts instructional quality, student achievement, and the students' opportunities for the learning of mathematics as noted by Veenman et al. (2006) and National Mathematics Advisory Panel, (2008).

This study will use the MAIT to collect information about the use of metacognition from the study population of a sample of mathematics teachers with differences in age (IV¬ 1), gender (IV-2), type of teacher preparation (IV-3), grade level of mathematics instruction (IV-4), number of years of education (IV-5), degrees earned (IV-6), age when entered the teaching profession (IV-7), years of teaching experience (IV-8), and any interruptions in teachers' years of experience (IV-9). This study examined the predictors of teacher metacognitive awareness and focuses on six subfactors of metacognition used by mathematics teachers for the adjustment of instruction of students and the learning of mathematics. The MAIT survey instrument is well established. The demographic variables were used to provide new knowledge and insight about the impact of age, gender, type of teacher preparation, grade level of mathematics instruction, number of years of education, degrees earned, age when entered the teaching profession, years of teaching experience, and any interruptions in teachers' years of experience as predictors of the teachers' awareness and use of the components of metacognition and the six subfactors examined. The six subfactors of metacognition examined by the Metacognitive Awareness Inventory for teachers are declarative knowledge, procedural knowledge, conditional knowledge, planning awareness, monitoring awareness, and evaluation awareness. Teachers use the components of metacognition and their subfactors for the planning, monitoring, adjusting, and evaluation of the instructional methodologies, as well as, student learning.

Research Questions and Hypotheses

There were six subfactors of metacognition examined in this study. Each of the six research questions addresses the potential influence of the independent predictor variables on a single subfactor of metacognition assessed by the MAIT. A null hypothesis and an alternative hypothesis was formulated for each of the research questions. The hypotheses examined in this research study are listed below.

RQ1: Do the demographic variables of: age, gender, type of teacher preparation, grade level of mathematics instruction, number of years of education, all degrees earned, age when entered the teaching profession, and number of years of teaching experience, including any interruptions in the teachers' years of experience predict or impact the mathematics teachers' awareness of their use of declarative knowledge in their mathematical instructional practices?

$H_0$1: There are no significant differences in the influence of age, gender, type of teacher preparation, grade level of mathematics instruction, number of years of education, all degrees earned, age when entered the teaching profession, and number of years of teaching experience, including any interruptions in the teachers' years of experience upon the declarative knowledge used by mathematics teachers as a part of their instructional practices.

$H_1$1: There are significant differences in the influence of age, gender, type of teacher preparation, grade level of mathematics instruction, number of years of education, all degrees earned, age when entered the teaching profession, and number of years of teaching experience, including any interruptions in the teachers' years of experience upon the declarative knowledge used by mathematics teachers as a part of their instructional practices.

RQ2: Do the demographic variables of: age, gender, type of teacher preparation, grade level of mathematics instruction, number of years of education, all degrees earned, age when entered the teaching profession, and number of years of teaching experience, including any interruptions in the teachers' years of experience predict or impact the mathematics teachers' awareness of their use of procedural knowledge in their mathematical instructional practices?

$H_0 2$: There are no significant differences in the influence of age, gender, type of teacher preparation, grade level of mathematics instruction, number of years of education, all degrees earned, age when entered the teaching profession, and number of years of teaching experience, including any interruptions in the teachers' years of experience upon the *procedural knowledge* used by mathematics teachers as a part of their instructional practices.

$H_1 2$: There are significant differences in the influence of age, gender, type of teacher preparation, grade level of mathematics instruction, number of years of education, all degrees earned, age when entered the teaching profession, and number of years of teaching experience, including any interruptions in the teachers' years of experience upon the *procedural knowledge* used by mathematics teachers as a part of their instructional practices.

RQ3: Do the demographic variables of: age, gender, type of teacher preparation, grade level of mathematics instruction, number of years of education, all degrees earned, age when entered the teaching profession, and number of years of teaching experience, including any interruptions in the teachers' years of experience predict or impact the mathematics teachers' awareness of their use of conditional knowledge in their mathematical instructional practices?

$H_0$3: There are no significant differences in the influence of age, gender, type of teacher preparation, grade level of mathematics instruction, number of years of education, all degrees earned, age when entered the teaching profession, and number of years of teaching experience, including any interruptions in the teachers' years of experience upon the *conditional knowledge* used by mathematics teachers as a part of their instructional practices.

$H_1$3: There are significant differences in the influence of age, gender, type of teacher preparation, grade level of mathematics instruction, number of years of education, all degrees earned, age when entered the teaching profession, and number of years of teaching experience, including any interruptions in the teachers' years of experience upon the *conditional knowledge* used by mathematics teachers as a part of their instructional practices.

RQ4: Do the demographic variables of age, gender, type of teacher preparation, grade level of mathematics instruction, number of years of education, all degrees earned, age when entered the teaching profession, and number of years of teaching experience, including any interruptions in the teachers' years of experience predict or impact the mathematics teachers' level of planning awareness used in their mathematical instructional practices?

*H_0*4: There are no significant differences in the influence of age, gender, type of teacher preparation, grade level of mathematics instruction, number of years of education, all degrees earned, age when entered the teaching profession, and number of years of teaching experience, including any interruptions in the teachers' years of experience upon the *planning awareness* used by mathematics teachers as a part of their instructional practices.

*H_1*4: There are significant differences in the influence of age, gender, type of teacher preparation, grade level of mathematics instruction, number of years of education, all degrees earned, age when entered the teaching profession, and number of years of teaching experience, including any interruptions in the teachers' years of experience upon the *planning awareness* used by mathematics teachers as a part of their instructional practices.

RQ5: Do the demographic variables of age, gender, type of teacher preparation, grade level of mathematics instruction, number of years of education, all degrees earned, age when entered the teaching profession, and number of years of teaching experience, including any interruptions in the teachers' years of experience predict or impact the mathematics teachers' level of monitoring awareness used in their mathematical instructional practices?

$H_0 5$: There are no significant differences in the influence of age, gender, type of teacher preparation, grade level of mathematics instruction, number of years of education, all degrees earned, age when entered the teaching profession, and number of years of teaching experience, including any interruptions in the teachers' years of experience upon the *monitoring awareness* used by mathematics teachers as a part of their instructional practices.

$H_1 5$: There are significant differences in the influence of age, gender, type of teacher preparation, grade level of mathematics instruction, number of years of education, all degrees earned, age when entered the teaching profession, and number of years of teaching experience, including any interruptions in the teachers' years of experience upon the *monitoring awareness* used by mathematics teachers as a part of their instructional practices.

RQ6: Do the demographic variables of age, gender, type of teacher preparation, grade level of mathematics instruction, number of years of education, all degrees earned, age when entered the teaching profession, and number of years of teaching experience, including any interruptions in the teachers' years of experience predict or impact the mathematics teachers' level of evaluating awareness used in their mathematical instructional practices?

$H_0 6$: There are no significant differences in the influence of age, gender, type of teacher preparation, grade level of mathematics instruction, number of years of education, all degrees earned, age when entered the teaching profession, and number of years of teaching experience, including any interruptions in the teachers' years of experience upon the *evaluating awareness* used by mathematics teachers as a part of their instructional practices.

$H_1$6: There are significant differences in the influence of age, gender, type of teacher preparation, grade level of mathematics instruction, number of years of education, all degrees earned, age when entered the teaching profession, and number of years of teaching experience, including any interruptions in the teachers' years of experience upon the *evaluating awareness* used by mathematics teachers as a part of their instructional practices.

Theoretical Framework

Flavell (1970) initially described metacognition as an awareness of the process of one's learning. He expanded this definition to encompass the one's conscious awareness of the cognitive processes and associated activities used for learning (Flavell, 1976). The definition evolved shortly after to emphasize the importance of knowledge about one's cognition and the necessity of this knowledge for comprehension and learning (Flavell, 1979). Flavell (1976; 1979) emphasized that metacognition included the monitoring and regulation of one's thought processes.

Schraw and Dennison (1994) referred to the ability of a person to understand, reflect, and control one's learning based upon reflection and understanding of one's thinking as metacognition. Metacognition is more than a selection of specific strategies but also includes the knowledge required for the selection of the appropriate strategy for a particular situation and conditions (Wilson & Bai, 2010). While there is no single and universal definition of metacognition, many researchers and theorists agree that metacognition involves the conscious processes of awareness of one's learning and regulation of one's learning (Wilson & Bai, 2010; Wen, 2012).

Learners that experience a greater degree of metacognitive awareness demonstrate higher academic performance in a pretest-posttest research study that measured both academic and metacognitive performance conducted by Schraw & Dennison (1994; Smith, 2013). Metacognitive skills may play a more a greater role in learning than intellectual capacity at the beginning of the mathematics problem solving process (Veenman et al., 2006). Veenman et al. determined that metacognition accounted for 17% of the variance in learning, which is greater than the 10% of the variance in learning attributed to intellectual ability in their study. In the findings of Magno (2010), it was noted that when a teacher provided explicit instruction and guidelines for metacognition to learn materials effectively, critical thinking was encouraged among the students in the classroom. Additional investigation of the impact of metacognitive development in formal academic settings and its connection with other contexts is needed.

Doganay and Demir (2011) described metacognition as "the act of learning to learn, focusing, step by step planning what is going to be done, evaluating every phase of the learning process, and making the necessary adjustments accordingly" (p. 2036). This phenomenon is paralleled by the teacher who continuously monitors and adjusts instruction to meet the needs of the learner. Teachers use processes of thinking and adjusting while instructing. The teacher's awareness, monitoring, and evaluation of these interactive processes are components of metacognition. In addition to Shavelson and

Stern (1981), Clark and Peterson (1986) also emphasized that these elements included planning, regulating, and monitoring throughout the different stages of a teacher's instructional practices. Within the classroom, there exists a constant monitoring and evaluation of the interactions between the teacher and the learner, as well as, the learning environment. Teachers have and use metacognitive strategies for teaching metacognition to their students, as well as, for monitoring their thinking and learning (Doganay & Demir, 2011). Little is known about the impact of teachers' modeling of metacognitive skills and knowledge while providing feedback to students (Veenman et al., 2006). Tomlinson and Allan (2000) noted that modification of instruction based upon the needs of the student while taking into account the learning style of the student will provide the opportunity for a greater number of pupils to demonstrate an increase in academic performance.

Math teachers must be aware of their cognitive processes in addition to the mathematics content and its required procedures. Doganay and Demir (2011) emphasized the interconnections of metacognition with all of the dimensions of the thought process as demonstrated by the learner's attentiveness and responsiveness to their thoughts and in controlling their actions. Using prior experiences and prior knowledge, as well as, innovation and imagination to acquire new skills demonstrates the interconnection of metacognition with the thought process (Dognay & Demir, 2011). Metacognition is a critical element in the reflective practices required for the improvement of teaching and learning (Barton, Freeman, Lewis, & Thompson, 2001; Marzano et al., 2012). The metacognitive mathematics teacher must monitor the attempts of the student to learn, provide scaffolds, and adapt the learning environment or methodology when necessary.

This study investigated the predictors of mathematics teachers' metacognitive awareness and focuses on six subfactors of metacognition used by mathematics teachers for the adjustment of instruction of students and the learning of mathematics. This study was guided by the need to understand the use of metacognition by mathematics teachers. The teachers' understanding of what is required for teaching significantly impacts instructional practices, as well as student learning (Wilson & Bai, 2010). The study critically examined the influence of the demographic and genetic variables upon the role of teacher metacognitive awareness for the adjustment of instruction of students.

Nature of the Study

The nature of this study was of quantitative survey design. Initially, the data was analyzed using stepwise multiple regression procedures. Unlike the previously conducted research study using the MAIT and factor analysis, a stepwise multiple regression was performed in order to identify the most influential of the predictor demographic and genetic variables on the criterion subfactor of metacognition variables. Multiple regression analysis allows for the measurement of the naturally occurring levels of the independent predictor variables upon the dependent criterion variables without direct manipulation of the independent variables. In addition, this statistical analysis was conducted to establish which of the demographic and genetic variables function as the best predictors of the metacognitive criterion. The results of this study added to the body of knowledge about teachers' use of metacognition and its subfactors.

Quantitative research is consistent with identifying and numerically describing the trends, attitudes and experiences of current teachers regarding their metacognitive awareness of the use of appropriate instructional strategies to meet the needs of students in a proficiency-based customized learning environment. Multiple regression techniques require larger sample sizes. Recommended sample sizes for multiple regression lies between ten and forty cases per for every predictor variable examined (Brace, Kemp, & Sneglar, 2000). Quantitative survey research was appropriate for the larger sample sizes than qualitative research. It also served to identify the phenomenon of interest for future research in quantitative, qualitative, or mixed methods studies.

When examining a highly abstract concept such as metacognition and its multiple subfactors, stepwise multiple regression analysis assists in the determination of the impact of multiple predictor variables. Many demographic variables were examined in relation to their influence upon the two components and six subfactors of metacognition in this research study. Stepwise multiple regression is an extremely sophisticated form of multiple regression. The value of the impact of each predictor variable is assessed as it is entered in sequence. If the addition of the variable contributes to the effect, it is retained, and all of the other proposed predictor variables are then reassessed to determine whether they still contribute to the model or hypothesis. Variables found to have no significant influence were removed. This method was designed to refine the set of predictor variables to the smallest size possible. The quantitative stepwise multiple regression of the results of the survey investigated the influence of the demographic and genetic variables upon the subfactors of metacognitive awareness experienced by teachers served to assist in finding the most influential predictors of the use of metacognition including those among mathematics teachers of different grade spans and different levels of teaching experiences.

Data collected addressing the research question and hypotheses for this study were examined using stepwise multiple linear regression analysis. Multiple regression (MR) was used to examine the significance of the results and determine the R^2 coefficient. The variance accounted for by each predictor variable (PV) was then determined using the R^2 coefficient and the standardized beta coefficient. The results of these statistical procedures examined all of the research hypotheses (Green & Salkind, 2008). Some of the demographic variables served as ordered predictors of the use of the metacognitive subfactors used by mathematics teachers. Other demographic and genetic variables served as unordered predictors of these subfactors of metacognition. As noted earlier in this text, no previous research has examined the impact or variation of these subfactors of mathematics teachers with differences in teaching experience in that can be attributed to the variety of demographic and genetic variables reviewed in this study.

The chosen instrument, the Metacognitive Awareness Inventory for Teachers (MAIT), was tested and refined in an initial study conducted by its author Balcikanli (2011). The MAIT was constructed from the Metacognitive Awareness Inventory of Schraw and Dennison (1994) and refined by a three-phase study conducted by Balcikanli (2011) for the purpose of examining the metacognitive awareness of teachers. Due to this fact, the instrument did not need to be refined in a pilot study prior to its use in the quantitative portion of this research study. The MAIT has been used and validated by

Balcikanli (2011) in an investigation of the metacognitive awareness of student teachers in an English Language Teaching Program. No literature has been located that has examined the use of the MAIT with samples of teachers of other content areas, such as mathematics, or with a larger sample size than 323. This study was designed with the intention of examining a larger sample size and metacognition of teachers in the field of mathematics.

Sample size is an important aspect of a quantitative research study. Creswell and Plano Clark (2007) stated that the sample size has a direct impact upon whether a study may qualify as a rigorous study. The goal is to reduce sampling error and thus making the findings a more accurate representation of the population. Creswell (2009) stated that the population of the study should be identified, and the sampling design should be representative of the overall population. In the academic year of 1999-2000, there were approximately 182,000 mathematics teachers in the United States. Assuming that there had been only a small increase in the number of mathematics teachers, the approximate value of 182,000 was chosen as representative of the population.

Locating a sample of mathematics teachers of appropriate size was an important consideration for this research study. Creswell (2009) suggested that cluster sampling would be appropriate when attempting to locate individuals as participants for a study on a population that it is very difficult or impossible to establish a complete list of members or elements. Cluster sampling allows for the use of the membership lists of particular organizations to select participants that are appropriate for the study. In the case of this research study, the selected group for the cluster sampling was the National Council of

Teachers of Mathematics. The sample was purposefully stratified, as much as possible, to examine both genders, male and female, and all grade spans (K-2, 3-5, 6-8, and 9-12) that were represented. The participants were located from the National Council of Teachers of Mathematics.

Size is equally important to strategy (Creswell 2007). Creswell emphasized that the size for a quantitative study should not require that the findings be generalized. A power analysis, conducted with G*Power 3.1 (Buchner, Erdfelder, Faul, & Lang, 2014), at the .80 level for the nine potential predictor variables, determined the desired sample size to be five hundred. In order to accomplish this task, a list of contact information for 5000 members' National Council of Teachers of Mathematics (NCTM) was purchased from Marketing General Incorporated. The members were mailed a request to participate in the study. The questionnaire was administered using Google Surveys (Google Inc., 2014) via the internet. As each survey was completed, the collected data was directly entered into a Google Sheet (Google Inc., 2014). This data was then exported to Excel (Microsoft Excel, 2010) and SPSS (IBM SPSS Statistics, 2012) for further analysis. The number of teachers teaching mathematics was approximately 182,000 in the academic year of 1999-2000. NCTM has approximately 80,000 members (NCTM, 2013). The *State Indicators of Science and Mathematics Education:* 2007 report contains a compilation of 2006 data collected from the state departments of education. In this report written by Blank, Langesen, and Petermann (2007), the authors indicated that there may be as many as 244, 839 teachers instructing mathematics in grades 7-12. It was difficult to determine the actual number of teachers of mathematics since most elementary teachers instruct mathematics. An additional complication was the possible overlap of teachers of grades seven and eight. Seventh and eighth grade are at times grouped with K-8 and at other times considered to be a part of middle school. The membership size of the NCTM makes the organization the most attractive for the recommended sample size of 500. At the time of this study, as much as twenty to thirty percent of the mathematics teachers may be represented by the membership of the NCTM.

Definitions

Components of metacognition: The two divisions of the six subfactors of metacognition defined below. The first component, metacognitive knowledge, consists of declarative knowledge, procedural knowledge, and conditional knowledge. The second component is that of metacognitive regulation and control and consists of planning, monitoring, and evaluating (Schraw, 2001).

Conditional knowledge: Knowledge of when and why to use a skill. It is the comprehension of which skill is appropriate for use and at what time it is appropriate to use the skill. Conditional knowledge includes comprehension why procedures should be used or used and the limitations of the procedures (Balcikanli, 2011; Pintrich, 2002).

Declarative knowledge: Knowledge about something. It includes an individual's conceptions and beliefs about something (Balcikanli, 2011; Desoete, 2007; Schraw & Moshman, 1995).

Demographic variables: Characteristics that define groups within a population. In this study the type of degree that a teacher has earned and the number of years of teaching experiences are examples of demographic variables (Creswell, 2009).

Evaluating awareness: Self-assessment and the regulation of one's learning upon completion of the task. It includes the review of the match/mismatch of the intended goal and the actual outcome as well as the revaluation of one's goals after the completion and evaluation of the task (Balcikanli, 2011; Schraw & Moshman, 1995).

Genetic variables: Variables that are demographic variables or characteristics that an individual cannot control, such as age and gender (Bevilacqua & Goldman, 2009) . These are inherited traits or characteristics (Rieger, Michaelis, & Green, 1976).

Metacognition: The ability of person to understand, reflect, and control one's learning based upon reflection and the understanding of one's thinking (Schraw & Dennison, 1994).

Metacognitive knowledge: Knowledge about the self as a learner, knowledge about learning strategies, and knowledge of when to use the strategies. This knowledge impacts one's performance as a learner. The subfactors examined by this study and the Metacognitive Awareness Inventory for Teachers included: declarative knowledge, procedural knowledge, and conditional knowledge (Balcikanli, 2011; Schraw, 2001; Schraw & Moshman, 1995).

Metacognitive regulation: Control of one's thinking, improved use of strategies, and an increased awareness of the level of comprehension (Balcikanli, 2011; Schraw, 2001). Metacognitive regulation is the planning, monitoring, and evaluation of learning and includes these three subfactors of metacognition (Balcikanli, 2011: Schraw & Moshman, 1995).

Monitoring awareness: A regulatory skill of the quality of performance and comprehension. It is a dynamic regulatory and control process that is conducted at periodic intervals throughout the execution of a task (Balcikanli, 2011; Schraw & Moshman, 1995).

Planning awareness: A regulatory skill of metacognition. It includes the selection of the appropriate strategies, the timing of the use of the strategies, and allocation of resources (Balcikanli, 2011; Schraw & Moshman, 1995).

Procedural knowledge: Knowledge of how skills are to be used and/or applied (Balcikanli, 2011; Deseote, 2007). It is the knowledge about the "execution of procedural skills" (Schraw & Moshman, 1995, p. 353).

Assumptions

This quantitative research study was conducted on the assumption that teachers of mathematics from grade kindergarten through grade twelve have differing degrees of their awareness of their use of metacognition during instruction to meet the needs of their students. It was assumed that the large membership of the National Council of Teachers of Mathematics was representative of the population of mathematics teachers of the United States in characteristics, beliefs, and practices. In addition, it was assumed that the mathematics teacher participants of this study completed the survey honestly, accurately, and to the best of their ability. It was also assumed that the survey was completed on a voluntary basis. This research study took into account the assumption that the stepwise multiple regression analysis would identify the most influential predictors of mathematics teachers' metacognitive awareness from the demographic and genetic variable information that was collected with the MAIT survey.

Scope and Delimitations

The intention of this study was to critically investigate and compare the degree of the influence of age, gender, type of teacher preparation, grade level of mathematics instruction, number of years of education, all degrees earned, age when entered the teaching profession, and number of years of teaching experience, including any interruptions in the teachers' years of experience upon the mathematics teachers' awareness and use of the six subfactors of metacognition. Teachers instructing mathematics in grades kindergarten through grade twelve from the National Council of Teachers of Mathematics were asked to participate voluntarily in this research study. Delimitations of this study included the investigation of the teachers of mathematics perspectives and responses of how they use metacognition to plan, adjust, and evaluate their instruction to meet the needs of their students. This study was not intended to examine the impact of teaching of metacognitive strategies to mathematics students or to examine the academic performance of pupils whose teachers use metacognitive strategies to adjust their instruction.

The definition of metacognition, the metacognitive components of knowledge and regulation, and the subfactors of metacognition were created with a blending of Flavell (1970; 1976; 1979), Pintrich (2002), and Schraw and Moshman (1995), as well as Balcikanli (2011). Balcikanli's Metacognitive Awareness Inventory for Teachers had been previously designed and validated for reliability and applicability to teachers. The examination of the use of metacognition by mathematics teachers expanded the use of the MAIT to a broader population of teachers and opens the door for future application of this instrument to larger populations and more diverse content areas. The additional examination of the impact of the demographic and genetic independent variables opens the door for comparison of the effects of multiple independent variables on the metacognitive experiences of teachers and learners.

Limitations

Limitations of this study include the number of voluntary responses collected from the online administration of the survey. The sampling methodology of cluster sampling removes any possibility of the use of a random sample for this study. The cluster sample was selected from the membership of the NCTM. The 5000 potential participants were randomly selected by an agency that is independent of this researcher and the NCTM. There also exists the possibility that some teachers completing the survey may not have fully understood metacognition and its importance in the teaching of mathematics. These teachers have used these practices to plan, monitor, and adjust their instruction without being aware of their thinking about this process. The teachers completing this survey may not have received previous instruction about metacognition and its application to teaching and learning. Participants will be asked to reflect on their teaching practices. Thus, their personal bias may impact their beliefs about their practices and performance.

Significance

This quantitative survey study critically examined the role of teacher metacognitive awareness in a sample of mathematics for the purpose of improving teaching and learning. The sample of participants will include teachers that differ in the number of years of teaching experience, from preservice to multiple decades, as well as teachers that that instruct students from kindergarten through grade twelve. The results of this study may provide insight into the metacognitive processes of mathematics teachers as identified and as validated by this study using the survey the Metacognitive Awareness Inventory for Teachers (MAIT). These procedures are used by mathematics teachers to adjust their instruction for the purposes of meeting the needs of their students' achievement and the students' opportunities for the thinking and learning of mathematics noted by Veenman et al. (2006). Unlike the study conducted by Balcikanli (2011) in which the MAIT was administered only to student teachers of English Language Teaching (ELT) Programs, this study investigated how the predictors of metacognitive knowledge and practices of mathematics teachers of differ. The levels of teacher experience and knowledge impact instructional quality, student achievement, and the students' opportunities for the learning of mathematics as noted by Veenman et al. and National Mathematics Advisory Panel, (2008).

This study used the MAIT to collect information about the use of metacognition from the study population of a sample of mathematics teachers with differences in age (IV-1), gender (IV-2), type of teacher preparation (IV-3), grade level of mathematics instruction (IV-4), number of years of education (IV-5), degrees earned (IV-6), age when entered the teaching profession (IV-7), years of teaching experience (IV-8), and any interruptions in teachers' years of experience (IV-9). The MAIT survey instrument was previously established, the demographic variables were used to provide new knowledge and insight about the impact of age, gender, type of teacher preparation, grade level of mathematics instruction, number of years of education, degrees earned, age when entered the teaching profession, years of teaching experience, and any interruptions in teachers' years of experience with the components of metacognition and the six subfactors examined. Teachers use the components of metacognition and their subfactors for the planning, monitoring, adjusting, and evaluation of the instructional methodologies, as well as, student learning.

The most influential predictors were selected from the demographic and genetic variable information collected during the survey using a stepwise multiple regression. The results of this analysis may have revealed previously unknown and unestablished evidence of existing bias in the MAIT in that some of the items of the MAIT did not produce statistically significant results that could be associated with the subfactor of metacognition that the survey item was intended to address. The multiple regression analysis examined the proposed research hypotheses. Some of the demographic components, such as age and number of years of teaching experience, may serve as ordered predictors of the use of the metacognitive subfactors used by mathematics teachers. Other demographic components, such as grade level, may serve as unordered predictors of these subfactors of metacognition (Green & Salkind, 2008). No previous research had examined the variation of these subfactors of mathematics teachers with differences in teaching experience in relation to the demographic information considered in this study.

Balcikanli (2011) suggested that additional studies should be conducted for validation of "the structure of the MAIT with larger and varied samples" (p. 1326). Balciknali's goal was to provide a tool that would prove useful for educational researchers for future examination and measure of teachers' metacognitive awareness. Since the conception of the MAIT, no other studies had used this instrument in its original form. One study examining the impact of science teacher metacognition through professional development used an extraction of the statements contained within the MAIT. The MAIT was designed through a three-phase study using teachers in an English Language Teaching Program. No literature was located that had indicated that the MAIT has been used with any other sample source or size. The results of this study will raise the awareness of the utility of the instrument, its availability and its purposeful design. Zohar (1999) emphasized that a great deal of research had been conducted that provides evidence of metacognition and its role in the success for the learner, but little research had been conducted that examined teachers' metacognitive knowledge and pedagogical comprehension of metacognition.

This study added to the body of knowledge of the use of metacognition for the teaching and learning of mathematics as well as to improve the metacognitive training and preparation of preservice and current mathematics teachers of kindergarten through grade twelve. Students will have a greater opportunity to increase their academic performance as a result of an increase in the teachers' understanding of metacognition and differentiation develops. The information from this study will serve to improve the metacognitive training and preparation of preservice and current mathematics teachers through the demonstration of the influence of teaching experience upon the teacher’s use of the subfactors of metacognition. Improvement in the training of metacognitive skills and awareness of preservice mathematics teachers will increase their level of performance from the onset. Improvement in education and performance of teachers should have a positive impact upon classroom instruction thus, improving the mathematics performance of numerous students, both struggling and non-struggling. The improvement in the teaching and learning of mathematics may create positive social change through the increase the numeracy skills of individuals, thus potentially impacting the workforce and level of mathematics competence during participation in civic and social activities.

Summary

Awareness of the importance of monitoring one’s thinking for the purpose of helping learners of mathematics is a requirement for every teacher of mathematics. Each learner has different needs and a different style of learning. Since all student needs must be met, the mathematics teacher is faced with an enormous challenge. It is important to find ways and means of assisting aspiring teachers to acquire the necessary skills and expertise to perform efficiently in order to meet the needs of the learner. Magno (2010) noted that when a teacher provided explicit instruction and guidelines for metacognition to learn materials effectively, critical thinking invariably developed among the students in the classroom. The ‘on the spot’ adjustment of instruction performed by some teachers is a critical element in improving the mathematical performance of students. Teacher's metacognitive practices during instruction provide an opportunity for 'real-time' monitoring of student learning and allow for the immediate adjustment to instruction. The continuous monitoring and evaluation of student progress and learning goal has a significant impact on the providing of appropriate instruction and tools. Student achievement can be significantly improved through the metacognitive practices of the instructor.

This study investigated potential predictors of mathematics teachers' use of metacognition to adjust their instructional practices to meet the needs of learners. Some schools focus learning on student needs through requiring and empowering teachers to plan continuously, check, and adjust their teaching to align with the students learning and the learning goals. Metacognitive awareness is required by both teacher and learner in order to help learners assume responsibility through the planning, monitoring and evaluating student learning.

The literature reviewed in Chapter 2 of this study examines the importance of metacognition in the teaching and learning of mathematics, as well as, the importance of metacognition in teaching and the monitoring and adjustment of instruction. This literature describes the complexity of the involvement of metacognition with the processes of the teaching and learning of mathematics. The theoretical foundation and conceptual framework for this study are presented as a foundation for the presentation of this literature. The resources reviewed focuses on metacognition, how the brain learns, how the brain learns mathematics, how teachers use metacognition, and how metacognition can impact the learning of mathematics. The resources reviewed in Chapter 2 present the support for the investigation and methodology of this research study as discussed in Chapter 3. The results of this quantitative survey study are discussed in Chapter 4. Chapter 5 provides a discussion and interpretation of the findings of the multiple regression analysis. Within the final chapter recommendations for further research, and the implications for positive social change are discussed.

Chapter 2: Literature Review

Introduction

Underachievement in mathematics among children in the United States remains a significant problem (Dowker, 2009; Posner, Rothbart, & Tang, 2013), in spite of a multitude of efforts to improve mathematics instruction and student learning (NSF, 2016). Little research exists regarding the role of the teacher as a demonstrator and communicator of the processes of thinking and learning of mathematics (Veenman et al., 2006). None of the studies reviewed by the National Mathematics Advisory Panel (2008) examined how elementary and middle school teachers' mathematics knowledge impacted instructional quality and student achievement and learning. Metacognition is known to improve student achievement through the planning, monitoring and execution of problem solving (Doganay & Demir, 2011; Ebdon et al., 2003; Kazemi, Fadaee, and Bayat, 2010; Veenman et al., 2006). It also plays a role in collaborative learning, awareness of the situation and strategy selections, and internalization of new skills and knowledge (Dogany & Demir, 2011; Ebdon et al., 2003; Schoenfield, 1987). The purpose of this study was to provide new knowledge and insight about the relationship and impact of demographic and genetic variables as potential predictors of mathematics teachers' use and awareness of metacognition in their instructional practices.

A literature review was conducted of electronic and print resources in order to locate information from current research and foundational research related to this study. Studies and articles that were published in journals, dissertations, national databases, and publications of government and professional organizations were critically examined for the appropriateness and application to this study. Key terms were entered in combinations to search for relevant information. The theoretical foundation of this study emphasizes the critical importance of metacognition to the improvement of teaching and learning practices. These skills are essential to assist students in the acquisition and application of knowledge in this rapidly changing world. The literature reviewed in this chapter is divided into seven focus areas. Each focus area discusses a particular aspect of the conceptual foundation for this research study. In the first section, metacognition is defined and described in general terms. The second section addressed metacognition and its relation to learning. In the third section, I discussed computational fluency, problem solving, number sense, and making connections to real life applications of mathematics. A brief overview of neuroscience research, neural imaging, and executive functions is provided in the fourth section. The fifth focus area of this literature review discusses the importance and influence of metacognition in the learning of mathematics. I then discuss how the variables of age, gender, teaching experience, and grade level may relate to metacognition. The chapter summary discusses the potential possibilities for improvement to teaching and learning should neuroscientists, educational researchers, and teacher find a more efficient way to collaborate and share resources. This discussion is centered on the potential impact of metacognition as one of the focus areas for this collaborative relationship and unification of theories. The potential impact on the teaching and learning of mathematics is central to this discussion.

Literature Search Strategy

An extensive literature review was conducted of electronic and print resources. In order to synthesize information from current research and foundational research related to this study, I searched for studies and articles that were published in journals, national databases, and dissertations. The publications of government and professional organizations were also reviewed. Key terms were entered in combinations to search for relevant information. Electronic databases that I used to conduct the search for resources included GoogleScholar, ProQuests, Springer, Eric, Education Research Complete, Education from Sage, Science Direct, and Academic Search Complete as well as Dissertation and Theses at Walden University. Keywords applied to the searches included *metacognition*, *teaching*, *learning*, *learning mathematics*, and *neuroscience*. The emerging sources focused on the neuroscience of learning, the neuroscience of learning mathematics, executive functions, the metacognition of teaching and learning, the regulation of learning, using metacognition for the improvement of learning, and using metacognition for the improvement of teaching. Related literature revealed the numerous terms and definitions applicable to metacognition, the regulation of cognition, and the regulation of teaching and learning.

Initially, I focused on the location of resources regarding metacognition, metacognition and the learning of mathematics, how teachers use metacognition, how the brain learns, how the brain learns mathematics, and how metacognition impacts the learning of mathematics. Journal articles and texts were critically examined and included when appropriate to the topic of consideration. The scope of the literature examined ranged from books, and journal articles published from that of Dewey in 1933 through the date of the writing of this proposal in the year of 2014. The majority of the literature was published in 1970 and later. While the primary goal of this literature search was to locate research from 2010 or newer, foundational literature cited by these more recent publications was also examined. Organizational publications from the North Central Regional Educational Laboratory, the National Council of the Teachers of Mathematics, Association for Supervision and Curriculum Development, and the U.S. Department of Education were examined for background information and for contributing evidence to the significance of this study.

Theoretical Foundation

The current demands of rapid progress and change in a highly scientific and technological environment have created an immediate necessity for the modification of the current educational system in the United States and other countries around the world. The goals and methods of education must be adapted to meet the continuously changing needs of the economy, science, and technology. To meet these demands, learning and instruction must transition from the acquisition of information and basic skills to one that is focused on the development of critical thinking skills that will assist students with the acquisition and processing of new knowledge (Zohar & David, 2008). The current changes in academic curricula place a greater emphasis on developing reasoning skills and deep comprehension in young people at all levels of academic ability (Zohar & David, 2008). Learners are no longer viewed as passive absorbers. Rather, they are considered active participants in the learning process (Perels, Dignath, & Schmitz, 2009). Students must be able to adapt existing knowledge to new and different requirements, as well as, to acquire new knowledge in this rapidly changing world that necessitates lifelong learning by all (Perels, Dignath, & Schmitz, 2009).

Most researchers and practitioners emphasize the critical role of metacognition in the improvement of teaching and learning practices (Sperling, Richmond, Ramsay, & Klapp, 2012). Sperling et al. noted that metacognitive learners recognized when their learning strategies are efficient and when the learning strategies are mismatched resulting in misunderstandings and struggles. These students were able to select and apply additional strategies to assist with learning or to monitor better and control their motivation. Subramaniam (2009) reported that teachers monitoring, planning, and evaluation of the effectiveness of their instructional strategies had positive effects on student achievement. Thinking about their thinking caused the teachers to analyze their strengths, weaknesses, and opportunities. The results indicated that teachers exhibited a prominence of specific strategies and showed a shift toward research-based practices through authentic learning experiences (Subramaniam, 2009). Teachers implemented critical and creative teaching techniques that replicated the critical thinking processes that they used in planning and implementing their instruction. Subramaniam emphasized that the use of metacognitive practices in teaching is significant in enculturating inherent lifelong learning for teachers.

Conceptual Framework

Flavell (1970, 1976), Hacker (1998), and other researchers have established a connection of metacognition to successful learning. Hacker stated that, "metacognition includes both knowledge of one's knowledge, processes, cognitive and affective states, and the ability to consciously and deliberately monitor and regulate one's knowledge, process, and cognitive and affective states" (p. 11). Rahman, Jumani, Sattti, and Malik (2010) emphasized that metacognitive learners perform better than learners that are unaware. The authors stressed that this phenomenon is true for both the teacher and the student.

The effective teacher must play the roles of teacher and student simultaneously. Metacognitive teaching is more than teaching with metacognition. It includes the explicit instruction of metacognitive skills and processes (Rahman et al., 2010). Teachers must think about how to develop their students' metacognitive skills (Hartman, 2001; Rahman et al., 2010). Teachers must adjust their instruction to meet the needs of the pupils, the situation, and the goals of the learning activity. Metacognition assists with planning, monitoring, and evaluating the learners' progress and the effectiveness of the instructional activity (Rahman et al., 2010). It allows for the provision of immediate scaffolding when necessary (Duffy, Miller, Parsons, and Meloth, 2009). Hartman emphasized that metacognition assists teachers with strategic use of instructional techniques.

The impact of metacognition and the use of metacognition are not well researched despite the increase in interest in this topic over the last three decades (Rahman, et al., 2010). The critical state of the information available is described by Rahman et al. in the statement below:

> In spite of its importance, the issue of teacher's metacognition is often not addressed openly in literature. Most of the research conducted about metacognition focuses on students thinking and learning processes. It seems obvious that teaches need to be in touch with their knowledge control and awareness of their own thinking and learning process. (p. 220)

The teacher is the mediator of the classroom interactions that also includes the social culture of the classroom, the available tools and learning supports, and the student's individual needs, as well as the nature of the mathematical task at hand (Lester, 2013). Strategically designed and executed incorporation of metacognition instruction into the mathematics curricula across age levels and courses will improve the academic performance and independence of students. Donavan et al. (1999) emphasized that the development and application of strong metacognitive strategies and learning to teach metacognitive strategies in the mathematics classroom should be an integral part of the curriculum of schools of education. It is upon this framework that the study of the impact of age, gender, type of teacher preparation, grade level of mathematics instruction, number of years of education, degrees earned, age when entered the teaching profession, years of teaching experience, and any interruptions in teachers' years of experience the upon the use of the components of metacognition and the six subfactors by mathematics teachers will be conducted.

Literature Review Related to Key Variables

The scholarly and research literature reviewed for this study focused on the role of metacognition in teaching and learning. The goal and emphasis of the literature search were to locate and critically analyze scholarly writing that investigated the use of metacognition for the teaching and learning of mathematics. The confines of this paper and research were limited to those articles addressing the variables and the application of metacognition in the teaching mathematics that were identifiable. Every theory or opinion could not be included, due to the vast differences in terminology and definitions regarding metacognition and self regulation for teaching and learning. The literature was discussed in the seven sections previously described in this chapter of this research paper.

Metacognition: A definition and description

Metacognition is frequently described as thinking about one's thinking (Ebdon, Coakley, & Legnard, 2003). Flavell (1970) initially described metacognition as one's awareness of the process of thinking. He further refined the definition to the conscious knowledge of one's processes of cognition and the products related to these processes (Flavell, 1976). Schraw and Dennison (1994) defined metacognition as, "the ability to reflect upon, understand, and control one's learning" (p. 460). Hacker (1998) stated that, "metacognition includes both knowledge of one's knowledge, processes, cognitive and affective states, and the ability to consciously and deliberately monitor and regulate one's knowledge, process, and cognitive and affective states" (p. 11). The development of expertise through reflection, evaluation, and deliberate practice requires metacognition (Marzano et al., 2012). Feltovich, Prietula, and Ericsson (2006) described this aspect of metacognition as “knowledge about one’s knowledge and knowledge about one’s performance” (p. 55). The definition of metacognition, its breadth, and all of the aspects of metacognition are not universally defined. It is, therefore, beyond the scope of this study to discuss all of its aspects. This research will address only the components and aspects of metacognition that are related to teaching and learning.

Metacognition is most often divided into the two components of “metacognitive knowledge” and “metacognitive skills” (Bromme, Pieschl, & Stahl, 2010). In their research Broome, Pieschl, and Stahl defined metacognitive skills as the factors and processes used to monitor actively and control one’s cognition. These authors explained metacognitive knowledge as what one knows about their cognition (Bromme, Pieschl, & Stahl, 2010). Flavell (1976, 1979) described metacognitive knowledge as the active thoughts about what one knows. In other words, metacognitive knowledge is the active thoughts that one has about one’s current actions. It includes the reflective thoughts of monitoring and evaluating, and other metacognitive thoughts focused on the evaluation of performance.

Flavell et al. (2002) described two aspects of metacognition: metacognitive knowledge and metacognitive monitoring and self regulation. He further divided metacognitive knowledge into three sub-categories: knowledge about persons, tasks and strategies. Within Flavell’s (1979) framework the components of metacognitive knowledge, goals, and strategies are highly influenced by person, task, and strategy.

Metacognitive knowledge denotes one's beliefs and knowledge about one's cognitive skills. The cognitive strategies include knowledge one possesses about what skills to perform and in which situations they would be appropriate to perform.

The framework initially created by Brown (1978) places emphasis on knowledge and regulation of cognition (Sperling et al., 2012). Building on this framework, Schraw (1998) described the differences between regulation of cognition and knowledge of cognition. He further divided knowledge of cognition into the sub-processes of declarative, procedural and conditional knowledge. Procedural knowledge applies to the effective use of strategies, such as acquiring a great number of strategies and how they might be used (Schraw & Dennison, 1994; Sperling et al., 2012). Conditional knowledge refers to the knowing of when and why to use strategies (Schraw & Dennison, 1994; Sperling et al. 2012; Young and Fry, 2008). Declarative knowledge is knowledge about one's self and strategies (Schraw & Dennison, 1994). Planning, monitoring, and evaluating are three regulatory skills that are considered to be important for students to be able to regulate their learning (Balcikanli, 2011; Kluwe, 1987). Metacognition requires both the knowledge of thought and skill, as well as the effective use of the knowledge, termed metacognitive control (Ozsoy, Memis &Temur, 2009).

The current interest in metacognition for teaching and learning is based on the concept that all students need to be lifelong learners and problem solvers. It is believed that students should acquire problem solving skills in school that will be useful and applicable to everyday life. Exposure to problems that resemble real life situations provides the best environment for the acquisition and refinement of these skills. Realistic situations help students make connections to prior experiences and to envision future applications of problem solving skills. Through the comprehension of the thinking, learning, and strategic approaches to problem solving attained at school, the student should be able to extrapolate these processes into life as necessary to function as an active participant in society (Prytula, 2012). Reflection and awareness of one's thinking aids in the processes of learning and the monitoring of the appropriateness and success of one's actions, as well as in strategic problem solving.

Metacognition refers to knowing how to reflect and analyze one's thoughts, as well as how make use of these ideas and analyses through action (Prytula, 2012; Downing, Kwong, Chan, Lam, & Downing, 2009). The emphasis in this definition is more of a social construct in that the learner can potentially regulate and direct the problems solving process, as well as knowing his or her thought processes and others' (Prytula, 2012). This definition supports the earlier definition provided in this study and allows for the consideration of social influences upon metacognition. The teaching and learning of mathematical problem solving and the metacognitive activities to perform these activities requires the development of metacognitive skills. Kazemi, Fadaee, and Bayat (2010) described mathematical problem solving as a series of complex interactions between cognition and metacognition.

Metacognition and self regulation have overlapping components and similar principles. Self regulation theories such as Zimmerman's (2000) cyclical model of self regulation provide a framework analogous to that of some of the metacognitive theories. Zimmerman's model contains a forethought phase (prior to performing the task), a performance phase (monitoring during the execution), and a self-reflection phase (post-performance evaluation). These phases contain elements of metacognitive planning, monitoring, and evaluating of performance. Self regulation is a critical component of a one's metacognitive awareness of one's learning processes or engagement in a learning activity (Labuhn et al., 2010; Pieschl, 2009). Labuhn et al. emphasized the objective of improving academic performance and achievement might be attained through the enhancing of learner self regulation. Successful students have the knowledge and awareness of their learning processes, as well as the suitable strategies to effectively manage their learning (Balcikanli, 2011).

Students can overcome personal shortcomings when they are encouraged to work collaboratively (Kim, Park, Moore, & Varma (2013). Kim et al. described the impact of metacognition on three different levels that take place within the classroom. The first level described was the most familiar and individual level of metacognition. On an individual level, the student has only the resources available to monitor and control one's thinking and learning that are known to the individual. When collaborating with the group, shared thinking and discussion increases the metacognitive resources available to the learner. On the environmental level in the classroom, stimulants, classroom supports and resources, and other activities may become accessible to the student. Metacognitive resources exist on multiple levels for all learners in the classroom (Kim et al., 2013).

Metacognition and Learning

In the current paradigm of education there is a greater emphasis on teaching and learning for deeper comprehension and the development of critical reasoning skills that empower students to obtain and develop new knowledge and skills (Zohar & David, 2008). Learning is a process of thinking and interacting with the environment. An increase in the thinking processes involved results in an increased permanence of the learning (Doganay & Demir, 2011). In other words, when one reflects upon and monitors interactions within the learning environment one is more capable of making associations and connections to prior experiences and previous learning that allows the new knowledge to be retained with other knowledge stored in long-term memory.

Metacognition is thinking that is at a deeper than regular cognition (Zohar & David, 2009). It is a critical skill for independent learning since it assists the student with control and regulating thoughts about learning and behaviors involved with learning (Balcikanli, 2011). Metacognition is a system of thinking that enhances the active participation of learners on multiple levels (Doganay & Demir, 2011). What and how one learns can be controlled through the use of the deeper thinking processes of metacognition (Balcikanli, 2011). Learning is complex and involves a number of processes including reflection, knowledge activation, planning, and metacognitive monitoring and regulation (Azevedo, 2009). Doganay and Demir (2011) indicated that learners need to obtain specific skills, such as effective planning, listening, writing, reading, and active participation, in order to plan, monitor, and evaluate their learning. A self regulated learner scrutinizes the learning conditions and required tasks, sets goals, and determines which strategies to use given the conditions, prior experiences, and the required tasks (Azevedo, 2009). Zohar and David (2009) provided additional support for theories incorporating multiple levels of metacognition through their description of a higher order type of metacognition that they termed meta-strategic knowledge. Within meta-strategic knowledge, the learner is aware of the thinking and the kind of thinking strategies that are used in particular environments for the purposes of problem solving. The level of motivation and beliefs of the student are based on prior experiences and prior knowledge. While participating in the learning experience, the student may evaluate the effectiveness of the selected strategies in helping the student achieve the desired goal. The student can also make adjustments in strategies or other aspects of the learning context based upon the reflective evaluation process executed (Azevedo, 2009).

Despite the differences in the existing definitions and descriptions of metacognition, there exists a general agreement and recognition among most researchers and practitioners that metacognition plays a crucial role in the memory, learning, and achievement of students (Sperling, Richmond, Ramsay, & Klapp, 2012). Regarding the monitoring and regulation of metacognition, Posner, Rothbart, and Tang (2013) emphasized that there exists ample evidence that demonstrates that self regulation is of great importance for learning in school and life. Facilitation of the decisions for what, how, and when to regulate and control, impact the student's choice of adaptations and adjustments. These decisions and adjustments are based on the constant monitoring and comparison of the desired outcome. Balcikanli (2011) cautioned that many researchers believe that learners cannot become autonomous without metacognitive and self regulatory skills. He also noted that very little research exists that directly links academic success with metacognition.

In order to insure academic success, it is critically important that teachers understand the complexity and of the nature of the underlying processes that impact learning and influence academic achievement (Azevedo, 2009). Metacognitive monitoring and regulation are intricate processes. In order to improve our understanding of metacognition and self regulated learning, additional research should be conducted that examines the underlying processes of metacognition, as well as, the role and function of these processes (Azevedo, 2009). Within this future research, the impact of these processes upon problem solving, learning, and transfer be critically examined. Beneficial information for the improvement of teaching and learning could be discovered through the detailed investigation of the role of the metacognitive processes and self regulatory processes under different learning conditions (Azevedo, 2009).

Research should also be conducted on the development of metacognitive and self regulatory skills. Information about the development of these processes could provide a deeper comprehension of the processes. It could also be used to improve academic achievement and learning environments. The information that is gained would help current and future educators to provide the necessary instructional supports to accommodate skills that teachers have not yet developed, are in the process of developing, or are in the process of becoming automatic through additional practice. This information is also relevant for the improvement of training of preservice teachers who have an active role in supporting and fostering student learning (Azevedo, 2009). Metacognition plays a significant role in the learner’s self regulatory processes (Abar & Loken, 2010; Lee, Lim, & Grabowski, 2009, Sperling et al., 2012; Winne & Nesbit, 2010). Learners use metacognition to monitor and adjust their learning through feedback loops that adequately evaluate their progress toward their goals. Preservice teachers are students of teaching strategies and methodologies. Inservice teachers are learners of these same skills, as well as learners with the needs of students. All teachers, preservice and inservice, must monitor the effectiveness of instruction, thus placing additional importance upon metacognition as a tool for the teacher as both an educator and a learner.

Learning is a goal-oriented process making discriminatory use of accessible information in the setting or memory and processing the information in a way that is guided by the desired outcome (Efklides, 2009). Learning is specific to condition and situation. It takes place in a particular context and may be limited by it. Learning is not automatically applied to new circumstances, and it does not result in a successful outcome every time. The resulting outcome of the learning process is dependent on the accessibility of declarative and procedural knowledge. It is also dependent on the proper ordering and use of the procedures to be applied for reaching the goal. The methods include the monitoring and control of one’s thoughts and on the reflective evaluation of the resulting outcome (Efklides, 2009).

Self regulated learning is based on the assumption that the self is an integral part of the learning process and serves as a guide in this process (Efklides, 2009). It is also based on the assumption that learning is a dynamic and on-going process. Self regulated learning involves both the cognition and motivation associated with the setting of goals and engagement with the learning activity. Metacognition is an important facet of self regulated learning. It does not have direct access to the learning behaviors. It functions through thought and reflection. Metacognition is the monitoring and control of one's thoughts as well as an evaluation and reflection of the learning outcome and on oneself as a learner (Efklides, 2009). Self regulated learning has phases of planning, monitoring, and evaluation. Within these continuous phases, the learning goal is set, and the task and learning situation are examined with respect to an individual's perception of competency.

Emotions, feeling, attitudes, and motivation impact learning. This affective feedback loop, in conjunction with motivation, is responsible for the drive of self regulation. Metacognition uses a cognitive loop and an affective loop to regulate cognition (Efklides, 2009). This approach interprets learning from a more holistic point of view that allows educators to assist students in adapting and progressing as self regulated learners. One's self-concept and self-perception of competence are impacted by self regulated learning as well as influencing the learning outcome. The perception of our performance, our feelings during the execution of the task, and the strategies chosen for execution of the task are stored in memory. These opinions are critical to the assessment of the thinking of reasoning for our thoughts and actions as well as the thoughts and actions of others. Individuals often construct knowledge at this social level of thinking. Metacognitive experiences impact an individual's motivation through their impact on contributory attributions, on self-concept, and possibly on the perception of the achievement goal (Efklides, 2009).

Metacognition has multiple facets, each one of them contributing to self regulated learning in a different way. Metacognition often fails to control behavior and cannot be reduced to the mere lack of strategic knowledge or avoidance of metacognitive strategies.

The interaction of all the facets of metacognition, in particular the motivation prompted by metacognitive experiences, activates metacognitive knowledge and metacognitive strategies (Efklides, 2009).

Metacognitive learners can recognize when they are learning efficiently and when they are struggling and therefore must employ the use of additional strategies or control and monitor their motivation (Alexander, 2008). The use of metacognitive knowledge and skills has a positive impact on upon academic performance. Young and Fry (2008) determined that a correlation exists between student performance on the Metacognitive Awareness Inventory and the cumulative Grade Point Average of the pupil. Further evidence of the positive impact of metacognition upon learning and academic success was provided by Dognay & Demir (2011). The results of their study demonstrated that permanent learning and academic achievement can be enhanced through the development of metacognitive skills (Doganay & Demir, 2011).

Nietfeld and Schraw (2002) provided evidence to support the concept that high-knowledge learners outperformed low-knowledge learners on assessments due in part to their ability to monitor their learning with greater accuracy as proposed by Glasser and Chi (1988). Students that have attained appropriate strategies also apply and monitor those strategies more accurately than less strategic learners (Nietfeld & Schraw, 2002). High academic performers use metacognitive and regulatory strategies to set goals, as well as to monitor and evaluate their learning (Lee et al., 2010). Mathematical skills are applicable to life experiences outside of the classroom and school. Learning is a lifelong process that is not limited to the confines of the school building. When one is aware of one's own thoughts and learning processes of learning, one's daily life reflects the application of these knowledge and skills through success in multiple activities and dimensions of life (Doganay & Demir, 2011).

The use of awareness for the monitoring of appropriate strategy use in problem solving both in the classroom and life applications can be applied to specific skills and their appropriate situations of use. One such example is that of the learning of mathematics and its particular sub-skills. For example, computational fluency is a paramount skill for mathematical literacy. In order for an individual to be able to use mathematic skills appropriately, a person must understand the skill and its appropriate applications, as well as be able to competently perform the skills. In the next section, the improvement of the learning and execution of mathematical skills through the use of metacognition is discussed.

Learning Mathematics

Computational fluency as described by the National Council of Teachers of Mathematics (NCTM) is more than knowing basic number facts. Computational fluency includes the understanding of these facts (NCTM, 2000). The learning of mathematics involves more than an individual's mental processes of knowledge and skill acquisition. Students are expected to develop mathematical reasoning skills and think mathematically. Good number sense allows students to move between the world of numbers and mathematical expressions and real-world applications of mathematics almost effortlessly. The understanding of the numerical properties, such as magnitude and cardinality, is the foundation upon which mathematical skill and ability is built (Menon, 2010). The learning of mathematics is not individualized rote memorization of concepts and step-by-step algorithms (Ebdon et al., 2003). Students should be encouraged to reflect on the meaning of the numbers and how the numbers connect to their lives as an integrated part of the performance of numerical computations. Communication of thinking and reasoning through illustrations, graphical representations, and with words are also a part of the demonstration of competency (Ebdon et al., 2003).

The learning of mathematics also includes the socio-cultural processes that impact mathematics and mathematics learning. These values, belief, and practices include interactions between groups and individuals regarding learning, mathematics, and the learning of mathematics. The socio-cultural influences are situation dependent and difficult to study out of context (De Smedt & Verschaffel, 2010). Some methods of determining a mathematic solution are more cognitively demanding than others (De Smedt & Verschaffel; Thomas et al., 2010). Transfer of acquired knowledge to new situations is critical to improving mathematics achievement. Simply learning steps to an algorithmic solving process or solving a multitude of simple calculations does not in itself lead to improvement in mathematics. Understanding of the mathematical skill and its appropriate applications is crucial to transfer performance (Lee et al., 2014).

Metacognition may have a great impact on how students learn mathematics. Lester and Kehle (2003) stated that “Successful problem solving involves coordinating previous experiences, knowledge, familiar representations and patterns of inference, and intuition in an effort to generate new images and related models of inferences that resolve some tension or ambiguity” (p. 510). The researchers noted that the resolution should solve or satisfy some condition the provoked the original problem solving activity. Previous studies on metacognition and problem solving have demonstrated that metacognition has a substantial impact on problem solving ability. Success in problem solving was strongly correlated with higher levels of metacognitive skills (Ozsoy & Ataman, 2009, Schoenfeld, 1992). When learners undertake a learning that is new or not routine, a different perspective is required. The student must create new meanings through inferences, making connections, and the construction of new representations (Lester, 2013). Students that have difficulty with monitoring their thought processes through metacognitive processes will face additional challenges in mathematical problem solving (Ozsoy & Ataman, 2009). Ozsoy and Ataman stated that these difficulties could manifest in how student plan, monitor, and regulate the steps and processes they choose and use in the problem solving process.

Understanding examples provided for the learning of mathematics is more important in the problem solving activities than the inclusion of verbal directions (Lee et al., 2014). Transfer of mathematical knowledge was more highly influenced by the level of mastery and understanding than by whether direct instruction was provided. For successful learning and transfer to take place, it is necessary for the learner to identify the hidden structure and nature of the problem. Lee et al. determined that the verbal instruction had little impact on transfer of mathematical knowledge. The authors emphasized that what students learned was of greater importance than how they learned. Comprehension of what an example represented impacted both brain activity and successful transfer of knowledge. Making connections between the current learning and prior knowledge was critical to identification and understanding of the hidden structure of the problem (Lee et al., 2014). The quickness and ease of memory retrieval of facts and calculations are dependent on prior learning and arithmetic proficiency (Menon, 2010). When results and calculations are not easily retrieved, the learner becomes dependent on the limited resources of working memory (Menon, 2010). When working memory resources become limited, children become more dependent on less mature and less advanced strategies for problem solving (Geary & Damon, 2006; Menon, 2010). The availability of working memory for the purpose learning is of great concern to educators, cognitive scientists, and neuroscientists. Stress and other emotional responses can sometimes act to reduce the available working memory thus inhibiting the learning potential of the student. Neuroscientists approach this research from a slightly different perspective than educational researchers and cognitive scientists. However, all of these parties agree that it is essential to reduce the responses that limit the availability of working memory. The researchers also agree that regulation of thinking and learning is critical to improving teaching and learning. Neuroscientists refer to these regulatory functions as executive functions.

Metacognition and Executive Functions

From a neuroscience perspective, the planning, monitoring, and evaluation used in the regulation of learning are described as executive control processes by Brown (1980), Kluwe (1982) and other researchers. Kluwe discriminated between the executive regulatory processes that regulate one's thinking and the executive monitoring processes that assist with the obtaining of information about one's thinking processes. As neuroscience, cognitive science, and education researchers continue to investigate teaching and learning, the cooperation between each of these fields continues to grow. While additional cooperation is necessary, the results of the studies continue to inform each of the fields. Neuroscience continually offers new practical and theoretical information with implications for teaching and learning (Becker, Miao, Duncan, & McClelland, 2014).

As described by Becker et al. (2014) executive function is a complex set of cognitive processes involved in higher level goal-directed processing consistently and highly related to academic achievement that is expressed through behavioral self regulation. Posner, Rothbart, and Tang (2013) defined executive function as a "group of processes that allow us to respond flexibly to our environment and engage in deliberate, goal-directed, thought and action" (p. 2). The component processes that comprise the executive functions are extremely interrelated. These components are often divided into and described as distinct elements. Cognitive flexibility and inhibitory control are examples of executive functions, as well as working memory that some researchers incorporate under the umbrella of the executive function known as updating. The modification of unconcealed behavior requires executive function as a part of the self regulation of emotion, cognition, and behavior (Becker et al., 2014; Posner, Rothbart, & Tang, 2013). In the classroom, the learner must integrate executive function with behavioral self regulation while following classroom instructions, as well as interacting with peers (Becker, Miao, Duncan, & McClelland, 2014).

Executive function skills have been demonstrated to have a role in carrying out mathematical operations, as well as learning new mathematical content. Improving one's executive working memory is highly influential in making progress in mathematics achievement (Posner et al., 2013; Swanson, 2011). Fuchs et al. (2012) investigated the effectiveness of mathematics tutoring upon the cognitive skills of first-grade mathematics learners. The results of their study demonstrated that attention and working memory skills predicted mathematics performance at the end of the training period. This study provided evidence that the executive skills of learners do have an impact on the ability to learn mathematics. Additional research, to better inform and influence classroom instruction, is necessary to investigate how and why executive function skills support acquiring new mathematical skills and applying mathematical knowledge to new situations (Posner et al., 2013).

Neural imaging studies have been used to identify the regions of the brain that are active during mathematics. Three areas of the parietals were identified as crucial for number processing, the horizontal intra parietal sulcus, the posterior superior parietal lobule, and the left angular gyrus (Dehaene, Piazza, Pinel, & Cohen, 2003; Lee et al., 2014). In addition, the posterior parietal cortex has been demonstrated to be highly involved in problem complexity and internal representations. The lateral inferior prefrontal cortex has also been identified as a critical region for the retrieval of declarative knowledge and proficiency (Anderson et al., 2011; Lee et al., 2014; Wintermute et al., 2012). Anderson et al. (2011) and Wintermute et al. identified by distinct neural networks involved in the solving of mathematical problems using both behavioral and imaging techniques. The cognitive network included the posterior parietal cortex and the posterior superior parietal lobule. The metacognitive network included the angular gyrus and the right lateral prefrontal cortex. The researchers also determined that the lateral inferior prefrontal cortex was involved in both the cognitive and metacognitive networks. Lee et al. identified the right lateral prefrontal cortex as highly involved with the transfer of mathematical learning.

Neuroscience and neural imaging are providing new information about the use of the brain for teaching and learning. Additionally, it is now possible to begin to study the different responses of the brain for the learning of different content and more specifically the different phases of learning content. Neural imaging also allows scientists to compare the brain activity of individual learners. Scientists can now study the brain responses of individuals with disabilities including mathematics learning disabilities such as dyscalculia. Similarities and differences between the responses of individuals may allow educators and researchers to work together to better design interventions for individuals with mathematics disabilities. Metacognitive practices can help teachers and students monitor, evaluate, and improve the effectiveness of these interventions by helping teachers choose appropriate scaffolds and other strategies for mathematics instruction.

Metacognition and Mathematics

Metacognition is commonly known as a strategy for use in the improvement of reading comprehension and other literacy skills. However, metacognition is equally as important for the improvement of student achievement and problem solving skills in mathematics (Ebdon et al., 2003). Metacognition is a crucial element in all stages of problem solving (Doganay & Demir, 2011). Development of a mathematics culture in the classroom assists with the development of metacognition (Ebdon et al., 2003; Schoenfeld, 1987). This culture should support that taking of risks in an attempt to solve unfamiliar problems and the sharing of reasoning and thinking during the problem solving process. This instructional approach provides students with the opportunity to participate in the process of thinking about the methods that could be used to obtain a solution. Problem solving requires the higher order thinking processes of analyzing, synthesizing, understanding, and generalizing (Doganay & Demir, 2011). When students are reflecting, evaluating, and communicating about their thinking during the problem solving process, they are using metacognition (Doganay & Demir, 2011; Ebdon et al., 2003).

Retrieval of facts, calculation, and reasoning are three of the major components of mathematical problem solving. These three elements are just a part of the highly complex task of mathematical problem solving (Lee, Fincham, Betts, & Anderson, 2013). Metacognition is viewed by many researchers as one of the most significant and efficient behaviors for the solving of problems and the learning of mathematics (Doganay & Demir, 2011; Kazemi, Fadaee, & Bayat, 2010; Lester 2013). Students often have the essential knowledge and skills for performing complex mathematical tasks, but neglect to use them. This phenomenon is frequently overlooked. Kazemi, Fadaee, and Bayat suggested that this may be due in part to the lack of confidence or lack of motivation. The authors also suggested that the student may not recognize that the situation calls for a particular strategy or set of skills. In other words, it may be that the learner does not have a conditional or contextual knowledge needed for the application and transfer of the declarative and procedural knowledge (Kazemi, Fadaee, & Bayat, 2010). Metacognition is a part of learning in a variety of ways. It provides the learner with the ability to determine the difficulty of the task. Metacognition is also used for monitoring comprehension and provides the student with the capacity to recognize that he or she does not understand something. Metacognition also plays a role in the planning of teaching and learning. It assists in determining what the learner will need to know and approximately how long each step in the learning process should take. Selection of the appropriate strategy, monitoring of performance, and the use of relevant information are also some of the metacognitive activities utilized in the mathematical problem solving process. Kazemi, Fadaee, and Bayat emphasized the knowing what to monitor, how to monitor, and when to monitor are necessary for efficient execution of metacognitive activities during the process of mathematical problem solving.

In an attempt to better understand the processes and mechanisms involved in mathematical problem solving, many researchers have investigated the neural basis of mathematical knowledge. Lee et al., (2014) examined the impact of differing instructional activities involving the learning of mathematics and transfer in problem solving upon the activity in the regions of the brain known to be involved with these mathematical events. The researchers were able to identify two areas of the brain that were highly involved with metacognitive activity in the learning of mathematics. Wintermute et al., (2012) demonstrated that the cognitive network was highly active during the solving of problems. The researchers noted little difference in activity level between the solving of regular problems and those of differing attributes. The metacognitive network was more active during reflection after problem solving and was more highly involved while solving problems of new or different characteristics (Wintermute et al., 2012). Ebdon et al. (2003) noted that reflection upon completion of the mathematical task provided an opportunity for students to make sense of mathematical tasks, internalize information, and thus reduced the possibility of forgetting the acquired skills and information over time.

The ability to make accurate judgments of one's abilities and performance is critical to successful academic achievement (Bandura, 1986; Labuhn, Zimmerman, & Hasselhorn, 2010). Students must accurately monitor and evaluate their progress in order to make appropriate alterations that are based on a precise critical examination of their performance (Labuhn et al., 2010). When students receive feedback about their performance, they develop greater accuracy in the self evaluation process. Feedback is vital to developing accurate self evaluation skills in learners of mathematics. When teaching complicated solution methods, appropriate scaffolds designed to reduce cognitive load should be a part of the instruction. These scaffolds should include techniques for increasing awareness of problem features that might aid in selecting the appropriate method for task solutions and ignoring inappropriate methods (De Smedt & Verschaffel, 2010).

The development of self evaluative and self regulative skills in mathematics students assists in facilitating student learning and aids in enhancing mathematical skills. One potential application of these skills is the knowledge and use of the sequential procedural computational problem solving algorithm known as the Order of Operations.

Many students are familiar with this algorithm and its pneumonic device, PEMDAS (parentheses, exponents, multiplication, division, addition, and subtraction) prior to entering the middle school grades (6-8). However, a considerable number of students cannot apply or use this algorithm appropriately upon entering high school. Teachers can assist the student with becoming more motivationally, behaviorally, and metacognitively responsible for their learning can help in promoting knowledge and skill acquisition (Labuhn et al., 2010).

Metacognition and Teaching

An examination of teachers' behaviors in the classroom demonstrated that teachers employ routines and procedures, but also they also engage in highly complex cognitive activity that goes beyond the mere application of methods (Duffy, Miller, Parsons, & Meloth, 2009). The teacher participated in a variety of activities some of which are thinking processes that help the teacher to guide students purposefully from skill and comprehension level to the next (Duffy et al., 2009). In order to promote student learning, teachers need to be able to create and maintain a classroom learning environment that encourages intellectual inquiry and creative thinking. When planning and instructing, teachers need to be self-aware of their instructing for thinking in order to engage and monitor students in metacognitive activities (Lee, Teo, & Chai, 2010). A metacognitive awareness of planning assists teachers with understanding the depth and complexity of the planning process. Teachers must have the knowledge and skills necessary continuously to promote student achievement and social change within the classroom. One such example noted by Duffy et al. is that of exemplary teachers that despite having a well-designed lesson plan will alter those plans to provide mini-lessons during teachable moments according as a real-time response to their students' needs.

To become responsible change agents, teachers must be aware of their thinking, as well as their teaching and learning practices (Lee et al., 2010). In order to develop and improve their practices, teachers need to be aware of their thoughts, understanding, and knowledge about teaching and learning. Teachers also need to be aware of their knowledge of the content of instruction, including their strengths and weaknesses within the content area. They also need to be conscious of the different strategies and types of knowledge available to them for use in developing and improving their practices (Doganay & Demir, 2011; Lee et al., 2010; Parsons & Stephenson, 2005).

The instruction of mathematical reasoning, problem solving, and computation should be performed in a manner that is meaningful to the learner. Teachers introduce a problem/task, guide and probe students through questioning, assess student understanding, and support students when they encounter roadblocks during mathematics instruction. The goal is for the students to achieve higher levels of understanding, as well as acquire new mathematical skills (Ebdon et al., 2003). Teachers should monitor their students' use of prior knowledge when problem solving and monitoring the selected strategies. A quick informal assessment of student understanding can be conducted through observation of the individual students during task performance. Teachers have been noted to be flexible regarding their intended instructional plan in order to meet the needs of students. Among other terms, this flexibility has been described as adaptive metacognition, adaptive instruction, adaptive expertise, and the response-based instruction (Duffy et al., 2009). Explicit instruction may be needed to provide additional knowledge and for the selection and use of appropriate strategies for problem solving. The explicit instruction of new knowledge and strategies should be conducted in an organized manner (Donovan, Bransford, & Pellegrino, 1999; Nietfeld & Schraw, 2002). Monitoring and performance are positively enhanced through strategy instruction (Dole et al., 1991; Nietfeld & Schraw, 2002; Pressley & Wharton-McDonald, 1997). Nietfeld & Schraw emphasized that strategy instruction improved monitoring by providing a transparent basis for the evaluation of one's problem solving. The authors stated that this case may be true even if the strategy instruction does not include explicit monitoring training.

Subramaniam (2009) reported a positive impact on student achievement when teachers planned and implemented strategies. Reflecting on the thinking process of teaching revealed that teachers used different criterion in the selection of their predominant teaching strategies. The approach they used demonstrated critical analysis based on strengths, weaknesses, perceived opportunities, and perceived threats. As a result of this planning and liberate application to practice, the teachers' instructional practices became customized (Subramaniam, 2009).

Monitoring student learning aids the teacher in making informed pedagogical decisions to help each student according to the particular needs of the student. The educator must understand what motivates the student (Walter & Hart, 2009). Influences on motivation include social pressures to not appear smart and choices to purposefully not engage in a mathematics activity. Relating interest and motivation, Koaler, Abumert, and Schnabel (2001) found that students who demonstrated and reported higher levels of interest in mathematics tended to enroll in higher level courses as well as demonstrate higher levels of achievement. Monitoring and awareness of the levels of student engagement and interest allow the teacher to adjust instruction more quickly according to student need.

Teaching includes the critical and creative thinking processes of the teacher. It also includes the transfer of these skills to the teachers' authentic instructional practices. Subramaniam (2009) stated that, "The skill of adapting, adopting, modifying, and consolidating appropriate teaching practices taps upon the metacognitive dimension of the teacher (p. 741). The author emphasized that the "thinking about thinking" was involved in the planning of lessons, 'real time' strategy adjustment and implementation, as well as post implementation evaluation are essential elements of the monitoring, evaluation, and justification of the teaching processes (Subramaniam, 2009).

Dewey (1933) emphasized that reflective teaching enables teachers to mediate creatively and integrate externally developed frameworks and concepts for teaching and learning. Teaching is conceptually described as an idealistic application of the knowledge of content, the knowledge of pedagogy, the pedagogical content knowledge, and pedagogical content knowledge of technology acquired during teacher education and professional development to authentic learning situations. There are very few guidelines to be following for the handling of crises in 'real time' within the classroom (Subramaniam, 2009).

Donovan, Bransford, and Pellegrino (1999) emphasized the following implications for bridging research to practice in teaching.

- Teachers must draw out work with the preexisting understandings that their students bring with them.
- Teachers must teach some subject matter in depth, providing many examples in which the same concept is at work and providing a firm foundation of factual knowledge.
- The teaching of metacognitive skills should be integrated into the curriculum in a variety of subject areas. (Donovan et al., 1999, pp. 15-17).

The prior knowledge that students bring to the classroom can be quite powerful and influential in student learning. Teachers must monitor and evaluate the previous knowledge of their pupils and make connections to that knowledge to improve student understanding and performance (Donovan, Bransford, & Pellegrino, 1999; Nietfeld & Schraw, 2002). Misunderstandings that challenge or impede learning should be sought out, identified, and replaced with appropriate understandings. Teachers must acquire the skills for identification, monitoring, and evaluating the understandings and misunderstandings of their students. Schools of education should support preservice and current teachers with training in these skills through coursework and professional development (Donovan et al., 1999).

Metacognition includes higher order thinking. Part of this higher order thinking is an awareness of that strategies leading to that type of thinking (Prytula, 2012; Zohar & David, 2009). Zohar and David (2009) described this thinking as deeper than the cognition required for teaching. Prytula accentuated this concept in the statement "teacher metacognition is the conscious realization that there is more profound thinking that motivates or influences one to regulate one's own learning or the learning of others within an environment" (p. 118). Because student achievement is impacted by metacognitive knowledge of strategies and tasks, many researchers believe that teaching today requires that educators should explicitly instruct the skills and strategies necessary for the performance of metacognitive activities (Lee et al., 2010; Pintrich, 2002a; 2002b). To be able to carry out these duties, teachers must be metacognitive individuals (Prytula, 2012; Schraw & Moshman, 1995). Teaching experience in itself may impact the level and effectiveness of teacher metacognition (Zohar, 1999). Lee et al. reported no significant differences in teacher metacognition accountable to education level existed in the results of their study with the exception of evaluation. The researchers explained that high academic achievers more adequately monitored and evaluated their learning practices. In addition, this study found no significant differences in teacher metacognition that could be accounted to gender (Lee et al., 2010). Regarding teacher experience, monitoring/regulation and procedural knowledge demonstrated significant differences in the metacognitive practices of teachers (Lee et al., 2010). The authors stated that the teachers' level of metacognition increased due to their experiences of teaching. Thus, they suggested that preservice teacher training could be improved by the providing of classroom experiences prior to their attendance in teacher education courses. Lee et al. (2010) emphasized that the increased level of metacognition gained by classroom teaching experience should improve the learning of the preservice teachers through the exposure to differing instructional practices and theories.

Prytula (2012) investigated the development of teachers' metacognition within the environment of a professional learning community. She demonstrated that this environment was suitable for the cultivation of teacher metacognition. The teachers developed their metacognitive theories and practices through the process of describing their metacognitive experiences. The descriptions demonstrated evidence of emerging comprehension of how the teachers began to take control of their learning and assisted with the learning of others (Prytula, 2012). The results of the study by Prytula provided evidence that the professional learning community was an efficient structure for the advancement of professional development for teachers, as well as the promotion of higher order thinking and metacognition. This study supported the findings of a previous study (Veenman et al., 2006) that demonstrated that learning environments, such as professional learning communities, have an impact on the growth and development of teacher metacognition. Professional learning communities must encourage learning to occur from the inside and move outward, in order to have this impact. Planning, monitoring, and regulating are three of the components of metacognition that influence instructional practices (Lee et al., 2010). Findings of recent teaching and learning research can be used to inform, develop, and improve instructional practices. Research about teacher metacognition could be incorporated into both preservice and inservice educational experiences to promote the development of an emphasis on thinking and reasoning, as well as metacognition (Prytula, 2012).

Duffy et al. (2009) described the necessity of learning about teachers' metacognition while cautioning that teaching practices can never be compacted into a neat and rigid algorithm in the statement:

> On the surface, then, the best teachers have proactive states of mind and emotional strength which allows them to 'take charge' of the complexities and uncertainties of daily teaching. The assumption is that they are metacognitive. That is, they make adaptive decisions as they teach because the unpredictability of the classroom and the nature of students' learning means that teaching can never be completely routinized. (Duffy et al., p. 246)

During scaffolding, educators provide clues and use questioning and clarification techniques, as well as elaboration to meet the varying needs of their students. These actions are assumed to be metacognitive in nature by the demands of instantaneous thought and action that are required in order to provide spontaneous scaffolding to meet student needs. In deciding how and when to insert these spontaneous scaffolds, teachers must regulate and control their knowledge, thinking, and actions (Duffy et al. 2009). When teachers encounter unanticipated challenges, problems, or new situations, metacognition allows them to function to meet the needs required by the circumstances. Parsons (2008) noted that teachers adapted their instruction in more thoughtful ways when they provided authentic and challenging instruction rather than worksheets that tend to constrict the assignment. Duffy et al. reasoned that this phenomenon may indicate that a relationship exists between the type of instruction a teacher provides and the level of the teachers' metacognitive thought.

Metacognition and Teaching Mathematics

The majority of mathematics teachers agree that the primary goal of mathematics education is to assist with the development and improvement of the students' problem solving abilities. How this objective is achieved depends on a great number of factors. The teacher must consider a wide variety of issues and make numerous decisions in order to accomplish this task (Lester, 2013). Lester described problem solving as "an activity requiring an individual (or group) to engage in a variety of cognitive actions each of which requires some knowledge and skill, and some of which are not routine" (p. 248).

Mathematics teachers must come to the profession with the experience of in-depth study and application of the content. He or she must be familiar and comfortable with the process of inquiry within the discipline. The mathematics teacher must also understand the relationship between information and the concepts that assist with the organization of that information within the discipline of mathematics and its subdivisions in order for the teacher to develop strong pedagogical skills. Coursework and professional development experiences designed specifically for teachers may be necessary to assist teachers in attaining this goal (Donovan et al., 1999). Metallidou (2009) stated, "It is assumed, nevertheless, that inservice teachers' metacognitive knowledge is a combined product of their vocational experience within the educational domain and their age" (p. 77).

Lester (2013) stressed that metacognition is one of the influential driving forces that greatly impact problem solving success. The ability to monitor and regulate cognitive behaviors is critical to successful problem solving. Lester stated that very little research has been conducted that demonstrates whether students can be taught these metacognitive behaviors. Researchers have shown that metacognitive behaviors of mathematics students can be improved (Lester, Garafalo, & Kroll, 1989; Schoenfeld, 1992). The proficiencies that teachers need to be able to provide instruction effectively for the purpose of improving student metacognitive abilities have not been adequately researched and identified (Lester, 2013). Lester cautioned that a teacher's ability and expertise in problem solving should not be equated with the proficiency to instruct students in problem solving. He stated that future research on mathematical problem solving should focus on the pedagogical and mathematical knowledge a teacher should possess, as well as the necessary proficiencies.

Many students are not aware of the importance of metacognition in learning because metacognition often occurs as a process of internal dialogue. Additionally, because metacognition is frequently associated with the learning of reading it may not be deemed as important to mathematics by students and mathematics teachers. Teachers of mathematics must explicitly emphasize the importance of metacognition. This emphasis must accompany and be integrated into the instruction of mathematics because the type of monitoring required for the learning and performing of mathematics is not exactly like that of reading or other disciplines. Differences in the application of vocabulary or the computations required by the vocabulary exist within the subdivisions of mathematics as well. Monitoring of student selection of strategies will help the mathematics teacher assess the comprehension of the student and allow for the adaptation of instruction to meet student needs if necessary. Student achievement can be enhanced through metacognitive instruction in mathematics. Students that learn to monitor and evaluate their progress during the problem solving process will develop the skills and ability to learn independently. The periodic monitoring and evaluation of progress toward the desired goal assists a student with the determination of whether strategy selection was appropriate, should be adapted, or replaced. The consciously designed and executed incorporation of metacognition instruction into the mathematics curricula across age levels and courses will improve the performance and independence of students. The development and application of strong metacognitive strategies and learning to teach metacognitive strategies in the mathematics classroom should be an integral part of the curriculum of schools of education (Donovan et al., 1999).

The need to monitor and regulate cognitive activity must be strategic for both teacher and learner. Teachers, however, have the additional responsibility and obligation to promote content learning, make instantaneous decisions, identify situationally appropriate strategies, and adjust instruction to meet the needs of individual students (Duffy et al., 2009). Schute and Kim (2014) described formative assessment as a progressive method of evaluating student progress and achievement for the purpose of determining whether the instruction should be adjusted. Formative assessment provides information to assist the teacher in the process of monitoring and evaluating student performance, as well as instructional effectiveness on the part of the teacher.

Incorporation of formative assessment into the daily classroom routine and curriculum allows the teacher to make informed decisions for the adjustment of instruction and the enhancement of learning in a timely manner. Because this type of assessment is administered much more frequently than summative assessment, it has an enormous potential for supporting learning across the content areas, including mathematics. Formative assessment provides educators with evidence about the quality of student learning, the level of student understanding, and the level of student engagement. Students are directly involved in the process that allows for feedback to be provided more quickly if not immediately. The student can receive feedback that may assist with the acquiring of insight about how to improve as a learner (Schute & Kim, 2014). Lester (2013) stated that "For non-routine tasks, a different type of perspective is required, one that emphasizes the making of new meanings through construction of new representations and inferential moves" (p. 255). Formative assessment can be the vehicle that allows the teacher to monitor the student's challenges briefly and provide instantaneous feedback for guiding inferences and the construction of new meanings.

A teacher is more than a change agent the influences instruction in order to attain the desired outcome. The teacher is a part of a dynamic system of classroom interaction that also includes the social culture of the classroom, the available tools and learning supports, and the student's individual needs, as well as the nature of the mathematical task at hand (Lester, 2013). Teachers need to be aware of when their students are experiencing cognitive overload due to the complexity of the task and poor problem solving abilities. For these students, the sorting out of irrelevant information may become difficult. Diagrams and illustrations can be visuals aids or distractions. The requirement of switching attention between two sources of information, the problem description and the diagram/illustration, in itself places a demand on the working memory resources. Additionally, the level of integration that is required to comprehend the material also impacts the load on the working (Berends & van Lieshout, 2009). As problems become more demanding, the student cannot simply apply the previously learned procedure (Lester, 2013). This phenomenon requires an element of awareness on the teacher's part during the planning phase, as well as the monitoring phase of the mathematics activity. Finally, awareness of this phenomenon during the evaluation phase of the lesson can help the teacher make adjustments for future implementations of the learning activity. Metallidou (2009) emphasized that the ability to monitor and exercise control over the problem solving process is highly involved with the development from novice to expert.

Berends and van Lieshout (2009) demonstrated that the performance in arithmetic word problems is not necessarily improved by the addition of graphics. Poor arithmeticians were found to have a lower working memory capacity than more skilled problem solvers. Illustrations can increase the time required for processing without positively impacting the learning process. When integration of the information in a graphic is essential to the solving of the problem, the learner may not reach a correct solution due to the fact that the formation and comprehension of the association between elements of arithmetic word problems and the schema of the solution is becoming difficult (Berends & van Lieshout, 2009). Proficient and effective mathematics teachers must be good at:

- Creating a classroom environment that is safe for taking risks and includes a culture that promotes learning, exploration, and sharing
- Designing and selecting appropriate tasks and activities
- Keeping learning activities appropriately challenging for the students

- Monitoring students, listening, making sense of their actions, and taking the appropriate actions as necessary
- Observing, monitoring, and being familiar with the methods that learners use to solve problems
- Taking the appropriate action and/or saying the right thing when necessary and appropriate (Lester, 2013; 2010).

Summary and Conclusions

This research study investigated the application of metacognition for the teaching and learning of mathematics. Metacognition was defined and described. The literature reviewed for this chapter was broken down into seven focus areas. Each focus area discusses a particular aspect of the conceptual foundation for this research study. The fundamental concepts of metacognition that known and suggested to student academic performance those notions of metacognition that aid in the improving the effectiveness of teaching were discussed. The literature regarding the teaching and learning of mathematics reviewed the learning of number sense, computational fluency, and problem solving which are areas of current interest in terms of mathematical literacy. A general overview of the impact of metacognition on the improvement of student academic performance was provided.

Computational fluency, number sense, problem solving, and making connections of mathematics are areas of great concern in today's educational paradigm. The goal is to help students become independent learners (Balcikanli, 2011) of mathematics. As the neuroscience and educational research become more integrated new insights may be revealed to assist with the improvement of instruction for inservice and preservice teachers. Metacognition offers promise for the improvement of the teaching and learning of mathematics. It is known to improve student achievement through the planning, monitoring and execution of problem solving. Metacognition also plays a role in strategy selection and internalization of new skills and knowledge. The variables of age, gender, teaching experience, and grade level were discussed in terms of their relation to metacognition in teaching and learning.

Duffy et al. noted, “metacognitive action by teachers is situational, varying as a function of setting, students, situations, and career level” (p. 244). Lester (2013) stated that “The challenge, then, is to determine ways to provide these teachers with opportunities to acquire the proficiencies needed to become craftsmen: opportunities that are my view are best provided through apprenticeship experiences in their real-world context and situation” (p. 263). One of these proficiencies is metacognition for the teaching and instruction of mathematics. The literature reviewed in this section described how metacognition is used and necessary for the teaching and learning of mathematics. In planning, evaluating, and revising of instruction or in monitoring and regulation of one’s personal learning, there exist numerous demands for the development of metacognitive awareness, knowledge, and regulatory skills. Lester (2013) suggested that the preservice teachers could receive some of the experience necessary to develop their craft and expertise through appropriately designed apprenticeships.

Prytula (2012) stated that educators could develop and nurture metacognition and other necessary skills through a supportive learning environment in professional learning communities. She emphasized that through collaborative learning and support, a professional learning community has the power to generate long-term impact and transform an organization. Some level of metacognition is likely to arise when teachers are engaged in collaborative problem solving and deeper reflective thinking encouraged within the professional learning community environment.

Lee et al. (2010) stressed that teacher metacognition influences lesson planning, as well as the manner and level of engagement of the students during instruction. Through frequent deliberate conscious and mindful actions, including metacognitive thought, expert teachers effectively instruct students according to their needs (Duffy et al., 2009). Investigation of the invisible actions and thoughts will assist in providing information for the preparation of new teachers and the development and improvement of inservice teachers. Duffy et al. described one of the challenges of researching the use of metacognition for instruction as “the difficulties in ‘getting inside teachers’ heads’ to gather data that substantiate that teachers are metacognitive” (p. 242). This research study provided additional insight about the use of metacognition by mathematics teachers, as well as insight about the use of metacognition for teaching and learning in general.

Chapter 3: Research Method

Introduction

The purpose of this study was to provide additional insight about the metacognitive processes of mathematics teachers. I also sought to investigate the predictors of teacher metacognitive awareness. I examined how the metacognitive knowledge and practices of mathematics teachers with different levels of experience impact their instructional quality and student achievement learning as described by the National Advisory Panel (2008). In addition, information attained by this study will provide a foundation regarding the impact of the teacher as demonstrator of metacognitive practices for the purpose of learning mathematics (Veenman et al., 2006).

This chapter outlines the methods that I used to answer my research questions and hypotheses. The methodology and design used in this investigation is discussed in this chapter. The targeted population, sampling size and methodology, instrumentation, and the selected data collection as well as the statistical analysis procedures are also provided. Information is also provided about the protection of study participants and issues of reliability and validity. This chapter concludes with a summary of the research design, sampling methodology, and administration of the online survey. Also included is an overview of the method of statistical analysis for all data collected.

Research Design and Rationale

This study used the MAIT (Balcikanli, 2011) to collect information about mathematics teachers' use of metacognition. Key variables included age (IV-1), gender (IV-2), type of teacher preparation (IV-3), grade span of mathematics instruction (IV-4), number of years of education (IV-5), degrees earned (IV-6), age when entered the teaching profession (IV-7), number of years of teaching experience (IV-8), and any interruptions in teachers' years of experience (IV-9). I sought to investigate the impact of these independent varialbes as potential predictors of six subfactors of teacher metacognitive awareness. The dependent variable subfactors examined are declarative knowledge, procedural knowledge, conditional knowledge, planning awareness, monitoring awareness, and evaluating awareness. The most influential predictors of mathematics teachers' metacognitive awareness were selected from the demographic and genetic variable information collected with the MAIT survey using a stepwise multiple regression analysis. The multiple regression analysis was performed to examine each of the six research hypotheses. Some of the demographic variables such as age and number of years of teaching experience, served as ordered predictors of the use of the metacognitve subfactors by the mathematics teachers. Other demographic variables, such as grade level of instruction, served as unordered predictors of these subfactors of metacognition (Green & Salkind, 2008).

A quantitative research design allows a researcher to compare the potential concurrent impacts of multiple variables upon behavior (Green & Salkind, 2008). This design enables the researcher to quantify the feedback of large samples of participants on a standardized set of questions (Creswell, 2009). Data can then be analyzed using statistical procedures for comparison and testing of hypotheses or theories (Creswell, 2009). I used a quantitative research design because I sought to identify and statistically analyze the trends, attitudes and experiences of mathematics teachers regarding their metacognitive awareness of the use of appropriate instructional strategies to meet the needs of their students. Quantitative survey research relies on the use of a larger sample sizes than that needed in qualitative research (Field, 2013; Patton, 2002). The quantitative approach is appropriate for surveys with closed ended questions, such as the MAIT. Qualitative research is better applied to exploratory investigations for which the variables may not be known prior to the investigation. It is better suited for smaller sample sizes and for questionnaires or interviews responses open ended responses. Qualitative research approaches are appropriate when attempting to explain phenomenon or explore their meanings (Creswell, 2009; Patton, 2002). A mixed methods design is appropriate when neither a quantitative or qualitative approach is sufficient. This design is used when both qualitative and quantitative data are collected (Creswell, 2009; Patton, 2002). A mixed methods approach is appropriate when there is a need to augment a study with a second source of data (Creswell & Clark, 2007).

Metacognitive awareness cannot be directly observed and is difficult to study. Duffy et al. (2009) described one of the challenges of researching the use of metacognition for instruction as “the difficulties in ‘getting inside teachers’ heads’ to gather data that substantiate that teachers are metacognitive” (p. 242). The investigation of another person’s thoughts and reflection activities can present numerous challenges. Survey research allows the researcher to create a numeric representation of trends, attitudes, or behaviors of a sample of the study population (Creswell, 2009). By using a survey design, I was able to collect and analyze a large amount of data from a large geographic area in a short amount of time. The design also provided the opportunity to study a large sample of mathematics teachers with diverse teaching experiences and diverse teaching environments. The results of this quantitative survey research study provided additional insight into the use of metacognition by mathematics teachers, as well as insight into the use of metacognition for teaching and learning in general.

The online administration of survey research reduced the time that was necessary for data collection. Survey research provides a platform for secure data collection and management. The ease of data collection and low cost expedited the online completion and collection of the survey data. The online administration also offered an opportunity for a large number of participants to complete a standardized survey in a very short amount of time across a broader geographic area that could be achieved by a solo researcher.

Methodology

Population

Mathematics teachers of Grades K-12 in the United States constituted the population for this study. It is difficult to estimate the size of this population since many teachers of kindergarten through Grade 8 instruct in multiple content areas while holding an elementary education certification and not a content specific teacher certification. There exists an overlap in the stratification of the grade levels for the types of schools especially with that of the middle grades (NSF, 2014). According to the NSF (2016), there were approximately 509,000 public school teachers that taught mathematics and/or science in 2011. The majority of content specific teachers, 415,000, taught in high schools and middle schools. In this same report, for 2011, the number of elementary level public school teachers was estimated to be 1.8 million with the majority of these teachers providing instruction in other content areas as well as in mathematics and science (NSF, 2016). The cluster sample was necessary due to the large size of the population of teachers of mathematics.

Creswell and Plano Clark (2007) stated that the sample size has a direct impact upon whether a study may qualify as a rigorous study. The goal is to reduce sampling error and thus making the findings a more accurate representation of the population. Creswell (2009) stated that the population of the study should be identified, and the sampling design should be representative of the overall population. In the academic year of 1999-2000, the number of teachers teaching mathematics was approximately 182,000 in the academic year of 1999-2000. NCTM has approximately 80,000 members (NCTM, 2013). The *State Indicators of Science and Mathematics Education:* 2007 report contains a compilation of 2006 data collected from the state departments of education. This report written by Blank, Langesen, and Petermann (2007) indicated that there may be as many as 244,839 teachers instructing mathematics in grades 7-12. The National Council of Teachers of Mathematics estimates that there may be as many as 300,000 teachers of mathematics in middle and high schools (NCTM, 2015).

Sampling and Sampling Procedures

The difficulty, impracticality, and extreme cost of including every member of a population in a research study created the necessity of selecting a representative sample from a population. It is for this reason that generalizations about populations are drawn from inferences collected through a research study that examines a representative sample of a population. As Frankfort-Nachmias and Nachmias (2008) emphasize, “Researchers can draw fairly precise inferences on all those units (a set) based on a relatively small number of units (a subset) when the subsets accurately represent the relative attributes of the entire set” (p. 163). The choice of how the subset is selected is referred to as the sampling method. The selected sampling must be appropriate to the design, purpose, and population of the research study.

Cluster sampling is commonly used in quantitative studies with large samples. Frankfort-Nachmias and Nachmias (2008) stated that this sampling method is least expensive to conduct. The lower cost makes these larger scale studies feasible. Cluster sampling involves the selection of the population to be studied, the selection of a large group subset of the population referred to as a cluster, and the selection and identification of smaller sampling unites from the cluster. Creswell (2009) suggested that cluster sampling would be appropriate when attempting to locate individuals as participants for a study from a population that it is very difficult or impossible to establish a complete list of members or elements. Cluster sampling allows for the use of the membership lists of particular organizations to select participants that are appropriate for the study. In the case of this research study, the identified population for study was teachers of mathematics in the United States. The sample groups within this population included a random selection of the membership of the National Council of Teachers of Mathematics, the groups of grade levels these mathematics teachers instruct, and the other groups of the demographic variables that they represent. If the number of responses allows, the sample could be stratified purposefully to be sure both genders, male and female, and all grade spans (K-2, 3-5, 6-8, and 9-12) are represented. The volunteer participants for this study were members of the National Council of Teachers of Mathematics. A limiting factor to increasing the sample size is the fee per 1000 contact names and addresses of NCTM members. The membership information is managed by an outside organization which provided access to approximately 5000 randomly selected names and addresses.

The value of 300,000 was examined as an approximate representation of the population. The selected confidence level for this investigation is 95%. The 95% confidence is typical for most research. The confidence interval constructed at this level would imply that 95% of the time the mean for similar research will lie within the range of the confidence interval constructed. Smaller confidence intervals, such as a 90% confidence level, require smaller sample size but increase the chance that the true mean value of the population may not be contained within the constructed interval (Field, 2013). In short, a lower level of confidence lowers the chance that the calculated results accurately represent the population from which the participant sample was selected.

Size is equally important to strategy (Creswell 2007). The size of a quantitative study should be large enough to provide a normal distribution of data and allow for the findings of the study to be generalized to the intended population. Since it is impossible to be one hundred percent sure about any behavior, phenomenon, attribute, or behavior that involves human subjects, social scientists frequently choose the 95% confidence level (Field, 2013). In order to achieve a large enough sample to accomplish this task, a portion of the member contact list will be purchased from the company that manages the membership list of the National Council of Teachers of Mathematics. The number of middle school and high school teachers, teaching mathematics, is currently is estimated to be between 244,000 and 300,000. NCTM has approximately 80,000 members (NCTM, 2013). This would make the organization the most attractive for achieving the sample size of 500 from a total of 5,000 requests for voluntary participation.

The MAIT and demographic portion of my survey study were administered via the internet using Google Surveys (Google Inc., 2014). As each survey is completed, the collected data was automatically entered into a Google Sheet (Google Inc., 2014). This data was then exported to Microsoft Excel (Microsoft Excel, 2010) to allow for additional editing that prepared the data in a format that was acceptable for SPSS version 21 (IBM SPSS Statistics, 2012). The descriptive statistical analysis, as well as the stepwise multiple regression analysis were conducted using SPSS. Analysis with G*Power 3.1 (Buchner, Erdfelder, Faul, & Lang, 2014) provided support to the large sample required for this study. The number of hypotheses created from the nine independent variable predictors to be tested created a necessity for a large sample size. The combined values of power, effect size, and sample size did suggest that there is value in conducting the study with a smaller or larger sample size should the response rate differ from the original goal of 500. The results indicated that for the Power of 0.80 there would be some value to conducting the study with a sample size as small as 54 and as large as 791. The actual sample size for this study was very close to the 114 with the medium effect. The results of the G*Power analysis are listed in Table 1 below.

Table 1

Analysis of Power and Effect Size Based Upon Sample Size

Effect size	A	Power	Sample size
0.02 (small)	0.05	0.80	791
0.15 (medium)	0.05	0.80	114
0.35 (large)	0.05	0.80	54

Procedures for Recruitment, Participation, and Data Collection

The randomly selected invitees from the membership list of the National Council of Teachers of Mathematics voluntarily elected to participate in this study. The NCTM has approximately 80,000 members (NCTM, 2013). This made the organization the most attractive for the desired sample size of 500. The smaller sample size prevented stratification of the sample into smaller grade level based subsets (Creative Research Systems, 2013). A limiting factor to increasing the sample size was the fee per 1000 contact names and addresses of NCTM members. The membership information is managed by an outside organization and the 5000 member names and postal addresses were randomly selected by that organization. The response rate to the questionnaire became highly important and increasingly challenging. The total design method will be applied to increase the response rate if necessary. In order to increase the possibility of collecting a minimum of 500 teacher responses, an expected response rate of ten percent was assumed and 5000 members of the NCTM will be contacted as potential participants for this survey study. The total design method includes mailings and follow-up communication if a forwarding address was provided to the postal service by the potential participants (Frankfort-Nachmias and Nachmias, 2008).

The NCTM members will be contacted via mail. The mailing will contain an introduction to the research, a statement of anonymity, and the link to complete the survey created in GoogleForms (2014). All mailing correspondence with participants and potential participants included a statement of informed consent, the contact information of this researcher, and the contact information for Walden University. Participant questions and additionally requested information were addressed via email. While age and gender information was collected, names, addresses, and other identifiers are not associated with this information. Thus, it was not possible to connect the email addresses of the potential participants with the data collected via the survey. The online administration of this survey permitted the immediate and automatic submission of the data at the time the participant completed and submitted the survey. The data collected included the 24 item responses of the MAIT and the responses to the items to be analyzed as potential independent demographic and genetic predictor variables. These demographic and predictor variables include: age (IV¬ 1), gender (IV-2), type of teacher preparation (IV-3), grade level of mathematics instruction (IV-4), number of years of education (IV-5), degrees earned (IV-6), age when entered the teaching profession (IV-7), years of teaching experience (IV-8), and any interruptions in teachers' years of experience (IV-9). No information will be collected or stored that is not necessary for the completion of this study.

The response data was reviewed in spreadsheet form for missing or invalid responses to the questions. The ideal response rate for this study was ten percent for a total of 500 complete responses. It did not become necessary to remove any of the cases because of incomplete or invalid responses. The only people having access to the response data were the researcher and the members of the Dissertation Supervisory Committee. Participants were not contacted in order to attain the minimum number of required responses. The collected data was then transformed into an SPSS version 21 (IBM SPSS Statistics, 2012) file for analysis at this point. The data was reviewed for translation errors, but each data point/response did not have to be individually typed into SPSS thus saving a great deal of time.

Instrumentation

The Metacognitive Awareness Inventory for Teachers (Balcikanli, 2011) was administered online to mathematics teachers on a voluntary participant basis. Permission to use the MAIT for this study was received from Cem Balcikanli, a Lecturer at Gazi University in Turkey and the creator of the instrument. A copy of this permission is included in the Appendix of this document. The MAIT is a 24 item survey that examines the two major components of metacognition and the six of the subfactors of these two components that are frequently used by teachers. The two major components of metacognition are knowledge of one's cognition and regulation and control of one's cognition. The subfactors of the metacognitive knowledge examined by the MAIT include: declarative knowledge, procedural knowledge, and conditional knowledge (Balcikanli, 2011; Schraw, 2001; Schraw & Moshman, 1995). The subfactors of the component of metacognitive regulation and control include: planning, monitoring, and evaluation (Balcikanli, 2011: Schraw & Moshman, 1995).

The chosen instrument, the Metacognitive Awareness Inventory for Teachers (MAIT), was tested and refined in an initial study conducted by its author Balcikanli (2011). The MAIT was constructed from the Metacognitive Awareness Inventory of Schraw and Dennison (1994) and refined through a three phase study conducted by Balcikanli (2011) for the purpose of examining the metacognitive awareness of teachers. Due to this fact, the instrument did not need to be refined in a pilot study prior to its use in the quantitative portion of my research. The MAIT has been used and validated by Balcikanli (2011) in an investigation of the metacognitive awareness of 323 student teachers in an English Language Teaching Program.

Balcikanli (2011) conducted the Kaiser-Meyer-Olkin Measure of Sampling Adequacy and the Bartlett Test to establish the validity of his instrument. Balcikanli (2011) used these results to justify the appropriateness of the factor analysis conducted upon the data he collected from the student teachers using the MAIT. Cronbach's Alpha was used to test the reliability of the survey instrument. The analysis of the five point Likert-type scaled displayed high alpha scores, from 0.79 to 0.85 indicating the reliability of the MAIT (Balcikanli, 2011). Statistical results of validity and reliability from this study examining the use of metacognition by mathematics teachers will be compared the results of Balcikanli (2011) in his investigation of the use of metacognition by 323 student teachers in an English Language Teaching Program.

Operationalization

The 24 items of the MAIT measure the six subfactors of metacognition. Each of the subfactors has four items on the MAIT that are used to measure one of the specific subfactors. A five point Likert type scale is used to provide a uniform scale for the respondent to rate his or her level of awareness of that particular metacognitive subfactor. The MAIT is located in the appendix A of this study. The Likert-type scale used in the MAIT is: (1) Strongly Disagree, (2) Disagree, (3) Neutral, (4) Agree, and (5) Strongly Agree. The subfactors that were measured through the administration of the MAIT using this Likert-type scale. The subfactors and indepedent variables are defined below:

Age (IV-1): Current age of the mathematics teacher at the time of completing the survey.

Age when entered the teaching profession (IV-7) differentiated the study participants by their age at the time the participants began their teaching career.

Conditional knowledge is the knowledge of when and why to use a skill. It is the comprehension of which skill is appropriate for use and at what time it is appropriate to use the skill. Conditional knowledge includes comprehension why procedures should be used or used and the limitations of the procedures (Balcikanli, 2011; Pintrich, 2002). Items 3, 9, 15, and 21 of the MAIT were designed to measure conditional knowledge.

Declarative knowledge is the knowledge about something. It includes an individual's conceptions and beliefs about something (Balcikanli, 2011; Desoete, 2007; Schraw & Moshman, 1995). Items 1, 7, 13, and 19 of the MAIT were designed to measure declarative knowledge.

Degrees earned (IV-6) defined the mathematics teacher participants of this study by the field, level, and number of degrees earned.

Demographic Variables are characteristics that define groups within a population. The independent variables defining differing characteristics of the research population of mathematics teachers for this study include the type of teacher preparation (IV-3), grade level of mathematics instruction (IV-4), number of years of education (IV-5), degrees earned (IV-6), age when entered the teaching profession (IV-7), years of teaching experience (IV-8), and interruptions in teaching experience (IV-9).

Evaluating awareness is the self-assessment and the regulation of one's learning upon completion of the task. It includes the review of the match/mismatch of the intended goal and the actual outcome as well as the revaluation of one's goals after the completion and evaluation of the task (Balcikanli, 2011; Schraw & Moshman, 1995). Items 6, 12, 18, and 24 of the MAIT were designed to measure evaluating.

Gender (IV-2): Gender reported by the teacher at the time of completing the survey.

Genetic Variables are variables that an individual cannot control, such as age and gender. The genetic variables for this study are the independent variables of age (IV-1) and gender (IV-2).

Grade level of mathematics instruction (IV-4) for this study was differentiated to the greatest degree possible by the individual grade or grade span of instruction. A Kindergarten teacher may instruct only Kindergarten level of mathematics, but a high school and/or middle school teacher may instruct multiple grade levels.

Interruptions in teachers' years of experience (IV-9) was designed to take into account interruptions in the teaching experience of the study participants that removed them from teaching in the classroom such as absences due to long term illness, pregnancy or family leave, career changes, and/or absences taken for additional education.

Monitoring awareness is a regulatory skill of the quality of performance and comprehension. It is a dynamic regulatory and control process that is conducted at periodic intervals throughout the execution of a task (Balcikanli, 2011; Schraw &

Moshman, 1995). Items 5, 11, 17, and 23 of the MAIT were designed to measure monitoring awareness.

Number of years of education (IV-5) differentiated the mathematics teacher participants by the number of years of post-secondary education they had completed.

Planning awareness is a regulatory skill of metacognition. It includes the selection of the appropriate strategies, the timing of the use of the strategies, and allocation of resources (Balcikanli, 2011; Schraw & Moshman, 1995). Items 4, 10, 16, and 22 of the MAIT were designed to measure planning awareness.

Procedural knowledge is the knowledge of how skills are to be used and/or applied (Balcikanli, 2011; Deseote, 2007). It is the knowledge about the “execution of procedural skills” (Schraw & Moshman, 1995, p. 353). Items 2, 8, 14, and 20 of the MAIT were designed to measure procedural knowledge.

Type of teacher preparation (IV-3) for this study was differentiated by whether the participant completed a traditional teacher preparation degree program, a content degree program with additional teacher preparation course work, a content degree program in mathematics, and/or a content degree program in another area of instruction.

Years of teaching experience (IV-8) differentiated the mathematics teacher participants of this study by the number of years the participants had been teaching.

Demographic and genetic independent variables to be evaluated as predictor variables included: age (IV-1), gender (IV-2), type of teacher preparation (IV-3), grade level of mathematics instruction (IV-4), number of years of education (IV-5), degrees earned (IV-6), age when entered the teaching profession (IV-7), years of teaching experience (IV-8), and any interruptions in teachers' years of experience (IV-9). A copy of the demographic survey that was administered for this study is located in the appendices of this document. The primary objective of this study was to determine which of these independent predictor variables function as predictors of the mathematics teachers' use of the subfactors of metacognition. Interruptions in teachers' years of experience (IV-9) were categorized and assigned values as necessary. Due to the lower than expected response rate, the grade level of mathematics instruction (IV-4) was grouped into grade spans as necessary for analysis.

Data Analysis

An analysis of the quantitative data collected from the surveys was conducted to determine any commonalities and differences emerging from the data collected about the two major components and the six subfactors examined by the MAIT regarding the mathematics teachers' use of metacognition. The data collected regarding each of the focus areas of metacognition and the six subfactors of metacognition was examined in each of the surveys. Demographic information also be collected from the volunteer participants included: age, gender, type of teacher preparation, grade level of mathematics instruction, number of years of education, all degrees earned, age when entered the teaching profession, and number of years of teaching experience, including any interruptions in the teachers' years of experience.

Stepwise multiple regression is a method of determining a set of variables that function as predictors of a particular dependent variable (Nathans, Oswald, & Nimon, 2012). In forward stepwise regression, the researcher chooses the first independent variable for entry into the regression equation. The equation is a model of the greatest bivariate correlation with the dependent variable (Nathans, Oswald, & Nimon, 2012). The second independent variable chosen for entry into the equation is responsible for the greatest increase in R^2 subsequent to the prediction strength of the first variable. As described by Field (2013), “This R^2 represents the amount of variance in the outcome explained by the model” (p. 302). To determine if the first independent variable maintains its strength as a statistically significant predictor, a second significance test is performed. If the first variable is no longer statistically significant, it is removed from the equation. The researcher repeats this process until all independent variables to be tested have been entered into the equation or the inclusion of the remaining independent variables to be tested does not produce a statistically significant increase in R^2(Nathans, Oswald, Nimon, 2012).

The stepwise method for this research study was performed using the Statistical Package for the Social Sciences (SPSS) software version 21 (IBM SPSS Statistics, 2012). The default method in SPSS is similar to the forward method. It differs in that each time a predictor is inserted into to the regression equation a removal test is conducted for the least useful predictor (Field, 2013). In SPSS, the regression equation is repeatedly evaluated to determine the strength of the predictors. As such, the regression equation is assessed repeatedly to see whether any of the predictors are redundant or unnecessary. Redundant predictors are removed. A researcher may elect to have SPSS perform the backward method of stepwise regression. This is the method begins with the placement of all the predictors into the model. The contribution of each of predictors is then calculated by examining the significance value of each predictor using the t-test. A comparison is then conducted using the probability value for the test statistic or the absolute value of the test statistic against a removal criterion (Field, 2013). If a predictor does not make a statistically significant contribution to the model, it is removed from the model. The model is then re-assessed with the remaining predictors (Field, 2013, pp. 322-323).

A stepwise multiple regression analysis was conducted to predict the overall impact of the demographic and genetic variables upon the use of the subfactors of metacognition by the mathematics teacher participants. Multivariate statistical analysis allows the researcher to investigate the potential impact of multiple variables upon behavior concurrently while also investigating the individual contribution of the variables (Green & Salkind, 2008). Multiple regression analysis allows for the examination of the impact of the demographic predictors upon the criterion of the metacognitive subfactors. It provides an examination of the naturally occurring levels of the predictors (Brace, Kemp, & Sneglar, 2000).

The calculated contribution of each of predictors of the dependent criterion metacognitive subfactor variables was tested for significance using ANOVA. The following results of these statistical procedures determined the accuracy of the proposed research hypotheses (Green & Salkind, 2008). The stepwise multiple regression analysis allowed for the determination of the best combination of predictor variables that impact the criterion (Myers, Gamst, & Guarino, 2012). In this study, stepwise multiple regression analysis would allow for the determination of the combination of genetic and demographic variables that serve as the most influential predictors upon the mathematics teachers' use of the metacognitive subfactor criterion. The stepwise multiple regression procedure provides a method for assessing the strength the relationship of each of the predictor demographic and genetic variables to the criterion metacognitive subfactors used by the mathematics teachers.

Research Questions and Hypotheses

RQ1: Do the demographic variables of: age, gender, type of teacher preparation, grade level of mathematics instruction, number of years of education, all degrees earned, age when entered the teaching profession, and number of years of teaching experience, including any interruptions in the teachers' years of experience predict or impact the mathematics teachers' awareness of their use of declarative knowledge in their mathematical instructional practices?

$H_0$1: There are no significant differences in the influence of age, gender, type of teacher preparation, grade level of mathematics instruction, number of years of education, all degrees earned, age when entered the teaching profession, and number of years of teaching experience, including any interruptions in the teachers' years of experience upon the declarative knowledge used by mathematics teachers as a part of their instructional practices.

$H_1$1: There are significant differences in the influence of age, gender, type of teacher preparation, grade level of mathematics instruction, number of years of education, all degrees earned, age when entered the teaching profession, and number of years of teaching experience, including any interruptions in the teachers' years of experience upon the declarative knowledge used by mathematics teachers as a part of their instructional practices.

RQ2: Do the demographic variables of: age, gender, type of teacher preparation, grade level of mathematics instruction, number of years of education, all degrees earned, age when entered the teaching profession, and number of years of teaching experience, including any interruptions in the teachers' years of experience predict or impact the mathematics teachers' awareness of their use of procedural knowledge in their mathematical instructional practices?

$H_0 2$: There are no significant differences in the influence of age, gender, type of teacher preparation, grade level of mathematics instruction, number of years of education, all degrees earned, age when entered the teaching profession, and number of years of teaching experience, including any interruptions in the teachers' years of experience upon the *procedural knowledge* used by mathematics teachers as a part of their instructional practices.

$H_1 2$: There are significant differences in the influence of age, gender, type of teacher preparation, grade level of mathematics instruction, number of years of education, all degrees earned, age when entered the teaching profession, and number of years of teaching experience, including any interruptions in the teachers' years of experience upon the *procedural knowledge* used by mathematics teachers as a part of their instructional practices.

RQ3: Do the demographic variables of: age, gender, type of teacher preparation, grade level of mathematics instruction, number of years of education, all degrees earned, age when entered the teaching profession, and number of years of teaching experience, including any interruptions in the teachers' years of experience predict or impact the mathematics teachers' awareness of their use of conditional knowledge in their mathematical instructional practices?

$H_0$3: There are no significant differences in the influence of age, gender, type of teacher preparation, grade level of mathematics instruction, number of years of education, all degrees earned, age when entered the teaching profession, and number of years of teaching experience, including any interruptions in the teachers' years of experience upon the *conditional knowledge* used by mathematics teachers as a part of their instructional practices.

$H_1$3: There are significant differences in the influence of age, gender, type of teacher preparation, grade level of mathematics instruction, number of years of education, all degrees earned, age when entered the teaching profession, and number of years of teaching experience, including any interruptions in the teachers' years of experience upon the *conditional knowledge* used by mathematics teachers as a part of their instructional practices.

RQ4: Do the demographic variables of age, gender, type of teacher preparation, grade level of mathematics instruction, number of years of education, all degrees earned, age when entered the teaching profession, and number of years of teaching experience, including any interruptions in the teachers' years of experience predict or impact the mathematics teachers' level of planning awareness used in their mathematical instructional practices?

$H_0$4: There are no significant differences in the influence of age, gender, type of teacher preparation, grade level of mathematics instruction, number of years of education, all degrees earned, age when entered the teaching profession, and number of years of teaching experience, including any interruptions in the teachers' years of experience upon the *planning awareness* used by mathematics teachers as a part of their instructional practices.

$H_1$4: There are significant differences in the influence of age, gender, type of teacher preparation, grade level of mathematics instruction, number of years of education, all degrees earned, age when entered the teaching profession, and number of years of teaching experience, including any interruptions in the teachers' years of experience upon the *planning awareness* used by mathematics teachers as a part of their instructional practices.

RQ5: Do the demographic variables of age, gender, type of teacher preparation, grade level of mathematics instruction, number of years of education, all degrees earned, age when entered the teaching profession, and number of years of teaching experience, including any interruptions in the teachers' years of experience predict or impact the mathematics teachers' level of monitoring awareness used in their mathematical instructional practices?

$H_0$5: There are no significant differences in the influence of age, gender, type of teacher preparation, grade level of mathematics instruction, number of years of education, all degrees earned, age when entered the teaching profession, and number of years of teaching experience, including any interruptions in the teachers' years of experience upon the *monitoring awareness* used by mathematics teachers as a part of their instructional practices.

$H_1$5: There are significant differences in the influence of age, gender, type of teacher preparation, grade level of mathematics instruction, number of years of education, all degrees earned, age when entered the teaching profession, and number of years of teaching experience, including any interruptions in the teachers' years of experience upon the *monitoring awareness* used by mathematics teachers as a part of their instructional practices.

RQ6: Do the demographic variables of age, gender, type of teacher preparation, grade level of mathematics instruction, number of years of education, all degrees earned, age when entered the teaching profession, and number of years of teaching experience, including any interruptions in the teachers' years of experience predict or impact the mathematics teachers' level of evaluating awareness used in their mathematical instructional practices?

$H_0$6: There are no significant differences in the influence of age, gender, type of teacher preparation, grade level of mathematics instruction, number of years of education, all degrees earned, age when entered the teaching profession, and number of years of teaching experience, including any interruptions in the teachers' years of experience upon the *evaluating awareness* used by mathematics teachers as a part of their instructional practices.

*H_1*6: There are significant differences in the influence of age, gender, type of teacher preparation, grade level of mathematics instruction, number of years of education, all degrees earned, age when entered the teaching profession, and number of years of teaching experience, including any interruptions in the teachers' years of experience upon the *evaluating awareness* used by mathematics teachers as a part of their instructional practices.

Threats to Validity

Improper application of inferences from the sample data could result in external threats to validity (Creswell, 2009). Care was taken to compare the results to previous studies using this instrument without improperly making generalizations to other populations or studies using alternate instruments. Application of the results of this study cannot be generalized to other cultures, populations, or time periods. Generalizations cannot be made to other groups, settings, or time periods can become external threats to validity due to the specific nature of the characteristics of the participants of this study (Creswell, 2009). Comparisons to other content teachers, mathematics teachers in other cultures, and groups of people other than mathematics teachers should be made with caution.

Internal threats to validity included the assumption that teachers of mathematics from grade kindergarten through grade twelve understand metacognition as defined for this study and recognize their use of metacognition during instruction to meet the needs of their students. Teachers must be aware of their thinking during instruction to be able to describe and evaluate the use of that thinking as a part of planning, monitoring, and evaluating their instruction of mathematics. Procedural knowledge, Declarative knowledge, and Conditional knowledge of teaching pedagogy as well as mathematics is required of mathematics teachers in order to perform their roles as instructors and facilitators in mathematics classrooms. An additional threat existed in that this study made the assumption that the participants of this study will complete the survey honestly, accurately, to the best of their ability, and without discussion with other participants.

This survey study was uniformly administered to the diverse population of K-12 mathematics teachers. The set of standardized questions, the ease of completion, and the small demand of time reduce some of the possible threats to validity. Additionally, the single administration of the survey eliminates threats such as maturation, diffusion, testing, and instrumentation threats. Less than anticipated response rate would reduce the sample size to less than 500 participants and thus reduced the effect size and confidence level while increasing the impact of extreme values to upon the regression design as described by Brace, Kemp, & Sneglar (2000). A smaller number of responses does not negate the study. A smaller response rate can impact the potential application and generalizability of the results. This was a special consideration for the selected method of cluster sampling which reduced the randomness of the selected sample from the population. The researcher was not involved with the selection of the sample. The 5000 names with associated addresses were randomly selected from the National Council of Teachers of Mathematics membership list by the employees at Marketing General Incorporated.

Ethical procedures

The contact information of potential participants was purchased from the National Council of Teachers of Mathematics via Marketing General Incorporated (NCTM, 2014). Potential participants were mailed a description of the study that included a statement of consent and confidentiality, as well as a link to complete the online survey. The recipients, were licensed teachers, and were by the implications of the licensing at a minimum age of 21 i.e. They were not minors, and were provided a letter of consent to utilize the data in a university based study, were provided with the information to make an informed and uninfluenced decision to either participate or not to participate in this study. Ethical care and concern was exercised throughout the duration of this research study. The guidelines for ethical behavior set in the Institutional Review Board (IRB) application were adhered to as required by Walden University. Data collected from all participants was securely handled during all phases of the research, to meet ethical, legal and privacy concerns of all participants and stakeholders.

Care was taken to protect the rights of all participants in this study. The survey was administered online via Google Forms (2014) which allowed for anonymity since the email address of the participant was either not collected. Submitted responses were immediately and automatically entered into a Google Sheet (Google Inc., 2014) that is associated with Walden University and is password protected. The researcher transferred the data from the Google Sheet to SPSS version 21 (IBM SPSS Statistics, 2012). The data and results of this study are stored in the password protected Google Drive of Walden University as well as a password protected secured USB drive. I am the only individual to have knowledge of the both the participant contact information and the responses. No demographic or other identifying information of the participants will be released. The data collected for this study will remain confidential and will be destroyed after a period of five years, as required by the IRB application located in the appendix of this document. The results of this study were be disseminated through ProQuest™ (2013) as required by Walden University. Additionally, the results of this study were made available to the National Council of Teachers of Mathematics and to Dr. Cem Balcikanli, Ph.D., the owner and designer of the Metacognitive Awareness Inventory for Teachers. The gratitude of the author of this study is extended to Dr. Balcikanli for the use of the Metacognitive Awareness Inventory for Teachers. His generosity is greatly appreciated.

Summary

This chapter provided an overview of the research design for this study. The method for sampling, the target population, and data collection procedures were also reviewed. Online survey administration of the Metacognitive Awareness Inventory for Teachers (Balcikanli, 2011) offered an extremely expedient, accurate, cost effective, and efficient method of gathering responses to research questions across a diverse geographic area. Stepwise multiple regression analysis will assist with the determination of the impact of multiple predictor variables. It is appropriate for the investigation of the highly abstract concept of metacognition and its multiple subfactors. The demographic and genetic variable data collected provide additional insight into the impact of these variables upon the use of metacognition by mathematics teachers. The results of the completed quantitative survey research study will be provided in Chapter 4. Chapter 5, of this study, provides a discussion and interpretation of the findings of the multiple regression analysis. Also included in Chapter 5 are the recommendations for further research, and the possible implications for positive social change.

Chapter 4: Results

Introduction

The purpose of this quantitative study was to provide new knowledge and insight about the relationship and impact of age (IV-1), gender (IV-2), type of teacher preparation (IV-3), grade level of mathematics instruction (IV-4), number of years of education (IV-5), degrees earned (IV-6), age when entered the teaching profession (IV-7), years of teaching experience (IV-8), and any interruptions in teachers' years of experience (IV-9) upon mathematics teachers use of subfactors of metacognition. Each of the six research questions and hypotheses addressed one of the six subfactors of metacognition investigated by the MAIT. The subfactors of metacognition investigated in this research study are: declarative knowledge, procedural knowledge, conditional knowledge, planning awareness, monitoring awareness, and evaluating awareness. In this chapter, I describe my data collection and analysis experiences. Survey items that address each of the specific subfactors of metacognition are discussed within the context of my research questions and the associated hypotheses. I then present and discuss descriptive statistics and results from my multiple linear regression analyses for each hypothesis. A summary of the results of the statistical analyses of the hypotheses is provided at the end of this chapter.

Data Collection

The original study was designed with the intent to email 5000 mathematics teachers of grades K- 12 who were members of the NCTM. Multiple communications and appeals with the Board of Directors of NCTM failed to gain permission to access the contact emails of this sample of members and mathematics teachers because of policy restrictions. The remaining option for the completion of this survey research study was to contact each of the members via a mailing via the United States Postal Service. The random selection of 5,000 names and addresses of the National Council of Teachers of Mathematics (NCTM) membership was purchased in July of 2015 from Marketing General Incorporated (MGI). An invitation to participate in this online survey was mailed to these members during the first week of August of 2015. Recipients of the mailing were supplied with a copy of the consent form for this research study that included the IRB approval number of Walden University and my contact information. From these 5,000 potential respondents, 167 of the invitations to participate were returned due to inability to deliver. One recipient of an invitation to participate had never taught in a K-12 classroom. He was a college professor, educational researcher, and member of the NCTM. This person determined that he was ineligible and stated that he would not complete the survey. Reminder cards were sent after approximately four weeks had expired with only 68 respondents completing the survey at that time. From the 4,833 remaining possible contacts, 120 participants volunteer to complete the online survey via Google Surveys (Google Inc., 2014). The online survey was closed after approximately eight weeks with 120 respondents having completed the survey at that time. The actual participation rate of 120 responses was below the 500 desired responses in the original design of this study. The response rate of 2.48% limited the number and types of analysis that could be performed.

One adjustment made from the original design of the study was the stratification of the teachers by grade span of instruction rather than a single grade of primary instruction. The variation of the grade level/span of instruction required the creation of the following groups: K–5, K–8, Grades 3–5, Grades 6–8, Grades 7 – 12, Grades 9–12, and Grades K–12. All responses of a single grade of instruction were placed into the lowest grade span of which they were an appropriate member. An example of this would be a response of instructing grade 2 mathematics. This response was placed into the grade span of K – 5 and appropriately coded for processing in SPSS version 21 (IBM SPSS Statistics, 2012). Also, the large range of varying type of teacher preparation experiences and post-secondary degrees earned by the participants of the study created the necessity of grouping the responses into categories. The categories created were as follows:

- Education degree fulfilling requirements for certification
- Degree in other field with additional course work
- Bachelor’s Degree in Mathematics
- Masters’ degree in Education or Math Education
- Masters’ degree in Mathematics
- Ph.D. in Mathematics
- Ph. D. in Education, Ph.D. in Mathematics Education, or Ed.D.
- Ph.D. other (such as Ph.D. in Physical Chemistry)

- Other (such as Linguistics)

The final area of consolidation of responses that was a result of the limited number of responses was that of the item requesting the mathematics teacher to describe any interruptions in his or her teaching experience. Just as with each of the aforementioned adaptations, the interruptions in teacher experience as described in the response provided by the teachers were grouped and assigned a numeric code for statistical analysis in SPSS version 21 (IBM SPSS Statistics, 2012). The interruptions were groups by duration and rate of as listed below:

- No interruptions
- Single interruption of less than one year (such as maternity or sick leave)
- Single interruption of 1-5 years
- Single interruption of 6-10 years
- Single interruption of greater than 10 years
- Multiple interruptions

Results

The data collected from the survey was automatically and electronically collected in a Google Sheet (Google, Inc., 2014). The response rate for the volunteer participants for this study was approximately 2.48% with the assumption that all of the unreturned mail reached the participants. Eighty-two of the participants were female (68.7%), ranging in age from 21 – 65 years with a mean age of 39.6 years. Thirty-eight of the participants were male (31.7%), ranging in age from 23–71 years with a mean age of 43.8

years. The overall mean age of the participants was 40.9 years. The grades of instruction ranged from K-12 with experience ranging from <1 (less than 1 year) through 40 years. Table 2 contains the data collected regarding the age and gender of the participants in this study.

Table 2

Age and Gender Statistics

	Men	Women	Total
N (%)	38 (31.7%)	82 (68.3%)	120
Age Range	48	44	50
Age Minimum	23	21	21
Age Maximum	71	65	71
Average Age	43.76	39.63	40.94
Median Age	41.5	39	40.5

The number of mathematics teachers was approximately 182,000 in the academic year of 1999-2000. The NCTM has approximately 80,000 members (NCTM, 2013). The State Indicators of Science and Mathematics Education: 2007 report contains a compilation of 2006 data collected from the state departments of education. In this report written by Blank, Langesen, and Petermann (2007), the authors indicated that there may be as many as 244,839 teachers instructing mathematics in grades 7-12. The number of participants represents only a very small sample of the NCTM, approximately 0.15%, of the 80,000 members of the organization. In reference to the estimates of the possible

182,000 and 244,839 K-12 mathematics teachers in the United States, 120 participants represent 0.0659% and 0.0490% respectively, but it does represent approximately 2.5% of the sample. Teacher training and certification requirements differ vastly across the United States. In some states, teachers of the elementary grades have very little mathematics as a part of their preparation experience. The teachers were asked to select the category that best described the route of training that they experience to attain certification. Table 3 contains the data referencing the type of teacher preparation that the participants in this study completed.

Table 3

Teacher Preparation Experience

Type of Teacher Preparation	N	%
Education Degree fulfilling certification requirements	25	20.8%
Degree in other field plus additional course work as required by certifying agency	20	16.7%
Bachelor's degree in Mathematics	20	16.7%
Master's Degree in Education	42	35.0%
Master's Degree in Mathematics	6	5.0%
Other – (Ph.D. in Mathematics, Education, Math Education, Physical Chemistry, Philosophy, or Ed.D.)	7	5.8%

The mathematics teachers were also asked to indicate the types of degrees they had earned and the number of years of post-secondary education that they had completed.

Many teachers were found to have multiple degrees. Some of the teachers had started with an Associate Degree and had continued to earn a degree that would allow them to teach in a classroom. The total number of degrees earned by the 120 teacher participants was 258. The average participant had obtained a minimum of two degrees, with the mean of $\mu = 2.15$. The number of years that the mathematics teachers had attended post-secondary education ranged from 0 to 20 with a mean of 5 years. One teacher was in preparation and training program that was not a part of a formal university or college. A large number of the teachers, 36.7%, had earned a Bachelor's Degree in a content area other than mathematics. Almost half of the teacher respondents, 48.3%, held a Master's Degree in Education. Table 4 contains the data collected regarding the types of degrees earned by the mathematics teachers.

All of the demographic and genetic variable data collected from the participants, as well as, the responses to the 24 items of the MAIT were collected within Google Sheets (Google Inc., 2014) and then transferred to Excel (Microsoft Excel, 2010) in the first step of preparation for the analysis. Within Excel, the narrative data was coded for quantitative analysis. The coding key is located in the appendices of this document (Appendix C). After the coding had been completed, the data was transferred to SPSS version 21 (IBM SPSS Statistics, 2012) for analysis.

A backward stepwise multiple regression was conducted using SPSS (IBM SPSS Statistics, 2012) as an initial analysis to determine whether any of the nine independent variables functioned as predictors of the four items of the MAIT (Balcikanli, 2011) that were designed to address the use of declarative knowledge. The backward stepwise

Table 4

Types of Degree Earned

Degree	N	% of 120 teachers that hold this degree
Associate Degree in Education Field	2	1.7%
Associate Degree in another content area	10	8.3%
Bachelor's Degree in an Education Field	42	35%
Bachelor's Degree in Mathematics	42	35%
Bachelor's Degree in another content area	45	37.5%
Master's Degree in Education	59	49.2%
Master's Degree in Mathematics	16	13.3%
Master's Degree in another content area	17	14.2%
Master's Degree in Instructional/Educational Technology	2	1.7%
Master's Degree in Administration	1	0.8%
Education Doctorate (Ed.D.)	5	4.2%
Ph.D. in Education	4	3.3%
Ph.D. in Mathematics	2	1.7%
Specialist Certification	2	1.7%
Other	9	7.5%

*Teachers may have earned multiple degrees multiple regression method begins with the placement of all the predictors in the model. The significance value of the contribution of each predictor is then calculated using the t-test. A comparison is then conducted using the probability value for the test statistic or the absolute value of the test statistic against a removal criterion (Field, 2013). If a predictor does not make a statistically significant contribution to the model, it is removed from the model. The model is then re-assessed with the remaining predictors (Field, 2013, pp. 322-323). Using the backward stepwise regression method, minimizes the occurrence of determining that a predictor has a significant effect while it only has that effect when the other variables are held constant (Field, 2013). For the purpose of model refinement, the stepwise method in SPSS version 21 (IBM SPSS Statistics, 2012) was conducted after the outliers and non-significant predictors were removed during the initial screening using the backward method in SPSS. The stepwise method in SPSS combines the forward stepwise method of entering predictor variables with an additional reassessment of the predictors after the addition of each predictor variable. As a predictor is added to the linear regression equation, a test is conducted that assesses the significance of the contribution of the predictor with the least influence. The predictor with the least influence was removed at this point, if it met the removal criteria as defined for this study. This process produced a refined linear regression equation that functioned as a mathematical model for the predictors of each factor.

The results of the regression procedures were analyzed by the subfactor of metacognition. Data collected for each of the four items designed to examine the subfactor was combined to examine the overall impact on that particular subfactor of metacognition. Using the model that included the most predictors while maintaining a significance level of $p < .05$ and a Variance Inflation Factor (VIF) of < 5, the most influential potential predictors were identified. The condition index for each factor was required to be less than 15. The analysis was conducted a second time using only the predictors selected during the first run of the analysis. The refined models were analyzed, and the results are discussed as appropriate for each of the research questions. Throughout both runs of the analysis for all six of the hypothesis, there were no correlations between variables that exceeded $R = .90$. This correlation coefficient, R, is a measurement of the strength of the association between variables. Thus, multi-collinearity was not determined to be of concern in this analysis.

The Durbin-Watson Test for Serial Correlation was conducted as a part of the model analysis. This test examines adjacent residuals for correlation which can accumulate and create a form of bias in the regression model (Field, 2013). The calculated Durbin-Watson Test statistic for each item was evaluated using the tables provided by Savin and White (1977) for models with an intercept at a significance of .05. This significance value is the same value as the significance value used for the regression models. After the backward stepwise multiple regression for each item was complete, the model was verified for strength and consistency using the forward stepwise automatic linear modeling (ALM) procedure in SPSS. The automatic data preparation was not used as suggested by Field (2013). However, after using the ALM for the purposes of model construction as recommended by Yang (2013), inconsistencies were discovered that existed within these models. This method was examined to confirm the existence of possible outliers using Cook's Distances and to identify the outliers for removal. The ALM method was not used in the final analysis with outliers and non-significant predictors. The ALM method uses Akaike's Information Criterion Corrected (AICC) as the evaluation criterion for the selection of the best possible model using the potential predictors (Yang, 2013) and does not use the level of significance of the predictor as elimination criterion.

The ability of a test to detect a particular magnitude of the effect is referred to as "power". Due to the complexity of this research study caused by the number of predictors and the sample size, G*Power 3.1 (Buchner, Erdfelder, Faul, & Lang, 2014) to determine a sample size of 114 and effect size of 0.15 at the power of 0.80 and a = 0.05. The number of respondent participants for this quantitative survey study was 120 and considered to be reasonably close to the 114 suggested by G*Power 3.1 (Buchner, Erdfelder, Faul, & Lang, 2014). The number of hypotheses created from the nine independent variable predictors to be tested created the necessity for a large sample size. The combined values of power, effect size, and sample size suggested that there was value in conducting the study with a smaller sample size than the originally desired goal of 500 responses.

Results of Research Question 1

The first research question investigated the metacognitive subfactor of declarative knowledge. Backward stepwise multiple regression was conducted with the data collected for the four items addressing this subfactor. The research question and hypothesis examined by these items are as follows:

RQ2: Do the demographic variables of: age, gender, type of teacher preparation, grade level of mathematics instruction, number of years of education, all degrees earned, age when entered the teaching profession, and number of years of teaching experience, including any interruptions in the teachers' years of experience, predict or impact the mathematics teachers' awareness of their use of declarative knowledge in their mathematical instructional practices?

$H_0 1$*:* There is no statistical relationship between the age, gender, type of teacher preparation, grade level of mathematics instruction, number of years of education, all degrees earned, age when entered the teaching profession, and/or number of years of teaching experience, including any interruptions in the teachers' years of experience and mathematics teachers' use of declarative knowledge as a part of their metacognitive instructional practices.

$H_1 1$: There is a statistical relationship between the age, gender, type of teacher preparation, grade level of mathematics instruction, number of years of education, all degrees earned, age when entered the teaching profession, and/or number of years of teaching experience, including any interruptions in the teachers' years of experience and mathematics teachers' use of declarative knowledge as a part of their metacognitive instructional practices.

The four items that address declarative knowledge in the MAIT are Item 1 "I am aware of the strengths and weaknesses in my teaching", Item 7 "I know what skills are most necessary in order to be a good teacher", Item 13 "I have control over how well I teach", and Item 19 "I know what I am expected to teach". For this item, as for all of the 24 items of the MAIT, the mathematics teachers completed a rating of the item on a scale of 1 (Strongly Disagree) to 5 (Strongly Agree). The backward stepwise multiple regression analysis of the data collected for the subfactor of declarative knowledge produced only one model in which all of the initial criteria were met. The values for the variance, R^2, and adjusted R^2 were determined to be relatively close which provided additional evidence to support the model mentioned above. The adjusted R^2 is a measurement of the variance of the outcome that accounted to the predictor if the model had been derived from the population of all mathematics teachers rather than the sample. This statistic is a measure of the generalizability of the mathematical model (Field, 2013). All of the β-coefficients for this study were reported as standardized beta values and indicated the number of standard deviation units that the outcome will change as a result of a one standard deviation change in the predictor (Field, 2013). The p-value determines the statistical significance of the value.

The ALM of determined several that several of the cases were potential outliers. The ALM feature of SPSS (IBM SPSS Statistics, 2012) uses Cook's Distance Values to locate items that are highly influential in the computations of the models. As potential outliers, cases with high Cook's Distance Values may distort the accuracy of the model produced. Cook's Distance is a diagnostic statistic that measures the individual impact of each of the identified outliers in the fitted model (Yang, 2013). There are differences in opinion as to the appropriate cut-off value for locating highly influential data points when using Cook's Distance. The most widely used value is $D_i > 1$ (McDonald, 2002). The cut-off value in SPSS was set at a more conservative value of Di > 4/n, where n is the number of observations or cases as suggested by Bollen and Jackman (1990). The calculated cut-off for the Cook's Distance Values for this research study is Di > 4/480 or Di > .008 and will be used throughout any remaining calculations.

After the initial investigation of the data collected by the items addressing declarative knowledge, a review of the outliers was conducted. Outliers were identified for examination and consideration of removal using the Cook's Distance statistic provided in the ALM procedure. Cases that appeared as outliers in for two or more of the items addressing declarative knowledge were removed. All of the potential predictors that were not determined to be statistically significant were removed. It was at this point that the stepwise multiple regression procedure in SPSS version 21 (IBM SPSS Statistics, 2012) was conducted, and a model for the final analysis of declarative knowledge was produced. Table 5 contains the results of the final analysis for this item. The confidence interval was determined at the 95% level of confidence. The mathematical model produced looking for linearity was:

$$\mathbf{y = 0.207(number\ of\ years\ teaching) + 0.098(interruptions) + \varepsilon}$$

The model was determined to have a significance of F (469) = 16.309 and $p \leq$ .001 at 469 degrees of freedom. The Durbin-Watson test statistic was examined to determine if there was any serial correlation between the residuals. The statistic is available in the SPSS linear regression analysis. For declarative knowledge, the Durbin-Watson statistic was 2.049. This statistic tests the null hypothesis that there is no serial correlation between the variable. At this level using the tables from Savin and White (Appendix A: Durbin-Watson Significance Tables, n. d.), both the null hypothesis for positive correlation and the null hypothesis for negative correlation cannot be rejected. Thus, there is no evidence of positive or negative correlation between the residuals.

Table 5

Declarative Knowledge

	Unstandardized B	SE	β	ΔR^2	*t*	*p*
Constant	4.092	.049			82.937	≤ .001
(confidence interval)	(3.995, 4.189)					
Years teaching	.015	.003	.207	.056	4.409	≤ .001
(confidence interval)	(.008, .021)					
Interruptions	.041	.020	.098	.009	2.090	= .037
(confidence interval)	(.002, .080)					

Note: R^2 = .065, adjusted R^2 = .061, SD of Declarative Knowledge = 0.679, SD of Years teaching = 9.678, SD of Interruptions = 1.625

While the "number of years of teaching" accounted for the majority of the predictive influence that can be accounted for in this model at 5.6%, the predictive effect of this independent variable was only 0.012. The "interruptions in teaching experience" accounted for only 0.9% of the influence upon declarative knowledge. The predictive effect of "interruptions in teaching experience" was determined to be 0.001. The predictive effect was calculated by multiplying the "r-squared change" associated with the predictor by the standardized β coefficient of the predictor. The analysis also demonstrated that as the “number of years teaching” increased by 9.7, the teachers’ rating of their declarative knowledge increased by 0.141, as assessed by the MAIT (Balcikanli, 2011). In other words, with each increase of one standard deviation in the “number of years of teaching experience”, the teachers’ rating of their declarative knowledge increased by the β-coefficient of the “number of years teaching” multiplied by the standard deviation of declarative knowledge.

This evidence demonstrated that the independent variables of “the number of years teaching”, and “interruptions in the teaching experience” do differ in the relationship that they have upon the mathematics teachers’ use of declarative knowledge in their instructional practices. For this subfactor of metacognition, the null hypothesis was rejected. Thus the alternative hypothesis was accepted that there are significant differences in the influence of age, age when entered the teaching profession, and number of years of teaching experience, including any interruptions in the teachers’ years of experience upon the declarative knowledge used by mathematics teachers as a part of their instructional practices. It should be noted that this model suggested that an increase in the “age” of the teacher appeared to have a negative impact upon the teacher’s awareness of their declarative knowledge. In addition, this model indicated that an increase in the “number of years of teaching” experience appeared to have a positive impact upon the teacher’s awareness of their declarative knowledge.

Results of Research Question2

The second research question, investigated the metacognitive subfactor of procedural knowledge. The items in the MAIT designed to investigate procedural knowledge are: Item 2 “I try to use teaching techniques that worked in the past”, Item 8 “I have a specific reason for choosing each teaching technique I use in class”, Item 14 “I am aware of what teaching techniques I use while I am teaching”, and Item 20 “I use helpful teaching techniques automatically”. Backward stepwise multiple regression was conducted with the data collected for the four items addressing this subfactor for a preliminary examination of the significant variables. After the initial investigation of the data collected with the four items addressing procedural knowledge was completed, a review of the outliers for the four items in the MAIT that address procedural knowledge was conducted. The ALM method was used to identify and verify possible outliers using Cook’s Distances. Cases that appeared as outliers in for two or more of the items addressing were removed as outliers and the model was re-analyzed in SPSS. The research question and hypothesis examined by these items are as follows:

RQ2: Do the demographic variables of: age, gender, type of teacher preparation, grade level of mathematics instruction, number of years of education, all degrees earned, age when entered the teaching profession, and number of years of teaching experience, including any interruptions in the teachers’ years of experience predict or impact the mathematics teachers’ awareness of their use of procedural knowledge in their mathematical instructional practices?

$H_0 2$: There is no statistical relationship between the age, gender, type of teacher preparation, grade level of mathematics instruction, number of years of education, all degrees earned, age when entered the teaching profession, and number of years of teaching experience, including any interruptions in the teachers' years of experience impact the mathematics teachers' use of procedural knowledge as a part of their metacognitive instructional practices.

$H_1 2$: There are significant differences in the influence of age, gender, type of teacher preparation, grade level of mathematics instruction, number of years of education, all degrees earned, age when entered the teaching profession, and number of years of teaching experience, including any interruptions in the teachers' years of experience upon the procedural knowledge used by mathematics teachers as a part of their instructional practices.

The backward stepwise multiple regression analysis of the next item of the MAIT addressing procedural knowledge produced a model in which only the "age" of the mathematics teacher and the "number of years teaching" were determined to be statistically significant. The outliers and non-significant independent variables were removed and a final analysis was conducted. The values for variance, R^2, and adjusted R^2, were determined to be relatively close which provided additional evidence to support the aforementioned model. Table 6 contains the results of the final analysis for this item. The confidence interval was determined at the 95% level of confidence. The mathematical model produced looking for linearity was found to be:

y = 0.274(number of years teaching) + -0.178(age) + ε

The model was determined to be significant at *F* (469) = 9.101 and $p \leq .001$ at 469 degrees of freedom. The values for R^2 and adjusted R^2 were determined to be relatively close which provided additional evidence to support the model. For procedural knowledge, the Durbin-Watson statistic was 2.026. At this level using the tables from Savin and White (Appendix A: Durbin-Watson Significance Tables, n. d.), both the null hypothesis for positive correlation and the null hypothesis for negative correlation cannot be rejected. Thus, there is no evidence of positive or negative correlation between the residuals.

Table 6

Procedural Knowledge

	Unstandardized B	SE	β	ΔR^2	*t*	*p*
Constant	4.278	.130			32.982	≤ .001
(confidence interval)	(4.023, 4.533)					
Years teaching	.023	.006	.274	.022	4.250	≤ .001
(confidence interval)	(.013, .034)					
Age	-.011	.004	-.178	.016	-2.761	= .006
(confidence interval)	(-.019, -.003)					

Note: R^2 = .037, adjusted R^2 = .033, SD of Procedural Knowledge = 0.809, SD of Years teaching = 9.487, SD of Age = 13.027

While the "number of years of teaching" accounted for the majority of the predictive influence that can be accounted for in this model at 2.2%, the predictive effect of this independent variable was only 0.006. The "age" of the teacher accounted for only

1.6% of the influence upon procedural knowledge. The predictive effect of “age” was determined to be 0.003. The analysis also demonstrated that as the “number of years teaching” increased by 9.5, the teachers’ rating of their procedural knowledge increased by 0.222, as assessed by the MAIT (Balcikanli, 2011). In other words, with each increase of one standard deviation in the “number of years of teaching experience”, the teachers’ rating of their procedural knowledge increased by the β-coefficient of the “number of years teaching” multiplied by the standard deviation of procedural knowledge. However, an increase of 13 years in the teachers’ “age” was determined to be associated with a decrease in the teachers rating of procedural knowledge by 0.144.

This evidence demonstrated that some of the independent variables: age and the number of years teaching do differ in the relationship that they have upon the mathematics teachers’ use of procedural knowledge in their instructional practices. For this subfactor of metacognition, the null hypothesis was rejected. Thus the alternative hypothesis was accepted that there are significant differences in the influence of age and number of years of teaching experience upon the procedural knowledge used by mathematics teachers as a part of their instructional practices. It should be noted that this model suggested that an increase in the “age” of the teacher appeared to have a negative impact upon the teacher’s awareness of their procedural knowledge**.** This model also suggested that an increase in the “number of years teaching” experience has a positive impact upon the teacher’s awareness of their procedural knowledge as assessed by the MAIT.

Results of Research Question 3

The third research question, investigated the metacognitive subfactor of conditional knowledge. The items in the MAIT designed to investigate conditional knowledge are: Item 3 “I use my strengths to compensate for my weaknesses in my teaching”, Item 9 “I can motivate myself to teach when I really need to teach”, Item 15 “I use different teaching techniques depending on the situation”, and Item 21 “I know when each teaching technique I use will be the most effective”. Backward stepwise multiple regression was conducted for the data collected for each of the four items addressing this subfactor. After the initial investigation of the four items addressing conditional knowledge was completed, a review of the outliers for the data collected with the four items in the MAIT that address conditional knowledge was conducted. Outliers were identified for examination and consideration of removal using the Cook’s Distance statistic provided in the ALM procedure. All of the potential predictors that were not determined to be statistically significant were removed. Backward stepwise multiple regression was again conducted and a model for the final analysis of conditional knowledge was produced. The research question and hypothesis examined by these items are as follows:

RQ3: Do the demographic variables of: age, gender, type of teacher preparation, grade level of mathematics instruction, number of years of education, all degrees earned, age when entered the teaching profession, and number of years of teaching experience, including any interruptions in the teachers’ years of experience predict or impact the mathematics teachers' awareness of their use of conditional knowledge in their mathematical instructional practice.

$H_0$3: There is no statistical relationship between the age, gender, type of teacher preparation, grade level of mathematics instruction, number of years of education, degrees earned, age when entered the teaching profession, and years of teaching experience impact the mathematics teachers' use of conditional knowledge as a part of their metacognitive instructional practices.

$H_1$3: There are significant differences in the influence of age, gender, type of teacher preparation, grade level of mathematics instruction, number of years of education, all degrees earned, age when entered the teaching profession, and number of years of teaching experience, including any interruptions in the teachers' years of experience upon the conditional knowledge used by mathematics teachers as a part of their instructional practices.

For this subfactor, the backward stepwise multiple regression analysis of the four items that addressed conditional knowledge produced a model in which only "age" and the "number of years teaching" were determined to be statistically significant. The outliers and non-significant independent variables were removed and a final analysis was conducted. Table 7 contains the results of the final analysis for this factor. The confidence interval was determined at the 95% level of confidence. The mathematical model produced looking for linearity was found to be:

$$\mathbf{y = 0.307(number\ of\ years\ teaching) + -0.246(age) + \varepsilon}$$

Table 7

Conditional Knowledge

	Unstandardized B	SE	β	ΔR^2	T	p
Constant	4.435	.139			31.857	≤ .001
(confidence interval)	(4.161, 4.709)					
Years teaching	.027	.006	.307	.015	4.525	≤ .001
(confidence interval)	(.015, .039)					
Age	-.016	.004	-.246	.027	-3.633	≤ .001
(confidence interval)	(-.025, -.007)					

Note: R^2 = .043, adjusted R^2 = .039, SD of Conditional Knowledge = 0.838, SD of Years teaching = 9.512, SD of Age = 12.817

The model was determined to be significant at F (461) = 10.328 and $p \leq .001$. The values for R^2 and adjusted R^2 were determined to be relatively close which provided additional evidence to support the model. For conditional knowledge, the Durbin-Watson statistic was 1.427. At this level using the tables from Savin and White (Appendix A: Durbin-Watson Significance Tables, n. d.) for positive serial correlation, the null hypothesis for positive correlation must be rejected. This statistic indicated that positive first-order autocorrelation may be present for this model. In other words, there may be a violation of the assumption of independent errors. However, the null hypothesis for negative serial correlation could not be rejected. There is some degree of evidence of positive serial correlation between the residuals. The model parameters that were produced in this analysis may appear greater than they actually are (Savin and White, n.d.).

The results for this factor of metacognitive knowledge differ in that "age" has a greater predictive effect than the "number of years of teaching". The "age" of the teacher accounted for the majority of the predictive influence that can be accounted for in this model at 2.7%. The predictive effect of this independent variable was only -0.007. The "number of years teaching" accounted for only 1.5% of the influence upon conditional knowledge. The predictive effect of "the number of years" was determined to be 0.005. The analysis also demonstrated that as t5he "number of years teaching" increased by 9.5, the teachers' rating of their conditional knowledge increased by 0.257, as assessed by the MAIT (Balcikanli, 2011). In other words, with each increase of one standard deviation in the "number of years of teaching experience", the teachers' rating of their conditional knowledge increased by the β-coefficient of the "number of years teaching" multiplied by the standard deviation of conditional knowledge. However, an increase of 12.8 years in the teachers' "age" was determined to be associated with a decrease in the teachers rating of conditional knowledge by 0.206.

This evidence demonstrated that some of the independent variables: age and the number of years teaching do differ in the relationship that they have upon the mathematics teachers' use of conditional knowledge in their instructional practices. For this subfactor of metacognition, the null hypothesis was rejected. Thus the alternative hypothesis was accepted that there are significant differences in the influence of age and number of years of teaching experience upon the conditional knowledge used by mathematics teachers as a part of their instructional practices. It also should be noted that the negative β coefficient of "age" indicated that as the teacher increased in age the teachers' rating demonstrated a decrease in the rating of awareness of conditional knowledge. In addition, the model produced demonstrated that as the "number of years teaching" experience increased the teachers rating of conditional knowledge also increased.

Results of Research Question 4

The fourth research question, investigated the metacognitive subfactor of planning awareness. The items in the MAIT designed to investigate planning awareness are: Item 4 "I pace myself while I am teaching in order to have enough time", Item 10 "I set my specific teaching goals before I start teaching", Item 16 "I ask myself questions about the teaching materials I am going to use", and Item 22 "I organize my time to best accomplish my teaching goals". Backward stepwise multiple regression was conducted for the data collected for the four items addressing this subfactor. After the initial investigation of the four items addressing planning awareness was completed, a review of the outliers for the data collected with four items in the MAIT that address planning awareness was conducted. Outliers were identified for examination and consideration of removal using the Cook's Distance statistic provided in the ALM procedure. All of the potential predictors that were not determined to be statistically significant were removed. Backward stepwise multiple regression was again conducted and a model for the final analysis of planning awareness was produced. The research question and hypothesis examined by these items are as follows:

RQ4: Do the demographic variables of age, gender, type of teacher preparation, grade level of mathematics instruction, number of years of education, all degrees earned, age when entered the teaching profession, and number of years of teaching experience, including any interruptions in the teachers' years of experience predict or impact the mathematics teachers' level of planning awareness used in their mathematical instructional practices?

$H_0$4: There is no statistical relationship between the age, gender, type of teacher preparation, grade level of mathematics instruction, number of years of education, all degrees earned, age when entered the teaching profession, and number of years of teaching experience, including any interruptions in the teachers' years of experience impact the mathematics teachers' use of planning awareness as a part of their metacognitive instructional practices.

$H_1$4: There are significant differences in the influence of age, gender, type of teacher preparation, grade level of mathematics instruction, number of years of education, all degrees earned, age when entered the teaching profession, and number of years of teaching experience, including any interruptions in the teachers' years of experience upon the planning awareness used by mathematics teachers as a part of their instructional practices.

For this subfactor, the backward stepwise multiple regression analysis of the four items that addressed planning awareness produced a model in which "gender", the "number of years teaching", and the "number of years of post-secondary education" were determined to be statistically significant. The outliers and non-significant independent variables were removed and a final analysis was conducted. Table 8 contains the results of the final analysis for this subfactor. The confidence interval was determined at the

95% level of confidence. The mathematical model produced looking for linearity was found to be:

y = 0.263(number of years teaching) + – 0.126(gender) + ε

Table 8

Planning Awareness

	Unstandardized B	SE	β	ΔR^2	t	p
Constant	3.864	.065			59.61	≤ .001
(confidence interval)	(3.736, 3.992)					
Years teaching	.022	.004	.263	.072	5.859	≤ .001
(confidence interval)	(.015, .030)					
Gender	-.229	.082	-.126	.016	-2.807	= .005
(confidence interval)	(-.390, -.069)					

Note: R^2 = .088, adjusted R^2 = .084, SD of Planning Awareness = 0.826, SD of Years teaching = 9.768, SD of Gender = .454

The model was determined to be significant at *F* (453) = 21.890 and $p \leq .001$. The values for R^2 and adjusted R^2 were determined to be relatively close which provided additional evidence to support the model. For planning awareness, the Durbin-Watson statistic was 2.111. At this level using the tables from Savin and White (Appendix A: Durbin-Watson Significance Tables, n. d.), both the null hypothesis for positive correlation and the null hypothesis for negative correlation cannot be rejected. Thus, there is no evidence of positive or negative correlation between the residuals.

While the “number of years of teaching” accounted for the majority of the predictive influence that can be accounted for in this model at 7.2%, the predictive effect of this independent variable was only 0.019. The “gender” of the teacher accounted for only 1.6% of the influence upon planning awareness. The predictive effect of “gender” was determined to be 0.002. The analysis also demonstrated that as the “number of years teaching” increased by 9.8, the teachers’ rating of their planning awareness increased by 0.217, as assessed by the MAIT (Balcikanli, 2011). In other words, with each increase of one standard deviation in the “number of years of teaching experience”, the teachers’ rating of their planning awareness increased by the β-coefficient of the “number of years teaching” multiplied by the standard deviation of planning awareness. For “gender”, it was determined that male teachers were more likely to rate themselves lower in planning awareness than female teachers.

This evidence demonstrated that the independent variables of “gender” and the “number of years teaching” do differ in the relationship that they have upon the mathematics teachers’ use of planning awareness in their instructional practices. For this subfactor of metacognition, the null hypothesis was rejected. Thus the alternative hypothesis was accepted that there are significant differences in the influence of gender, the number of years of teaching experience and the number of years of post-secondary education upon the mathematics teachers’ use of planning awareness in their instructional practices. This model suggested that an increase in the “number of years teaching” experience has a positive impact upon the teacher’s awareness of their planning awareness as assessed by the MAIT. In addition, the model indicated that as the teachers’ "number of years of post-secondary education" increased their rating of their planning awareness tended to decrease as assessed by the MAIT. The negative β coefficient of "gender" indicated that men were more likely to rate themselves lower than women when assessing their planning awareness using the MAIT.

Results of Research Question 5

The fifth research question, investigated the metacognitive subfactor of monitoring awareness**.** The items in the MAIT designed to investigate monitoring awareness are: Item 5 "I ask myself periodically if I meet my teaching goals while I am teaching", Item 11 "I find myself assessing how useful my teaching techniques are while I am teaching", Item 17 "I check regularly to what extent my students comprehend the topic while I am teaching", and Item 23 "I ask myself questions about how well I am teaching". Backward stepwise multiple regression was conducted for the data collected for each of the four items addressing this subfactor. After the initial investigation of the four items addressing monitoring awareness was completed, a review of the outliers for the data collected with the four items in the MAIT that address monitoring awareness was conducted. Outliers were identified for examination removing based on the Cook's Distance statistic provided in the ALM procedure. All of the potential predictors that were not determined to be statistically significant were removed. Backward stepwise multiple regression was again conducted and a model for the final analysis of monitoring awareness was produced. The research question and hypothesis examined by these items are as follows:

RQ5: Do the demographic variables of age, gender, type of teacher preparation, grade level of mathematics instruction, number of years of education, all degrees earned, age when entered the teaching profession, and number of years of teaching experience, including any interruptions in the teachers' years of experience predict or impact the mathematics teachers' level of monitoring awareness used in their mathematical instructional practices?

$H_0$1: There is no statistical relationship between the age, gender, type of teacher preparation, grade level of mathematics instruction, number of years of education, all degrees earned, age when entered the teaching profession, and number of years of teaching experience, including any interruptions in the teachers' years of experience impact the mathematics teachers' use of monitoring awareness as a part of their metacognitive instructional practices.

$H_1$5: There are significant differences in the influence of age, gender, type of teacher preparation, grade level of mathematics instruction, number of years of education, all degrees earned, age when entered the teaching profession, and number of years of teaching experience, including any interruptions in the teachers' years of experience upon the monitoring awareness used by mathematics teachers as a part of their instructional practices.

For this subfactor, the backward stepwise multiple regression analysis of the four items that addressed monitoring awareness produced a model in which "gender" and the "number of years teaching" were determined to be statistically significant. The outliers and non-significant independent variables were removed and a final analysis was conducted. Table 9 contains the results of the final analysis for this subfactor of metacognition. The confidence interval was determined at the level of 95% confidence. The mathematical model produced looking for linearity was found to be:

y = 0.230(number of years teaching) + -0.114(gender) + ε

The model was determined to be significant at *F* (453) = 16.567 and $p \leq .001$. The values for R^2 and adjusted R^2 were determined to be relatively close which provided additional evidence to support the model. For monitoring awareness, the Durbin-Watson statistic was 1.848. At this level using the tables from Savin and White (Appendix A: Durbin-Watson Significance Tables, n. d.), both the null hypothesis for positive correlation and the null hypothesis for negative correlation cannot be rejected. Thus, there is no evidence of positive or negative correlation between the residuals.

Table 9

Monitoring Awareness

	Unstandardized B	SE	β	ΔR^2	*T*	*p*
Constant	4.066	.062			32.982	≤ .001
(confidence interval)	(3.945, 4.187)					
Years teaching	.018	.004	.230	.055	4.250	≤ .001
(confidence interval)	(.011, .025)					
Gender	-.194	.078	-.114	.013	-2.761	≤ .006
(confidence interval)	(-.346, -.041)					

Note: R^2 = .068, adjusted R^2 = .064, SD of Monitoring Awareness = 0.776, SD of Years teaching = 9.771, SD of Gender = .454

While the "number of years of teaching" accounted for the majority of the predictive influence that can be accounted for in this model at 5.5%, the predictive effect of this independent variable was only 0.013. The "gender" of the teacher accounted for only 1.3% of the influence upon monitoring awareness. The predictive effect of "gender" was determined to be 0.001. The analysis also demonstrated that as the "number of years teaching" increased by 9.8, the teachers' rating of their monitoring awareness increased by 0.178, as assessed by the MAIT (Balcikanli, 2011). In other words, with each increase of one standard deviation in the "number of years of teaching experience", the teachers' rating of their monitoring awareness increased by the β-coefficient of the "number of years teaching" multiplied by the standard deviation of monitoring awareness. For "gender", it was determined that male teachers were more likely to rate themselves lower in monitoring awareness than female teachers.

This evidence demonstrated that some of the independent variables: gender and the number of years teaching do differ in the relationship that they have upon the mathematics teachers' use of monitoring awareness in their instructional practices. For this subfactor of metacognition, the null hypothesis was rejected. Thus the alternative hypothesis was accepted that there are significant differences in the influence of gender and number of years of teaching experience upon the mathematics teachers' use of monitoring awareness in their instructional practices. The negative β coefficient of "gender" indicated that women were more likely to rate themselves higher than men when assessing their monitoring awareness. This model suggested that an increase in the "number of years teaching" experience has a positive impact upon the teacher's awareness of their monitoring awareness as assessed by the MAIT.

Results of Research Question 6

The sixth and final research question of this study, investigated the metacognitive subfactor of evaluating awareness. The items in the MAIT that were designed to examine evaluating awareness are: Item 6 "I ask myself how well I have accomplished my teaching goals one I am finished", Item 12 "I ask myself if I could have used different techniques after each teaching experience", Item 18 "After teaching a point, I ask myself if I'd teach it more effectively next time", and Item 24 "I ask myself if I have considered all possible techniques after teaching a point". Backward stepwise multiple regression was conducted for the data collected with the four items addressing this subfactor. After the initial investigation of the data was completed, a review of the outliers for the items in the MAIT that address evaluating awareness was conducted. Cases were identified as outliers using the Cook's Distance statistic provided in the ALM procedure. All of the potential predictors that were not determined to be statistically significant were removed. Backward stepwise multiple regression was again conducted. No models were produced for the final analysis of evaluating awareness that met the required level of significance of $p \leq .05$. For evaluating awareness, the null hypothesis as stated below was retained. The research question and hypothesis examined by these items are as follows:

RQ6: Do the demographic variables of age, gender, type of teacher preparation, grade level of mathematics instruction, number of years of education, all degrees earned, age when entered the teaching profession, and number of years of teaching experience, including any interruptions in the teachers' years of experience predict or impact the mathematics teachers' level of evaluating awareness used in their mathematical instructional practices?

$H_0 6$: There is no statistical relationship between the age, gender, type of teacher preparation, grade level of mathematics instruction, number of years of education, all degrees earned, age when entered the teaching profession, and number of years of teaching experience, including any interruptions in the teachers' years of experience impact the mathematics teachers' use of evaluating awareness as a part of their metacognitive instructional practices.

Summary

As previously stated in this chapter, the purpose of this quantitative study was to provide new knowledge and insight about the nine independent variables served as predictors of the teachers use of metacognition for the purpose of improving teaching and learning in mathematics. The sample of volunteer participants included mathematics teachers that differ in the number of years of teaching experience, from preservice to multiple decades, as well as teachers that that instruct students from kindergarten through grade twelve. The examination of the six research questions of this study provided additional insight into the metacognitive processes of mathematics teachers as identified and as validated by this study using the survey the Metacognitive Awareness Inventory for Teachers (MAIT, Balcikanli, 2011). Insight into how these nine variables may impact the use of metacognition by mathematics teachers could be used to predict an outcome and assist with the development and refinement of training for preservice and inservice teachers of mathematics. Table 10 provides a summary and comparison of the predictors of significance for each of the models produced in the final analyses. It should be noted that throughout the analyses of the data for this research study, the values for R^2 and adjusted R^2 remained below .20 or 20%. In some situations, this phenomenon may not be acceptable. This research study attempted determine predictors of the metacognitive behaviors of mathematics teachers. In such a context, a researcher might be looking for a weak relationship in very noisy data (Nau, 2009).

Table 10:

Summary of Final Analysis model predictors of teachers use of metacognition

	Independent variables								
Subfactor of Metacognition	IV- 1	IV-2	IV-3	IV-4	IV-5	IV-6	IV-7	IV-8	IV-9
Metacognitive Knowledge									
Declarative Knowledge								S	S
Procedural Knowledge	S							S	
Conditional Knowledge	S							S	
Metacognitive Regulation									
Planning Awareness		S						S	
Monitoring Awareness		S						S	
Evaluating Awareness									

* Independent Variables (IV): age (IV-1), gender (IV-2), type of teacher preparation (IV-3), grade level of mathematics instruction (IV-4), number of years of post-secondary education (IV-5), degrees earned (IV-6), age when entered the teaching profession (IV-7), number of years of teaching experience (IV-8), and any interruptions in teachers' years of experience (IV-9)
** S = Model is statistically significant and β-coefficient is statistically significant

Regarding RQ1**,** data collected with the four items addressing declarative knowledge in the MAIT during the administration of this survey was examined and then refined in successive runs using SPSS version 21(IBM SPSS Statistics, 2012). The results for this analysis demonstrated that the "number of years teaching", and "interruptions in the teaching experience" offered promise as a predictor of the use of declarative knowledge by mathematics teachers. The model produced demonstrated that these independent variables that were determined to be statistically significant predictors of the mathematics teachers use of declarative knowledge differed in their influence when compared to each other, as well as, to those determined not to have a statistically significant influence. Using the mathematical model produced by the analysis of the four items addressing declarative knowledge in the MAIT as the criteria for examination of the mathematics teachers use of declarative knowledge, there was sufficient evidence to reject the null hypothesis and accept the alternative hypothesis that there are significant differences in the influence of age, age when entered the teaching profession, and number of years of teaching experience, including any interruptions in the teachers' years of experience upon the declarative knowledge used by mathematics teachers as a part of their instructional practices. It should be noted that this model suggested that an increase in the "age" of the teacher appeared to have a negative impact upon the teacher's awareness of their declarative knowledge.

During the examination of the data collected for RQ2, age and number of years teaching were determined to be the strongest potential predictors of procedural knowledge that were assessed during this research study. The backward and stepwise multiple regression analysis of data collected with the four items addressing procedural knowledge produced a statistically significant mathematical model with the predictors of "age" and the "number of years of teaching". Using the mathematical model produced by the analysis of the four items addressing procedural knowledge in the MAIT as the criteria for examination of the mathematics teachers use of procedural knowledge, there is sufficient evidence reject the null hypothesis and accept the alternative hypothesis that there are significant in the influence of age and number of years of teaching experience upon the procedural knowledge used by mathematics teachers as a part of their instructional practices.

The analysis of the data collected that addressed RQ3, demonstrated that “age” of the mathematics teacher and the “number of years teaching” also offer promise as potential predictors of conditional knowledge. The successive runs during analysis with SPSS (IBM SPSS Statistics, 2012), produced a mathematical model in which these independent variables were determined to be statistically significant predictors of conditional knowledge. Using the mathematical model produced by the analysis of the four items addressing conditional knowledge in the MAIT as the criteria for examination of the mathematics teachers use of conditional knowledge, there is sufficient evidence to reject the null hypothesis and accept the alternative hypothesis that there are significant differences in the influence of age and number of years of teaching experience upon the conditional knowledge used by mathematics teachers as a part of their instructional practices.

Regarding RQ4, the “gender” and the “number of years teaching” offered promise as predictors of the mathematics teachers use of the metacognitive subfactor of planning awareness. As a part of the data analysis for this research study, the data collected with the four items addressing planning awareness in the MAIT during the administration of this survey was examined and then refined in successive runs using SPSS version

21(IBM SPSS Statistics, 2012). The results for this analysis produced a mathematical model in which these independent variables functioned as statistically significant predictors of the use of planning awareness by the mathematics teachers. Using the mathematical model produced by the analysis of the four items addressing planning awareness in the MAIT as the criteria for examination of the mathematics teachers use of planning awareness**,** there is sufficient evidence to reject the null hypothesis.The alternative hypothesis that there are significant differences in the influence of gender, the number of years of teaching experience and the number of years of post-secondary education upon the mathematics teachers' use of planning awareness in their instructional practices was therefore accepted.

During the examination of the data collected for RQ5, only the "gender" and the "number of years teaching" offered promise as a predictor of the mathematics teachers use of the metacognitive subfactor of monitoring awareness as assessed by the MAIT. The results for this analysis produced a mathematical model in which these independent variables functioned as statistically significant predictors of the use of monitoring awareness by the mathematics teachers. Using the mathematical model produced by the analysis of the four items addressing monitoring awareness in the MAIT as the criteria for examination of the mathematics teachers use of monitoring awareness**,** there is sufficient evidence to reject the null hypothesis. The alternative hypothesis that there are significant differences in the influence of gender and number of years of teaching experience upon the mathematics teachers' use of monitoring awareness as a part of their instructional practices was therefore accepted.

The analysis of the data collected that addressed RQ6, demonstrated that none of the independent variables offer promise as potential predictors of the metacognitive subfactor of evaluating awareness. No models were produced for the final analysis of evaluating awareness that met the required level of significance of $p \leq .05$. For evaluating awareness, the null hypothesis that there are no significant differences in the influence of age, gender, type of teacher preparation, grade level of mathematics instruction, number of years of education, all degrees earned, age when entered the teaching profession, and number of years of teaching experience, including any interruptions in the teachers' years of experience upon the evaluating awareness used by mathematics teachers as a part of their instructional practices, could not be rejected. These analyses demonstrated that there needs to be further research to determine the predictors of evaluating awareness used by the teachers of mathematics.

The examination of the six research questions of this quantitative survey research study provided additional insight into the metacognitive processes of mathematics teachers as identified and as validated by this study using the survey the Metacognitive Awareness Inventory for Teachers (MAIT, Balcikanli, 2011). Insight into how these nine variables may impact the use of metacognition by this small sample of mathematics teachers could be used with the results of future and larger studies to predict an outcome and assist with the development and refinement of training for preservice and inservice teachers of mathematics. Implications for the indications provided by the results of this study and recommendations for further research that examines the use of metacognition by mathematics teacher through the unification of neuroscience, cognitive science, and educational research to improve mathematical instruction will be discussed in the next chapter.

Chapter 5: Discussion, Conclusions, and Recommendations

Introduction

A quantitative survey research study was designed and conducted in order to provide new knowledge and insight about the relationship and impact of nine demographic and genetic variables as potential predictors of U.S. mathematics teachers's use of the subfactors of metacognition in their instructional activities. Veenman et al., (2006) noted that little research exists that investigated the role of the teacher as a demonstrator and communicator of thinking and learning processes of mathematics. Lester (2013) stated that the proficiencies that teachers need to be able to provide instruction effectively for the purpose of improving student metacognitive abilities have not been adequately identified (Lester, 2013). He stated that metacognition is one of the influential driving forces that greatly impact problem solving success, but cautioned that a teacher's ability and expertise in problem solving should not be equated with the proficiency to instruct students in problem solving. The ability to monitor and regulate cognitive behaviors is critical to successful problem solving. Future research on mathematical problem solving should focus on the pedagogical and mathematical knowledge a teacher should possess, as well as the necessary proficiencies (Lester, 2013). This quantitative survey study critically examined the impact of the potential predictor variables upon the six subfactors of teacher metacognitive awareness in a sample of mathematics teachers for the purpose of improving the teaching and learning of mathematics. Stepwise multiple regression was performed in order to identify the influential demographic and genetic predictor variables on the subfactors of metacognition assessed by the MAIT. The results of the study indicate that the number of years of teaching experience impacted five of the six subfactors of metacognition that were investigated.

The results of this study provide evidence that there are significant differences in the influence of age, gender, number of years teaching experience, and any interruptions in the teachers' years of experience for declarative knowledge, procedural knowledge, conditional knowledge, planning awareness and monitoring awareness. The results also demonstrate that none of the nine potential predictors had a universally consistent influence on the teachers use of all six of the metacognitive subfactors examined at a level of statistical significance. The number of years of teaching experience, however, did have an influence on the teachers' use of five of the six subfactors of metacognition. With reference to the component of metacognitive knowledge, the results of this study demonstrate that the number of years of teaching experience was demonstrated as a universally positive influence on the three subfactors of the component of metacognitive knowledge; declarative knowledge, procedural knowledge, and conditional knowledge. The model indicates that as the number of years of teaching experience increased, the mathematics teachers' rating of these three subfactors on the MAIT also increased. Interruptions in teaching experience appeared to have a small predictive effect on the metacognitive subfactor of declarative knowledge. The age of a mathematics teacher appeared to be a statistically significant predictor of two of these three subfactors, but this influence appeared to be negative. For this predictor, the model indicates that as the age of the mathematics teachers increased the teachers' rating of procedural knowledge and conditional knowledge decreased.

Regarding the component of metacognitive regulation, gender was determined to have a statistically significant influence on planning awareness and monitoring awareness. The model indicated that women were more likely to rate themselves higher on the items investigating planning awareness on the MAIT than men. The number of years of teaching experience was also determined to have a degree of influence on the teachers' use of two of the subfactors of the component of metacognitive regulation; planning awareness and monitoring awareness. For the predictor of the number of years teaching experience, the regression equation that was produced indicated that an increase in the number of years of teaching experience was associated with an increase in the mathematics teachers rating of both planning awareness and monitoring awareness. In addition, the regression equation produced for planning awareness indicated that the number of years of post-secondary education also had a negative impact on the metacognitive subfactor of planning awareness.

Concerning evaluating awareness, the results of the backward stepwise multiple regression analyses of the data collected for this study did not provide sufficient evidence to reject the null hypothesis that there are no significant differences in the influence of age, gender, type of teacher preparation, grade level of mathematics instruction, number of years of education, all degrees earned, age when entered the teaching profession, and number of years of teaching experience, including any interruptions in the teachers' years of experience on the evaluating awareness used by mathematics teachers as a part of their instructional practices. None of the nine independent variables for this study appeared to function as a predictor of the mathematics teachers' use of evaluating awareness.

The slow rate of improvement as indicated in the standard deviation of 9.5 to 9.8 years of teaching experience, demonstrated the necessity of providing training in metacognitive practices to mathematics teachers of varying experience in order to *decrease* the amount of time necessary to demonstrate improvement in these practices and reach a level of expertise. Preservice and teachers with less experience should be trained in metacognitive practices that raise their awareness with monitoring and adjusting their use of declarative knowledge**,** procedural knowledge**,** conditional knowledge**,** planning awareness and monitoring awareness. None of the other nine independent variables had a consistently positive impact on these five subfactors of metacognition. Nor did any of the nine independent variables of this study appeared to have an impact on the mathematics teachers' use of their metacognitive skills of evaluating awareness. Training in the efficient use of metacognitive practices may reduce the time that it takes teachers to attain expertise in these skills.

Interpretation of the Findings

Teachers use metacognition for planning, monitoring, adjusting, and evaluating instructional methods and student learning (Duffy et al., 2009; Lee et al., 2010). Zohar (1999) stated that research had been conducted that examined teachers' metacognitive knowledge and pedagogical comprehension of metacognition. Contemporary changes in academic curricula place an emphasis on developing reasoning skills and deep comprehension in students at all levels of academic ability (Zohar & David, 2008). To meet these demands learning and instruction must include practices that are focused on the development of critical thinking skills. Metacognition is an integral part of the critical thinking process (Zohar, 1999). The results of the backward stepwise multiple linear regression allowed for the creation of a mathematical model that illuminates the influence of the independent variables to act as predictors of the six subfactors of metacognition. This study provided evidence that there are significant differences in the influence of age, gender, number of years teaching experience, and interruptions in the teachers' years of experience for declarative knowledge, procedural knowledge, conditional knowledge, planning awareness, and monitoring awareness. The number of years of teaching experience had a consistent statistically significant impact on five of the six subfactors of metacognition. The only subfactor of metacognition not affected by the number of years of teaching experience was that of evaluating awareness. Experience seems to be important in the development of five of the six subfactors of metacognition.

The inconsistencies in the models give hints of some of the differences that exist among mathematics teachers in their awareness and use of the six subfactors of metacognition. For example, the values of the β coefficients for the number of years teaching differed in each of the regression equations in which this predictor appeared. The type of teacher preparation, the grade level/span of mathematics instruction, the number of years of post-secondary education, the degrees earned, and the age that the teacher entered the profession did not appear as statistically significant in any of the models produced in the investigation of the 24 items of the MAIT (Balcikanli, 2011).

Future studies with larger numbers of mathematics teachers may help educational researchers to further refine models and predictors of mathematics teachers' use of the metacognitive subfactors. Additional studies may provide greater consistency in evidence of the demographic and genetic variables that function as predictors of the use of metacognition by mathematics teachers for the purposes of adjusting their instructional practices. The teaching and learning of mathematics could be further improved by the information gained of future studies that are focused on the use and awareness of teachers metacognitive practices.

Connection to Literature on Metacognition and Teaching

Through the use of the MAIT, Mathematics teachers were asked to reflect on their teaching regarding their use of declarative knowledge, procedural knowledge, conditional knowledge, planning awareness, monitoring awareness, and evaluating awareness to learn about and meet the needs of their students. This reflective action incorporates the theories of metacognition presented in the literature review of this research study. The mathematics teachers reflected on, described, and evaluated their conscious knowledge of their cognition and the products related to the processes are described by Flavell (1970, 1976), and Ebdon, Coakley, and Legnard (2003). The teachers provided ratings of their use and awareness of items in the MAIT that were designed as measurements of the six subfactors of metacognition. The teachers provided demographic and genetic information regarding nine different items to allow for the examination of the impact of these items on their use of the six subfactors of metacognition mentioned above. The relationship and impact of age (IV-1), gender (IV-2), type of teacher preparation (IV-3), grade level of mathematics instruction (IV-4), number of years of education (IV-5), degrees earned (IV-6), age when entered the teaching profession (IV-7), years of teaching experience (IV-8), and any interruptions in teachers' years of experience (IV-8) on mathematics teachers use of subfactors of metacognition were examined to determine whether these independent variables functioned as predictors of the mathematics' teachers use of metacognition.

The number of years of teaching experience offered the most promise as a predictor of mathematics teachers use and awareness of the six subfactors of metacognition. The number of years of teaching experience appeared in each of the regression equations produced by backward stepwise multiple regression to describe the impact of the potential predictors on the teachers use of declarative knowledge**,** procedural knowledge**,** conditional knowledge**,** planning awareness and monitoring awareness. Monitoring student learning assists teachers with making informed pedagogical decisions about the particular needs of each student. Educators must understand what motivates each student (Walter & Hart, 2009). Relating interest and motivation, Koaler, Abumert, and Schnabel (2001) found that students who demonstrated and reported higher levels of interest in mathematics tended to enroll in higher level courses as well as demonstrate higher levels of achievement.

Teachers engage in highly complex cognitive activities in addition to the routines and procedures that they use in the classroom (Duffy, Miller, Parsons, & Meloth, 2009). These complex activities include the thinking processes that help the teacher to guide students purposefully from skill and comprehension level to the next (Duffy et al., 2009). The use of the metacognitive subfactors is among those highly complex activities that teachers use to monitor and adjust instruction within their classrooms. Mathematics teachers use these metacognitive activities to create and maintain a classroom learning environment that encourages intellectual inquiry and creative thinking in order to promote student learning that is appropriate for the diverse student population within the classroom.

While planning and instructing, teachers need to be self-aware of their instructing for thinking in order to engage and monitor students in metacognitive activities (Lee, Teo, & Chai, 2010). Metacognitive awareness of planning assists teachers with understanding the depth and complexity of the planning process. This study examined the awareness that teachers of mathematics have during the planning, evaluating, and monitoring of their instruction. The study examined potential predictors to determine if any of the predictors might, in part, impact the teachers use of the six subfactors of metacognition. Procedural knowledge and conditional knowledge greatly impact the mathematics teachers' abilities to plan, monitor, and adjust their instruction. This study helped to provide additional evidence that the number of years a mathematics teacher has been teaching has an influence on the teacher's conditional knowledge and procedural knowledge as well as the planning and monitoring awareness of the teacher. Teachers must have the knowledge and skills necessary continuously to promote student achievement and social change within the classroom. Duffy et al. (2009) noted that exemplary teachers will alter lesson plans to provide mini-lessons during teachable moments as a real-time response to their students' needs. Among the knowledge and skills necessary to make these real-time adjustments are the subfactors of metacognition that were examined in this study.

Some methods of determining a mathematics solution are more complicated and more cognitively demanding than others (De Smedt & Verschaffel; Thomas et al., 2010). The ability to monitor and exercise control over the problem solving process is highly involved with the development from novice to expert (Metallidou, 2009). Transfer of knowledge to new situations is critical for improving performance in mathematics. Comprehension of what an example represents impacts successful transfer of knowledge. Making connections between current learning and prior knowledge is critical to identification and understanding of the hidden structure of a problem. Understanding of the mathematical skill and the appropriate application is crucial to transfer performance (Lee et al., 2014). A teacher of mathematics must have and use the declarative knowledge, procedural knowledge, and conditional knowledge of the mathematical skill in order to plan, monitor, and evaluate the instruction of the skill as well as the transfer of the use of the mathematical skill to new situations. Teachers are also charged with monitoring the effectiveness of the students use of metacognitive skills.

Zohar (1999) found that teaching experience in itself may impact the level and effectiveness of teacher metacognition. This study found evidence of this phenomenon regarding the impact of teaching experience on the teachers use of the metacognitive subfactors of declarative knowledge, procedural knowledge, conditional knowledge, planning awareness, and monitoring awareness. The results of this study also support the findings of Lee et al. (2010) in reference to the demonstration of significant differences of teacher experience on monitoring and procedural knowledge. Metallidou (2009) emphasized that, “It is assumed, nevertheless, that inservice teachers’ metacognitive knowledge is a combined product of their vocational experience within the educational domain and their age” (p. 77). The results of this current research study support the statement of Metallidou (2009) in that this study provides evidence that the subfactors of Metacognitive Knowledge are impacted by the number of years of teaching experience. In addition, the findings of this study extend the available information about mathematics teachers’ metacognitive knowledge and awareness used during their instruction by examining the potential relationship to the other demographic and genetic factors examined as independent variables of this research study.

Previous knowledge and learning are not automatically applied to new circumstances. The outcome of the learning process is dependent on the accessibility of declarative knowledge and procedural knowledge. The proper ordering and use of the procedures needs to be applied in order to attain the learning goal. The monitoring and control of one’s thoughts and on the reflective evaluation of the resulting outcome are a critical part of the learning process (Efklides, 2009). Regarding the evaluating awareness used in the instructional practices of mathematics teachers, this results of this study did not provide sufficient evidence significant differences were accountable to the age, gender, type of teacher preparation, grade level of mathematics instruction, number of years of education, all degrees earned, age when entered the teaching profession, and number of years of teaching experience, including any interruptions in the teachers’ years of experience. The results for the examination of evaluating awareness in this investigative study were inconclusive. None of the nine independent variables examined as potential predictors of the mathematics teachers' use of the metacognitive subfactors in their instructional practices were determined to be statistically significant predictors of evaluating awareness. Additional research should be conducted to determine the predictors of evaluating awareness used by the teachers of mathematics.

Connection to Theoretical Framework

The ability of a person to understand, reflect, and control one's learning based on reflection and understanding of one's thinking as metacognition (Schraw & Dennison, 1994). The knowledge required for the selection of the appropriate strategy for a particular situation and conditions is an important aspect of metacognition for teaching and learning (Wilson & Bai, 2010). While there is no single widely accepted definition of metacognition, many researchers and theorists agree that metacognition involves the conscious processes of awareness of one's learning and regulation of one's learning (Wilson & Bai, 2010; Wen, 2012). The mathematics teachers that voluntarily participated in this research study were asked to reflect on, and to the best of their ability, honestly respond to the items in the Metacognitive Awareness Inventory for Teachers (Balcikanli, 2011). The responses of the mathematics teachers analyzed for this research study demonstrated that the number of years of teaching experience of the mathematics teachers impacted their use of five of the six metacognitive subfactors in their instructional practices. Mathematics teachers perform these highly complex activities as both teachers of mathematics skills for students and as learners of how the students learn mathematics.

It has been demonstrated in the past that learners who experience a greater degree of metacognitive awareness demonstrated higher academic performance in a pretest-posttest research study that measured both academic and metacognitive performance conducted by Schraw & Dennison (1994; Smith, 2013). During the beginning of the mathematics problem solving process, metacognitive skills were determined to play a more a greater role in learning than intellectual capacity (Veenman et al., 2006). The findings of Veenman et al. demonstrated that metacognition accounted for a greater portion of the variance in learning than that of intellectual ability. In the findings of Magno (2010), it was noted that when a teacher provided explicit instruction and guidelines for metacognition to learn materials effectively, critical thinking was encouraged among the students in the classroom. Additional investigations of the impact of metacognitive development in formal academic settings and its connection with other contexts are needed to better understand the predictors of metacognition. This current research study determined that the number of years of teaching experience had a positive influence on the use of five of the subfactors of metacognition by the teachers of mathematics who participated in this study. This study also indicated that age had an influence on two of the three subfactors of metacognitive knowledge while gender appeared to impact two of the three subfactors of metacognitive regulation. Interruptions in the teaching experience was determined to impact only the subfactor of metacognitive knowledge. Teachers use these metacognitive subfactors to monitor the students learning and the students use of the metacognitive subfactors in their learning in addition to using the metacognitive subfactors to monitor and adjust their instructional practices.

Metacognition was described by Doganay and Demir (2011) as “the act of learning to learn, focusing, step by step planning what is going to be done, evaluating every phase of the learning process, and making the necessary adjustments accordingly” (p. 2036). The teacher who continuously monitors and adjusts instruction to meet the needs of the learner performs this role in a parallel manner. Teachers use the interactive metacognitive processes of thinking and adjusting while instructing to learn about themselves as practitioners as well as to monitor and evaluate student learning. These elements include planning, regulating, and monitoring throughout the different stages of a teacher’s instructional practices (Clark & Peterson, 1986; Shavelson & Stern, 1981). In this dual level parallel process, teachers use metacognitive strategies for teaching metacognition to their students, as well as, for monitoring their thinking and learning (Doganay & Demir, 2011). The impact of teachers’ modeling of metacognitive skills and knowledge while providing feedback to students has not been studied to great depth (Veenman et al., 2006). The results of this current research study extended existing information about the use of metacognition by mathematics teachers to plan, monitor, and adjust instruction their instructional practices. This study also laid the ground work for further research into the use of metacognition by mathematics teachers. The creation of regression equations of statistical significance in this study opens the doors for further exploration and the creation of mathematical models that better predict the use and awareness of metacognition by mathematics teachers. This study demonstrated that the number of years of teaching experience has an influence on at least five of the subfactors of metacognition. Declarative knowledge**,** procedural knowledge**,** conditional knowledge**,** monitoring awareness, and planning awareness were positively impacted by the number of years of teaching experience of the mathematics teacher participants of this research study. As further investigations of these phenomenon are conducted, training programs for inservice and preservice teachers can implement methods of assisting new and future mathematics teachers with improving their development of their declarative knowledge, procedural knowledge, conditional knowledge, planning awareness, and monitoring awareness in order to help these teachers establish a level of expertise with these subfactors of metacognition.

Doganay and Demir (2011) emphasized The interconnections of metacognition with all of the dimensions of the thought process as demonstrated by the learner's attentiveness and responsiveness to their thoughts and in controlling their actions (Doganay & Demir, 2011). In order to monitor student learning, mathematics teachers must be aware of their cognitive processes in addition to the mathematics content and its required procedures. The teachers' reflection on their prior experiences and knowledge, as well as, innovation and imagination to acquire new skills during the planning, monitoring, and evaluation of their instructional practices demonstrated the interconnection of metacognition with the thought process (Dognay & Demir, 2011). Metacognition is a critical element as a part of the reflective practices required for the improvement of teaching and learning (Barton, Freeman, Lewis, & Thompson, 2001; Marzano et al., 2012). The results of this research study provided additional evidence that the metacognitive mathematics teacher monitors the attempts of the student to learn, provides scaffolds, and adapts the learning environment or methodology in real-time interactions with the students when necessary. This research study provided insight about the impact of demographic and genetic variables on the use of the metacognitive subfactors by mathematics teachers to adjust their instructional practices.

This study investigated the impact of potential predictors on the six subfactors of metacognition used by mathematics teachers for the adjustment of instruction of students and the learning of mathematics. This study was guided by the need to understand the use of metacognition by mathematics teachers. The teachers' understanding of what is required for teaching significantly impacts instructional practices, as well as student learning (Wilson & Bai, 2010). The teachers were asked to reflect on their use of metacognition during the planning, monitoring, and evaluating of instruction. The rating responses provided by the mathematics teachers as a measurement of their use and awareness of the metacognitive subfactors in their instructional practices provided data for the examination of the impact of the nine independent variables on the teachers use of these subfactors. The study critically examined the influence of potential demographic and genetic predictor variables on the role of teacher metacognitive awareness for the adjustment of instruction of students. The most promising of those potential predictors proved to be the number of years of teaching experience of the mathematics teachers. The number of years teaching experience appeared to impact the teachers' use of declarative knowledge, procedural knowledge, conditional knowledge, planning awareness, and monitoring awareness. In addition, age appeared to impact the subfactors of metacognitive knowledge, while gender impacted two of the three subfactors of metacognitive regulation. The regression equations produced in this study provided a baseline and a foundation for future studies of the instructional practices of mathematics teachers and how to assist mathematics teachers in developing expertise in their instructional practices.

Limitations of the Study

This study critically investigated and compared the degree of the influence of age, gender, type of teacher preparation, grade level of mathematics instruction, number of years of education, all degrees earned, age when entered the teaching profession, and number of years of teaching experience, including any interruptions in the teachers' years of experience on the mathematics teachers' awareness and use of the six subfactors of metacognition. One hundred twenty teachers (120) of mathematics for grades kindergarten through grade twelve from the National Council of Teachers of Mathematics participated voluntarily in this research study. This study included the investigation of the teachers of mathematics perspectives and responses of how they used metacognition to plan, adjust, and evaluate their instruction to meet the needs of their students. Each of the twenty-four items of the MAIT was designed to serve as a measurement of one of the six subfactors of metacognition. The impact of the nine independent variables was examined to determine if any could serve as predictors of the teachers use of the subfactors of metacognition. This study demonstrated that the number of years of teaching experience has a positive impact on five of the six subfactors of metacognition. These subfactors are those of declarative knowledge, procedural knowledge, conditional knowledge, planning awareness, and monitoring awareness. This research study was not intended to examine the impact of teaching of metacognitive strategies to mathematics students or to examine the academic performance of pupils whose teachers use metacognitive strategies to adjust their instruction. The goal of this study was to examine the impact of the nine independent variables as potential predictors of the awareness and use of the six subfactors of metacognition in the instructional practices of mathematics teachers. The results of this study can provide insight for preservice and inservice training to assist teacher in developing expertise with their use of metacognition.

Limitations of this study included small number of voluntary responses collected from the online administration of the survey. The 120 responses collected were less than one fourth of the desired sample as described in the proposal of this study. The smaller sample size reduced the effect size of the study to 0.15 which is a medium level of effect at the 0.80 level of power. The strength of generalizability of the results was thus reduced from its potential effect but the still maintains some strength for potential application to future studies. The sampling methodology of cluster sampling removed any possibility of the use of a random sample for this study. The contact information of the 5000 potential participants was randomly selected by an independent agency that manages the membership list of the National Council of Teachers of Mathematics. Additionally, the r-squared values were extremely low and indicated a very small predictive effect on the dependent variables.

It was possible that some teachers completing the survey may not have fully understood metacognition and its importance in the teaching of mathematics. These teachers may have used practices to plan, monitor, and adjust their instruction without being aware of their thinking about the metacognitive processes involved. Mathematics teachers completing this survey may not have received previous instruction about metacognition and its application to teaching and learning. Participants were asked to reflect on their instructional practices. Thus, their personal bias may impact their beliefs about their practices and performance.

Recommendations

The examination of the use of metacognition by mathematics teachers expanded the use of the MAIT to a broader population of teachers. Study results opened the door for future application of this instrument to larger populations and more diverse content areas. The additional examination of the impact of the demographic and genetic independent variables opens the door for comparison of the effects of multiple independent variables on the metacognitive experiences of teachers and learners especially for those teachers of mathematics. Additional studies should be conducted to further explore the demographic and genetic variables that predict the use of metacognition by mathematics teachers. It has been demonstrated that the number of years of teaching experience has a positive impact on the teachers' rating of their use of declarative knowledge, procedural knowledge, conditional knowledge, planning awareness, and monitoring awareness in their instructional practices. Additional training in development of the skills of these five subfactors of metacognition may help preservice teachers and new teachers develop expertise with these skills at an earlier point in their careers.

Implications

Positive Social Change

Information from this study will assist with the improvement of metacognitive training and preparation of preservice and current mathematics teachers. Improvement in education and performance of teachers should have a positive impact on classroom instruction. The improvement in the teaching and learning of mathematics will create positive social change by improving the quantitative literacy and numeracy skills of students. Stronger numeracy skills will improve the quality of the workers entering the workforce. In addition, improving the numeracy skills of students assists in decreasing the number of students that need remediation in mathematics at the college and university level. Further research should be conducted on the development of metacognitive and self regulatory skills of mathematics teachers. Additional Information about the development of these processes as mediated by the mathematics teacher could provide a deeper comprehension of how these processes are used for the teaching and learning of mathematics. This knowledge may also lead to improve academic achievement in mathematics as well as learning environments for mathematics.

Learners monitor and adjust their learning through the use of metacognition in feedback loops that adequately evaluate their progress toward their goals. Metacognition plays a crucial role in the self regulatory processes used by learners. Preservice teachers are students of teaching strategies and methodologies. Inservice teachers are learners of these same skills, as well as learners with the needs of students. All teachers, preservice and inservice, must monitor the effectiveness of instruction, thus placing additional importance on metacognition as a tool for the teacher as both an educator and a learner. The goal, for preservice and inservice teachers alike, is to increase the level of expertise in the planning, monitoring, and adjustment of student learning.

This knowledge may also assist teacher educators in provide the necessary instructional supports to build skills that teachers have not yet developed, are in the process of developing, or are in the process of becoming automatic through additional practice. The results of this study expanded previous knowledge of the use of metacognition by teachers and offers promise of relevancy for the improvement of training of preservice teachers who have an active role in supporting and fostering student learning (Azevedo, 2009). In order to reduce the 9.7 years that it takes to increase the mathematics teachers' awareness and use of the metacognitive subfactors and assist teachers in attaining expertise, teachers and preservice teachers should be trained in the metacognitive practices. As described in the literature reviewed for Chapter 2, teachers must be aware of their thinking, as well as their teaching and learning practices to become responsible change agents (Lee et al., 2010). Teachers can be trained in methods that assist them with becoming more aware of their thoughts, understanding, and knowledge about teaching and learning in order to develop and improve their instructional practices. Teachers also need to be aware of their knowledge of the content of instruction, including their strengths and weaknesses within the content area. They also need to be conscious of the different strategies and types of knowledge available to them for use in developing and improving their practices (Doganay & Demir, 2011; Lee et al., 2010; Parsons & Stephenson, 2005). This study has demonstrated that it takes numerous years to develop these skills and supports the necessity of training the metacognitive skills described by the researchers cited in the literature reviewed for Chapter 2 of this research study. Additional research should be conducted to investigate the potential predictors of metacognition in groups that differ in size, geographical area, and content area from that of this research study.

Conclusion

Metacognition is an important facet of self regulated learning. It functions through thought and reflection and does not have direct access to learning behaviors. Previous studies on metacognition and problem solving have demonstrated that metacognition has a substantial impact on problem solving ability. Metacognition may have a significant impact on how students learn mathematics particularly with the learning of more complex skills, application of skills to new situations, or with the abstract theoretical applications of mathematics. Previous research has established the association of success in problem solving with higher levels of metacognition. Learners must employ a different perspective when undertaking learning that is new or not routine.

Teachers need to monitor the global classroom environment as well as the individual students' interactions within the environment. This monitoring of information in combination with the students' engagement and experiences within the learning environment and with the learning activity provides the teacher with the necessary information to adjust instruction through the provision of scaffolds, alternative instruction, or resources. On the spot adaptation of instruction as emphasized by Marzano et al. (2012). is critical to improving students' mathematical achievement. The real-time adaptation of instruction or educational environment may also be essential to the reduction of stress perceived by the learner. The information gained through this study has the potential to assist with the improvement of metacognitive training and preparation of preservice and current mathematics teachers in the skills mentioned above. Improvement in the teaching and learning of mathematics may create positive social change through the increase of the numeracy skills and quantitative literacy of students assisting them with their preparation for their career or with post-secondary studies. Since American school systems have been struggling with improving achievement in science, technology, engineering, and mathematics for decades, providing teachers with additional tools to help their instruction can only benefit our children and our Nation.

References

Abar, B., & Loken, E. (2010). Self-regulated learning and self-directed study in a pre-college sample. *Learning and Individual Differences,* 20, 25-99.

Anderson, J. R., Betts, S., Ferris, J. L., & Fincham, J. M. (2011). Cognitive and metacognitive activity in mathematical problem solving: Prefrontal and parietal patterns. *Cognitive, Affective, & Behavioral Neuroscience*, 11(1), 52-67.

Appendix A: Durbin-Watson Significance Tables (n.d.). Retrieved from: https://www3.nd.edu/~wevans1/econ30331/Durbin_Watson_tables.pdf

Azevedo, R. (2009). Theoretical, conceptual, methodological, and instructional issues in research on metacognition and self-regulated learning: A discussion. *Metacognition & Learning,* 4(1), 87-95. doi:10.1007/s11409-009-9035-7

Balcikanli, C. (2011). Metacognitive awareness inventory for teachers (MAIT). *Electronic Journal of Research in Educational Psychology,* 9(3), 1309-1332.

Bandura, A. (1986). *Social foundations of thought and action: A cognitive social theory*. Englewood Cliffs, NJ: Prentice Hall.

Barton, V., Freeman, B., Lewis, D., & Thompson, T. (2006). *Metacognition: Effects on reading comprehension and reflective response* (Unpublished master's research project). St. Xavier University, Chicago, IL. Retrieved from http://www.eric.ed.gov

Becker, D. R., Miao, A., Duncan, R., & McClelland, M. M. (2014). Behavioral self-regulation and executive function both predict visuomotor skills and early academic achievement. *Early Childhood Research Quarterly,* 29, 411-424.

Berends, I. E., & van Lieshout, E. C. (2009). The effect of illustrations in arithmetic problem-solving: Effects of increased cognitive load. *Learning and Instruction*, 19(4), 345-353.

Bevilacqua, L., & Goldman, D. (2009). Genes and Addictions. *Clinical Pharmacology and Therapeutics*, *85*(4), 359–361. http://doi.org/10.1038/clpt.2009.6

Blank, R., Langesen, D., & Petermann, A. (2007). State indicators of science and mathematics education: 2007. Retrieved from http://www.ccsso.org/Documents/2007/State_Indicators_of_Science_and_Mathematics_2007.pdf

Brace, N., Kemp, R., & Sneglar, R. (2000). *SPSS for psychologists: A guide to data analysis using SPSS for Windows*. Mahwah, NJ: Earlbaum.

Bransford, J. D., Brown, A., & Cocking, R. (1999). *How people learn: Mind, brain, experience, and school*. Washington, DC: National Research Council.

Bollen, K., & Jackman, R. W. (1990). Regression diagnostics: An expository treatment of outliers and influential cases. In J. Fox & S. J. Long (Eds.), *Modern methods of data analysis* , (pp. 257-291). Newbury Park, CA: Sage.

Boonen, T., Van Damme, J., & Onghena, P. (2014). Teacher effects on student achievement in first grade: which aspects matter most?. *School Effectiveness and School Improvement*, *25*(1), 126-152.

Bromme, R., Pieschl, S., & Stahl, E. (2010). Epistemological beliefs are standards for adaptive learning: A functional theory about epistemological beliefs and metacognition. *Metacognition and Learning*, 5(1), 7-26.

Brown, A. L. (1980). Metacognitive development and reading. In R. J. Spiro, B. C. Bruce, and W. F. Brewer (Eds.), *Theoretical issues in reading comprehension* (pp. 453-479). Hillsdale, NJ: Erlbaum.

Buchner, A., Erdfelder, E., Faul, F., & Lang, Albert-Georg (2014). *G*Power 3.1.9.2 for Windows* (Version 3.1.9.2) [Software]. Available from: http://www.gpower.hhu.de/

Clark, C. M., & Peterson, P. L. (1986). Teachers' thought processes. In M. C. Wittrock (Ed.), *Handbook of research on teaching* (pp. 255-296). New York, NY: MacMillan.

Cobb, P., Boufi, A., McClain, K., & Whitenack, J. (1997). Reflective discourse and collective reflection. *Journal for Research in Mathematics Education*, *28*, 258–277.

College Board. (2014). The 10th annual AP report to the nation. New York. Retrieved from: http://apreport.collegeboard.org/

Creative Research Systems (2013). *Sample size calculator*. Retrieved from: http://www.surveysytem.com/sscalc.htm

Creemers, B. P., Kyriakides, L., & Antoniou, P. (2013). A dynamic approach to school improvement: main features and impact. *School Leadership & Management*, *33*(2), 114-132.

Creswell, J.W. (2007). *Qualitative inquiry & research: Choosing among the five approaches* (2nd ed.). Thousand Oaks, CA: Sage.

Creswell, J. W. (2009). *Research design: Qualitative, quantitative, and mixed methods approaches* (3rd ed.). Thousand Oaks, CA: Sage.

Creswell, J. W., & Clark, V. L. P. (2007). *Designing and conducting mixed methods research*. Thousand Oaks, CA: Sage.

Cubukcu, F. (2009). Learner autonomy, self-regulation and metacognition. *International Electronic Journal of Elementary Education*, 2(1), 53-64.

Dehaene, S., Molko, N., Cohen, L., & Wilson, A. J. (2004). Arithmetic and the brain. *Current Opinion in Neurobiology*, 14(2), 218-224.

De Smedt, B., & Verschaffel, L. (2010). Traveling down the road: From cognitive neuroscience to mathematics education… and back. *ZDM: The International Journal on Mathematics Education*, 42(6), 649-654.

Desoete, A. (2007). Evaluating and improving the mathematics teaching-learning process through metacognition. *Electronic Journal of Research in Educational Psychology*, 5(3), 705-730.

Dewey, J. (1933). *How we think: A restatement of the relation of reflective thinking to the educative process*. Chicago, IL: Regnery.

Doganay, A., & Demir, O. (2011). Comparison of the level of using metacognitive strategies during study between high achieving and low achieving prospective teachers. *Educational Sciences: Theory and Practice*, 11(4), 2036-2043.

Donovan, M. S., Bransford, J. D., & Pellegrino, J. W. (Eds.) (1999). *How people learn: Bridging research and practice.* Washington, DC: National Academies Press.

Dole, J. A., Duffy, G. G., Roehler, L. R., & Pearson, P. D. (1991). Moving from old to new: Research on reading instruction. *Review of Educational Research,* 61, 239-264.

Dowker, A. (2005). *Individual differences in arithmetic: Implications for psychology, neuroscience and education*. New York, NY: Psychology Press. Retrieved from: http://zung.zetamu.net/Library/Education/Education_Neuroscience/Dowker_IndividualDifferencesInArithmeticalAbilities__2005.pdf

Dowker, A. (2009). *What works for children with mathematical difficulties? The effectiveness of intervention schemes*. London, England: Department Children, Schools, and Families. Retrieved from: http://dera.ioe.ac.uk/2505/1/ma_difficulties_0008609.pdf

Downing, K., Kwong, T., Chan, S. W., Lam, T. F., & Downing, W. K. (2009). Problem-based learningand the development of metacognition. *Higher Education*, 57(5), 609-621.

Duffy, G. G., Miller, S., Parsons, S., & Meloth, M. (2009). Teachers as metacognitive professionals. In D. J. Hacker, J. Dunlosky, & A. C. Graesser (Eds.), *Handbook of Metacognition in Education* (pp. 240-251). New York, NY: Routledge.

Dunlosky, J., & Rawson, K. A. (2012). Overconfidence produces underachievement: Inaccurate self evaluations undermine students' learning and retention. *Learning and Instruction*, 22(4), 271-280.

Durbin, J., & Watson, G. S. (1951). Testing for Serial Correlation in Least Squares Regression. II. *Biometrika*, 38(1/2), 159–177.

Appendix A: Durbin-Watson Significance Tables (n.d.). Retrieved from: https://www3.nd.edu/~wevans1/econ30331/Durbin_Watson_tables.pdf

Ebdon, S. A., Coakley, M. M., & Legnard, D. S. (2003). Mathematical mind journeys: Awakening minds to computational fluency. *Teaching Children Mathematics*, 9, 486-493.

Edwards, A. R., Esmonde, I., & Wagner, J. F. (2011). Learning mathematics. In R. E. Mayer & P. A. Alexander (Eds.), *Handbook of research on learning and instruction* (pp. 55-77). New York, NY: Routledge.

Efklides, A. (2009). The role of metacognitive experiences in the learning process. *Psicothema*, 21(1), 76-82.

Edwards, A. R., Esmonde, I., & Wagner, J. F. (2011). Learning mathematics. In R. E. Mayer, & P. A. Alexander (Eds.), *Handbook of research on learning and instruction* (pp. 55-77). New York, NY: Routledge.

Farrell, P. (2010). School psychology: Learning lessons from history and moving forward. *School Psychology International*, 31(6), 581-598.

Faul, F., Erdfelder, E., Lang, A.-G., & Buchner, A. (2007). G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods, 39*, 175-191.

Faul, F., Erdfelder, E., Buchner, A., & Lang, A.-G. (2009). Statistical power analyses using G*Power 3.1: Tests for correlation and regression analyses. Behavior Research Methods, 41, 1149-1160.

Feltovich, P. J., Prietula, M. J., & Ericsson, K. A. (2006). Studies of expertise from psychological perspective. In K. A. Ericsson, N. Charness, P. J. Feltovich, & R. R. Hoffman (Eds.), *The Cambridge handbook of expertise and expert performance* (pp. 41-67). New York: Cambridge University Press.

Fennema, E., Franke, M., & Carpenter, T., & Carey, D. (1993). Using children's mathematical knowledge in instruction. *American Educational Research Journal*, *30*(3), 555–583.

Fennema, E., Carpenter, T. P., Franke, M., Levi, L., Jacobs, V. R., & Empson, S. B. (1996). A longitudinal study of learning to use children's thinking in mathematics instruction. *Journal for Research in Mathematics Education*, *27*(4), 403–434.

Field, A. (2013). *Discovering statistics using IBM SPSS Statistics* (4th ed.). London, England: Sage.

Flavell, J. H. (1970). Developmental studies of mediated memory. In W. Reese & L. Lipsitt (Eds.), *Advances in child development and behavior* (pp.181-211). New York: Academic Press

Flavell, J. H. (1976). Metacognitive aspects of problem solving. In L. B. Resnick (Ed.)., *The nature of intelligence* (pp. 231-235). Hillsdale, NJ: Erlbaum.

Flavell, J. H. (1979). Metacognition and cognitive monitoring; A new area of cognitive-developmental inquiry. *American Psychologist*, 34, 906-911.

Flavell, J. H. (2004). Theory-of-mind development: Retrospect and prospect. *Merrill-Palmer Quarterly*, 50(3), 274-290.

Forman, E. A., Larreamendy-Joerns, J., Stein, M. K., & Brown, C. A. (1998). "You're going to want to find out which and prove it": Collective argumentation in a mathematics classroom. *Learning and Instruction*, *8(6)*, 527–548.

Frankfort-Nachmias, C., & Nachmias, D. (2008). *Research methods in the social sciences*, (7th ed.), New York, NY: Worth.

Fritzsche, E. S., Kröner, S., Dresel, M., Kopp, B., & Martschinke, S. (2012). Confidence scores as measures of metacognitive monitoring in primary students? (Limited) validity in predicting academic achievement and the mediating role of self-concept. *Journal for Educational Research Online*, 4(2), 120-142.

Fuchs, L. S., Geary, D. C., Compton, D. L., Fuchs, D., Schatschneider, C., Hamlett, C. L., & Changas, P. (2013). Effects of first-grade number knowledge tutoring with contrasting forms of practice. *Journal of Educational Psychology*, 105(1), 58.

Geary, D. C., & Damon, W. (2006). Development of mathematical understanding. In D. Kuhl & R. S. Siegler (Eds.), *Handbook of Child Psychology*. New York, NY: Wiley.

Geist, E. (2010). The anti-anxiety curriculum: Combating math anxiety in the classroom. *Journal of Instructional Psychology*, 37(1), 24-31.

Gillard, E., Van Dooren, W., Schaeken, W., & Verschaffel, L. (2009). Dual processes in the psychology of mathematics education and cognitive psychology. *Human Development*, 52(2), 95-108.

Glaser, R., & Chi, M. T. H. (1988). Overview. In M. T. H. Chi, R. Glaser, & M. J. Farr (Eds.), *The nature of expertise* (pp. xv-xxviii). Hillsdale, NJ: Earlbaum.

Google Inc. (2014). Create a survey using Google Forms. Google, Inc. Mountain View California. Retrieved from: https://support.google.com/docs/answer/87809?hl=en

Green, S. B., & Salkind, N. J. (2008). *Using SPSS for Windows and Macintosh: Analyzing and understanding data*. Upper Saddle River, NJ: Pearson Prentice Hall.

Gross, J. (2007). Supporting children with gaps in their mathematical understanding: the impact of the National Numeracy Strategy (NNS) on children who find mathematics difficult. *Educational and Child Psychology*, 24(2), 146-156.

Hacker, D. J., (1998). Definitions and empirical foundation. In D. Hacker, J. Dunlosky, & A. Graesser (Eds). *Metacognition in educational theory and practice* (pp. 1-23). New York, NY; Routledge.

Hammerness, K., Darling-Hammond, L., Bransford, J., Berliner, D., Cochran-Smith, M., McDonald, M., & Zeichner, K. (2005). How teachers learn and develop. In Linda Darling-Hammond & John Bransford (Eds.), *Preparing teachers for a changing world: What teachers should learn and be able to do*, (pp. 358-389). San Francisco, CA: Jossey-Bass.

Hartman, H. J. (Ed.). (2001). *Metacognition in learning and instruction: Theory, research and practice* (Vol. 19). Dordrecht, Netherlands: Kluwer Academic.

Heck, D. J., Weiss, I. R., & Pasley, J. D. (2011). *A priority research agenda for understanding the influence of the Common Core State Standards for Mathematics*. Technical Report Center for Mental Health in Schools at UCLA.

Hembree, R. (1990). The nature, effects, and relief of math anxiety. *Journal for Research in Mathematical Education*, 21, 22-46.

Hofer, B. K., & Sinatra, G. M. (2010). Epistemology, metacognition, and self-regulation: musings on an emerging field. *Metacognition and Learning*, 5(1), 113-120.

IBM SPSS Statistics (2012) Graduate Pack (Version 21) [Computer software]. San Ramon, CA: PASW, Inc.

Ifenthaler, D. (2012). Determining the effectiveness of prompts for self-regulated learning in problem-solving scenarios. *Journal of Educational Technology & Society*, 15(1).

Jackson, C. K. (2012). *Teacher quality at the high-school level: The importance of accounting for tracks* (No. w17722). National Bureau of Economic Research. Cambridge, MA. Retrieved from: http://www.nber.org/papers/w17722.

Jackson, C. K., Rockoff, J. E., & Staiger, D. O. (2014). Teacher effects and teacher-related policies. *Annual Review of Economics, 6*(1), 801-825.

Kazemi, F., Fadaee, M. R., & Bayat, S. (2010). A subtle view to metacognitive aspect of mathematical problems solving. *Procedia-Social and Behavioral Sciences*, 8, 420-426.

Kistner, S., Rakoczy, K., Otto, B., Dignath-van Ewijk, C., Büttner, G., & Klieme, E. (2010). Promotion of self-regulated learning in classrooms: Investigating frequency, quality, and consequences for student performance. *Metacognition and learning*, 5(2), 157-171.

Kluwe, R. H. (1982). Cognitive knowledge and executive control. In D. Griffin (Ed), *Human mind – animal mind* (pp. 201-224). New York, NY: Springer.

Kluwe, R. H. (1987). Executing decisions and regulation of problem solving behavior. In F. E. Weinert & R. H. Kluwe (Eds.)., *Metacognition, motivation and understanding* (pp. 31-34). Hillsdale, NJ: Earlbaum.

Koaler, O., Abumert, J., & Schnabel, K. (2001). Does interest matter? The relationship between academic interest and achievement in mathematics. *Journal for Research in Mathematics Education,* 32(5), 448-470.

Kramarski, B. (2009). Developing a pedagogical problem solving view for mathematics teachers with two reflection programs. International Electronic Journal of Elementary Education, 2(1).

Labuhn, A. S., Zimmerman, B. J., & Hasselhorn, M. (2010). Enhancing students' self-regulation and mathematics performance: the influence of feedback and self-evaluative standards. *Metacognition and Learning*, 5(2), 173-194.

Lai, E. R. (2011). Metacognition: A literature review. Retrieved from: http://www.Pearsonassessments.com/hai/images/tmrs/metacognition_Literature_Review_Final.pdf.

Lee, C. B., Teo, T., & Chai, C. S. (2010). Profiling preservice teachers' awareness and regulation of their own thinking: Evidence from an Asian country. *Teacher Development,* 14(3), 295-306.

Lee, H. S., Fincham, J. M., Betts, S., & Anderson, J. R. (2014). An fMRI investigation of instructional guidance in mathematical problem solving. *Trends in Neuroscience and Education.* Retrieved from: http://dx.doi.org/10.1016/j.tine.2014.01.001

Lee, H. W., Lim, K. Y., & Grabowski, B. (2009). Generative learning strategies and metacognitive feedback to facilitate comprehension of complex science topics and regulation. *Journal of Educational Media and Hypermedia,* 18(1), 5-25.

Lester, F. K. (2010). The role of problem solving in the secondary mathematics classroom. In J. Lobato (Ed.), *Teaching and learning mathematics: Translating research for secondary school teachers* (pp. 7-12). Reston, VA: National Council of Teachers of Mathematics.

Lester, F. (2013). Thoughts about research on mathematical problem-solving instruction. *The Mathematics Enthusiast*, 10(1 & 2), 245-278.

Lester, F. K. Kehle, P. (2003). From problem solving to modeling: The evolution of thinking about research on complex mathematical activity. In R. Lesh & H. M. Doerr (Eds.), *Beyond constructivism: Models and modeling perspectives on mathematical problem solving, learning, and teaching* (pp. 501-507). Mahwah, NJ: Erlbaum.

Magiera, M. T., & Zawojewski, J. S. (2011). Characterizations of social-based and self-based contexts associated with students' awareness, evaluation, and regulation of their thinking during small-group mathematical modeling. *Journal for Research in Mathematics Education*, 42(5), 486-520.

Magno, C. (2010). The role of metacognitive skills in developing critical thinking.

Metacognition and Learning, 5(2), 137-156.

Marzano, R., Brandt, R. S., Hughes, C., Jones, B. F., Presseisen, B. Z., Rankin, S., & Suhor, C. (1988). *Dimensions of thinking*. Alexandria, VA: Association for Supervision and Curriculum Development.

Marzano, R.J., & Kendall, J.S. (2006). *The new taxonomy of educational objectives* (2nd ed.). Thousand Oaks, CA: Corwin.

Marzano, R. J., Boogren, T., Heflebower, T., Kanold-McIntyre, J., & Pickering, D. (2012). *Becoming a reflective teacher*. Bloomington, IN: Marzano Research Laboratory.

McDonald, B. (2002). A teaching note on Cook's distance-a guideline. *Res. Lett. Inf. Math. Sci.* (2002), 3, 127-128. Retrieved from: http://www.massey.ac.nz/~wwiims/research/letters/

Menon, V. (2010). Developmental cognitive neuroscience of arithmetic: Implications for learning and education. *ZDM: The International Journal on Mathematics Education,* 42(6), 515-525.

Metallidou, P. (2009). Preservice and inservice teachers' metacognitive knowledge about problem-solving strategies. *Teaching and Teacher Education,* 25, 76-82.

Microsoft (2010). Microsoft Excel [computer software]. Redmond, Washington.

Myers, L. S., Gamst, G., & Guarino, A. J. (2012). *Applied multivariate research: Design and interpretation* (2nded.). Thousand Oaks, CA: Sage.

Nathans, L. L., Oswald, F. L., & Nimon, K. (2012). Interpreting multiple linear regression: A guidebook of variable importance. *Practical Assessment*, *Research*

& Evaluation, *17*(9), 2. Retrieved from: http://pareonline.net/getvn.asp?v=17&n=9

National Council of Teachers of Mathematics (2000). *Principles and standards for school mathematics.* Reston, VA: NCTM.

National Council of Teachers of Mathematics (2013). *National Council of Teachers of Mathematics: Executive director position profile*. Retrieved from: http://www.assnstrategies.com/pdf/NCTMProfileFinal.pdf

National Council of Teachers of Mathematics (2014). *NCTM 2014Annual Meeting Mailing List Order Forms.* Retrieved from: http://www.nctm.org/uploadedFiles/About_NCTM/Advertising/NCTM%202014%20Annual%20Meeting%20Mailing%20List%20Order%20Forms.pdf

National Council of Teachers of Mathematics (2015). *NCTM membership: Solving for you.* Retrieved from: http://www.nctm.org/membership/

National Council of Teachers of Mathematics (2015). *Why certified math teachers are in demand.* Retrieved from: http://www.nctm.org/resources/content.aspx?id=536

National Mathematics Advisory Panel (2008). *Foundations for success: The final report of the National Mathematical Advisory Panel*. Washington, DC: U.S. Department of Education.

National Science Board. (2016). *Science and Engineering Indicators 2016*. Arlington, VA: National Science Foundation (NSB-2016-1). Retrieved from: http://www.nsf.gov/statistics/2016/nsb20161/#/report

National Science Board. (2014). *Science and Engineering Indicators 2014*. Arlington, VA: National Science Foundation (NSB 14-01). Retrieved from: http://www.nsf.gov/statistics/seind14/

NCTM Linking Research and Practice Task Force (2005). *Harnessing the power of research for practice*. Retrieved April 9, 2012, from http://www.nctm.org/uploadedFiles/About_NCTM/Board_and_Committess/research_practice.pdf

NCTM Research Committee. (2006). The challenge of linking research and practice. *Journal for Research in Mathematics Education*, 37, 76−86.

Nau, R. F. (2009). What's a good value of R-squared? *Duke University*, *12*. Retrieved from: http://people.duke.edu/~rnau/rsquared.htm

Nietfeld, J. L., & Schraw, G. (2002). The effect of knowledge and strategy training on monitoring accuracy. *The Journal of Educational Research,* 95(3), 131-142.

Ozsoy, G., & Ataman, A. (2009). The effect of metacognitive strategy training on mathematical problem solving achievement. *International Electronic Journal of Elementary Education*, 1(2), 68-83.

Ozsoy, G., Memis, A., & Temur, T. (2009). Metacognition, study, and attitudes. *International Electronic Journal of Elementary Education,* 2(1), 154-166.

Parsons, S. A. (2008). Providing all students ACCESS to self-regulated literacy learning. *The Reading Teacher,* 61(8), 628-635.

Parsons, M., & Stephenson, M. (2005). Developing reflective practice in student teachers: Collaboration and critical partnerships. *Teachers and Teaching: Theory and Practice,* 11(1), 95-116.

Patton, M. Q. (2002). *Qualitative research and evaluation methods* (3rd ed.). Thousand Oaks, CA: Sage.

Perels, F., Dignath, C., & Schmitz, B. (2009). Is it possible to improve mathematical achievement by means of self-regulation strategies? Evaluation of an intervention in regular math classes. *European Journal of Psychology of Education*, 24(1), 17-31.

Pintrich, P. R. (2002a). The role of metacognitive knowledge in learning, teaching, and assessing. *Theory into Practice*, 41(4), 219.

Pintrich, P. R. (2002b). The role of goals and goal orientation. In P. R. Pintrich and D. H. Schunk (Eds.), *Motivation in education: Theory, research, and application* (pp. 190-242). Englewood Cliffs, NJ: Prentice Hall.

Posner, M. I., Rothbart, M. K., & Tang, Y. (2013). Developing self-regulation in early childhood. *Trends in Neuroscience and Education*, 2, 107-110.

Pressley, M., & Ghatala, E. S. (1990). Self-regulating learning: Monitoring learning from text. *Educational Psychologist*, 25, 19-33.

Pressley, M. & Wharton-McDonald, R. (1997). Skilled comprehension and its development through instruction. *School Psychology Review,* 26, 448-466.

Prytula, M. P. (2012). Teacher metacognition within the professional learning community. *International Education Studies*, 5(4), p112.

Rahman, F., Jumani, N. B., Satti, M. G., & Malik, M. I. (2010). Do metacogntively aware teachers make any difference in students' metacognition? *International Journal of Academic Research*, 2(6), 219-223.

Rieger R., Michaelis A., & Green M. M. (1976) Glossary of genetics and cytogenetics: Classical and molecular (4th ed.). New York, NY: Springer-Verlag.

Rubensten, O., & Tannock, R. (2010). Mathematics anxiety in children with developmental dyscalculia. *Behavioral and Brain Functions*, 6(1). Retrieved from: http://www.behavioralandbrainfunctions.com/content/6/1/46

Sacher, M., Landré, L., & Taconnat, L. (2013). Age-related differences in episodic feeling-of-knowing arise from differences in memory performance. *Memory*, (ahead-of-print), 1-8.

Savin, N. E., & White, K. J. (1977). The Durbin-Watson Test for Serial Correlation with extreme sample sizes or many regressors. *Econometrica*, *45*(8), 1989–1996.

Schoenfeld, A. H. (1987). What's all the fuss about metacognition? In *Cognitive Science and Mathematics Education.* Hilldale, NJ: Lawrence Earlbaum.

Schoenfeld, A. H. (1992). Learning to think mathematically: Problem solving, metacognition, and sense-making in mathematics. In D. A. Grouws (Ed.), *Handbook of research on mathematics teaching and learning* (pp. 334-370). New York, NY: MacMillan.

Schoenfeld, A. H. (2006). Mathematics teaching and learning. In P. A. Alexander, & P. H. Winne (Eds.), *Handbook of educational psychology* (2nd ed.) (pp. 479–510). Mahwah, NJ: Erlbaum.

Schraw, G. (2001). Promoting general metacognitive awareness. In H. J. Hartman (Ed.), *Metacognition in learning and instruction: Theory, research and practice* (pp. 3-16). Boston, MA: Kluwer.

Schraw, G. (2009). A conceptual analysis of five measures of metacognitive monitoring. *Metacognition and Learning*, 4(1), 33-45.

Schraw, G., & Dennison, R. S. (1994). Assessing metacognitive awareness. *Contemporary Educational Psychology*, 19, 460-475.

Schraw, G., Kuch, F., & Gutierrez, A. P. (2013). Measure for measure: Calibrating ten commonly used calibration scores. *Learning and Instruction*, 24, 48-57.

Schraw, G., & Moshman, D. (1995). Metacognitive theories. *Educational psychology review*, 7(4), 351-371.

Science Buddies (2013). *Sample size: How many survey participants do I need*? Retrieved from: http://www.sciencebuddies.org/science-fair-projects/project_ideas/Soc_participants.shtml

Seraphin, K. D., Philippoff, J., Kaupp, L., & Vallin, L. M. (2012). Metacognition as means to increase the effectiveness of inquiry-based science education. *Science Education International*, 23(4), 366-382.

Shavelson, R. J., & Stern, P. (1981). Research on teachers' pedagogical thoughts, judgements, decisions and beliefs. *Review of Educational Research*, 51, 455-498.

Shute, V. J., & Kim, Y. J. (2014). Formative and stealth assessment. In *Handbook of research on educational communications and technology* (pp. 311-321). New York: NY: Springer.

Silver, E.A. (1982). Knowledge organization and mathematical problem solving. In F.K. Lester & J. Garafalo (Eds.), *Developing cognitive competence: New approaches to process modeling* (pp. 15-25). Hillsdale, NJ: Earlbaum.

Silver, E. A. (1987). Foundations of cognitive theory and research for mathematic problem-solving instruction. In A.H. Schoenfield (Ed.), *Cognitive science and mathematics education* (pp. 33-60). Hillsdale, NJ: Earlbaum.

Smith, M. J. (2013). An exploration of metacognition and its effect on mathematical performance in differential equations. *Journal of the Scholarship of Teaching and Learning*, 13(1), 100-111.

Sperling, R. A., Richmond, A. S., Ramsay, C. M., & Klapp, M. (2012). The measurement and predictive ability of metacognition in middle school learners. *The Journal of Educational Research*, 105(1), 1-7.

Subramaniam, S. R. (2009). Metacognition in Teaching. In *Proceedings of 14th International Conference on Thinking (ICOT14)* (pp. 23-35). Retrieved from: http://www.furnware.co.nz/sites/default/files/51%20Selva%20Ranee.pdf

Swanson, H. L. (2011). Working memory, attention, and mathematical problem solving: A longitudinal study of elementary school children. *Journal of Educational Psychology*, 103(4), 821.

Thomas, J.J., Wilson, A. J., Coraballis, M.C., Lim, V. K., & Yoon, C. (2010). Evidence from cognitive neuroscience for the role of graphical and algebraic representations in understanding function. *ZDM: The International Journal on Mathematics Education.* doi: 10.1007/s11858-010-0272-7

Tomlinson, C., & Allan, S. D. (2000). *The differentiated classroom: Responding to the needs of all learners*. Alexandria, VA: Association for Supervision and Curriculum Development.

Veenman, M. V., & Alexander, P. (2011). Learning to self-monitor and self-regulate. In R. E. Mayer, & P. A. Alexander (Eds.), *Handbook of research on learning and instruction* (pp. 197-218). New York, NY: Routledge.

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

Vukovic, R. K., Kieffer, M. J., Bailey, S. P., & Harari, R. R. (2013). Mathematics anxiety in young children: Concurrent and longitudinal associations with mathematical performance. *Contemporary educational psychology*, 38(1), 1-10.

Walter, J. G., & Hart, J. (2009). Understanding the complexities of student motivations in mathematics learning. *The Journal of Mathematical Behavior*, 28, 162-170.

Wen, Y. H. (2012). A study on metacognition of college teachers. *The Journal of Human Resource and Adult Learning*, 8(1), 80-91.

Wilson, N. S., & Bai, H. (2010). The relationships and impact of teachers' metacognitive knowledge and pedagogical understandings of metacognition. *Metacognition and Learning, 5*(3), 269-288. doi:http://dx.doi.org/10.1007/s11409-010-9062-4

Winne, P. H., & Nesbit, J. C. (2010). The psychology of academic achievement. *Annual Review of Psychology,* 61, 653-678.

Wintermute, S., Betts, S., Ferris, J. L., Fincham, J. M., & Anderson, J. R. (2012). Brain networks supporting execution of mathematical skills versus acquisition of new mathematical competence. *PloS one*, 7(12), e50154. Retrieved from: http://dx.doi.org/10.1371/journal.pone.0050154

Yang, H. (2013). The case for being automatic: Introducing the Automatic Linear Modeling (LINEAR) Procedure in SPSS Statistics. *Multiple Linear Regression Viewpoints*, 39(2), 27-37.

Young, A., & Fry, J. D. (2008). Metacognitive awareness and academic achievement in college students. *Journal of the Scholarship of Teaching and Learning,* 8(2), 1-10.

Zimmerman, B. J. (2008). Investigation self-regulation and motivation: Historical back-ground, methodological developments and future prospects. *American Educational Research Journal,* 45(1), 166-183.

Zohar, A. (1999). Teachers' metacognitive knowledge and the instruction of higher order thinking. *Teaching and Teacher Education*, 15(4), 413-429.

Zohar, A., & David, A. B. (2008). Explicit teaching of meta-strategic knowledge in authentic classroom situations. *Metacognition and Learning,* 3, 59-82.

Zohar, A., & David, A. B. (2009). Paving a clear path in a thick forest: a conceptual analysis of a metacognitive component. *Metacognition and Learning,* 4(3), 177-195.

Appendix A: Survey Instrument

Survey of Metacognitive Awareness and Predicting Variables

Part 1: The Metacognitive Awareness Inventory for Teachers (MAIT)

The MAIT is a list of 24 statements. There are no right or wrong answers in this list of statements. It is simply a matter of what is true for you. Read every statement carefully and choose the one that best describes you.

Part 2: Demographic Information

Please provide information about your age, gender, type of teacher preparation, grade level of mathematics instruction, number of years of education, degrees earned, age when entered the teaching profession, years of teaching experience, and any interruptions in teachers' years of experience. This information is being collected to determine if these variables are predictors of mathematics teachers awareness of metacognition.

Part 1 -- Metacognitive Awareness Inventory for Teachers (MAIT)

"The MAIT is a list of 24 statements. There are no right or wrong answers in this list of statements. It is simply matter of what is true for you. Read every statement carefully and choose the one best describe you. Thank you very much for your participation" (Balcikanli, 2011, p. 1331).

1. **1. I am aware of the strengths and weaknesses in my teaching** *
   1 = Strongly Disagree 2 = Disagree 3 = Neutral 4 = Agree 5 = Strongly Agree
   Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

2. **2. I try to use teaching techniques that worked in the past.** *
   1 = Strongly Disagree 2 = Disagree 3 = Neutral 4 = Agree 5 = Strongly Agree
   Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

3. **3. I use my strengths to compensate for weaknesses in my teaching** *
   1 = Strongly Disagree 2 = Disagree 3 = Neutral 4 = Agree 5 = Strongly Agree
   Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

4. **4. I pace myself while I am teaching in order to have enough time.** *
1 = Strongly Disagree 2 = Disagree 3 = Neutral 4 = Agree 5 = Strongly Agree
Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

5. **5. I ask myself periodically if I meet my teaching goals while I am teaching.** *
1 = Strongly Disagree 2 = Disagree 3 = Neutral 4 = Agree 5 = Strongly Agree
Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

6. **6. I ask myself how well I have accomplished my teaching goals one I am finished.** *
1 = Strongly Disagree 2 = Disagree 3 = Neutral 4 = Agree 5 = Strongly Agree
Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

7. **7. I know what skills are most important in order to be a good teacher.** *
1 = Strongly Disagree 2 = Disagree 3 = Neutral 4 = Agree 5 = Strongly Agree
Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

8. **8. I have a specific reason for choosing each teaching technique I use in class.** *
1 = Strongly Disagree 2 = Disagree 3 = Neutral 4 = Agree 5 = Strongly Agree
Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

9. **9. I can motivate myself to teach when I really need to teach.** *
1 = Strongly Disagree 2 = Disagree 3 = Neutral 4 = Agree 5 = Strongly Agree
Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

10. **10. I set my specific teaching goals before I start teaching. ***
1 = Strongly Disagree 2 = Disagree 3 = Neutral 4 = Agree 5 = Strongly Agree
Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

11. **11. I find myself assessing how useful my teaching techniques are while I am teaching. ***
1 = Strongly Disagree 2 = Disagree 3 = Neutral 4 = Agree 5 = Strongly Agree
Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

12. **12. I ask myself if I could have used different techniques after each teaching experience. ***
1 = Strongly Disagree 2 = Disagree 3 = Neutral 4 = Agree 5 = Strongly Agree
Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

13. **13. I have control over how well I teach. ***
1 = Strongly Disagree 2 = Disagree 3 = Neutral 4 = Agree 5 = Strongly Agree
Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

14. **14. I am aware of what teaching techniques I use while I am teaching. ***
1 = Strongly Disagree 2 = Disagree 3 = Neutral 4 = Agree 5 = Strongly Agree
Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

15. **15. I use different teaching techniques depending on the situation. ***
1 = Strongly Disagree 2 = Disagree 3 = Neutral 4 = Agree 5 = Strongly Agree
Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

16. **16. I ask myself questions about the teaching materials I am going to use. ***
Carefully choose the one that best describes you
Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

17. **17. I check regularly to what extent my students comprehend the topic while I am teaching. ***
1 = Strongly Disagree 2 = Disagree 3 = Neutral 4 = Agree 5 = Strongly Agree
Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

18. **18. After teaching a point, I ask myself if I'd teach it more effectively next time. ***
1 = Strongly Disagree 2 = Disagree 3 = Neutral 4 = Agree 5 = Strongly Agree
Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

19. **19. I know what I am expected to teach. ***
1 = Strongly Disagree 2 = Disagree 3 = Neutral 4 = Agree 5 = Strongly Agree
Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

20. **20. I use helpful teaching techniques automatically. ***
1 = Strongly Disagree 2 = Disagree 3 = Neutral 4 = Agree 5 = Strongly Agree
Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

21. **21. I know when each teaching technique I use will be most effective. ***
1 = Strongly Disagree 2 = Disagree 3 = Neutral 4 = Agree 5 = Strongly Agree
Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

22. **22. I organize my time to best accomplish my teaching goals. ***
1 = Strongly Disagree 2 = Disagree 3 = Neutral 4 = Agree 5 = Strongly Agree
Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

23. **23. I ask myself questions about how well I am doing while I am teaching. ***
1 = Strongly Disagree 2 = Disagree 3 = Neutral 4 = Agree 5 = Strongly Agree
Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

24. **24. I ask myself if I have considered all possible techniques after teaching a point. ***
1 = Strongly Disagree 2 = Disagree 3 = Neutral 4 = Agree 5 = Strongly Agree
Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

Reference

Balcikanli, C. (2011). Metacognitive awareness inventory for teachers (MAIT). Electronic Journal of Research in Educational Psychology, 9(3), 1309-1332.

Part II -- Demographic Information

Please provide a little information about yourself. The data collected in this section will be used to identify potential predictor variables that influence the awareness and use of metacognition by mathematics teachers. This information will remain confidential.

25. **25. Please provide your age ***
Type your age in the text box

____

26. **26. Please provide your gender ***
Please select your gender
Mark only one oval.

- ◯ Male
- ◯ Female

27. **27. Please provide your age when you entered the teaching profession ***
At what age did you begin your teaching experience

____

28. **28. Please provide your grade level of mathematics instruction ***
For which grade(s) do you instruct mathematics?

____

29. **29. Please provide the number of years you have been teaching. ***

____

30. **30. Please describe your type of teacher preparation experience ***
Describe your pre-certification experience
Mark only one oval.

- ◯ Education Degree fulfilling certification requirements
- ◯ Degree in other field plus additional course work as required by certifying agency
- ◯ Bachelor's degree in Mathematics
- ◯ Master's Degree in Education
- ◯ Master's Degree in Mathematics
- ◯ Other: _______________

31. **31. Please provide your the number years of your post-secondary education ***
What is the total number of years of your post-secondary education experience

____

32. **32. Please select all of the degrees you have earned. ***
Select all that apply
Check all that apply.

- [ ] Associate Degree in an Education Field
- [ ] Associate Degree in another content area
- [ ] Bachelor's Degree in an Education Field
- [ ] Bachelor's Degree in Mathematics
- [ ] Bachelor's Degree in another content area
- [ ] Master's Degree in Education
- [ ] Master's Degree in Mathematics
- [ ] Master's Degree in another content area
- [ ] Education Doctorate (Ed.D.)
- [ ] Ph.D. in Education
- [ ] Other: ____________________

33. **33. Please describe your any interruptions in your teaching experience ***
Describe interruptions such as changes in occupation and the duration of your absence, leaves or absences for educational purposes, maternity or family leave, or other lapses and/or interruptions in your employment as a mathematics teacher. Please include the duration of the interruption in your description.

____
____
____
____
____

- [ ] Send me a copy of my responses.

Appendix B: Permission to Use the Metacognitive Awareness Inventory for Teachers

Sent: Thursday, 12 September, 2013 1:40:09 AM
Subject: Permission for use of the Metacognitive Awareness Inventory for Teachers

Dr. Balcikanli,

I am currently beginning the dissertation phase of my doctoral studies at Walden University. I am a Ph.D. student in Education with a specialization in curriculum, instruction, and assessment. The focus of my study is the use of metacognition by mathematics teachers to modify their instruction to meet the needs of their learners. With your permission, I would like to use the Metacognitive Awareness Inventory for Teachers as one of my instruments for data collection in my study. The instrument and your publication will be appropriately cited using the most recent APA format.

Please let me know if you need any further information or have any additional concerns.

Thank you for your time and consideration in this matter.

Sincerely,

Regina Lewis

Fri, Sep 13, 2013 at 3:45 PM

Dear Regina,
Thank you very much for your interest in the use of the MAIT. You are welcome to use it in your research.
Good luck
Best wishes
Cm

Appendix C: Key to Coding

Coding for Part II – Demographic Information (Questions 25-33)

Question 25 – Please provide your age.

- Age is numeric no coding necessary.
- May consider grouping by decades or spans of 5 years as data analysis proceeds

Question 26 – Please provide your gender

- Female = 0 (labelled as the reference group since the majority of the teachers participating in this study were female)
- Male = 1

Question 27 – Please provide your age when you entered the teacher profession

- Age is numeric no coding necessary.
- May consider grouping by decades or spans of 5 years as data analysis proceeds

Question 28 – Please provide your grade level of instruction

All single grades recoded to smallest grade span of which they are an appropriate member. (Example grade 2 coded as K-5, grade 3 coded as 3-5). If also taught pre-school or college, these were ignored as not applicable to the study

- K-5 = 0 (reference group for comparison)
- K-8 = 1
- 3-5 = 2
- 6-8 = 3
- 7-12 = 4
- 9-12 = 5
- K-12 = 6

Question 29 – Please provide the number of years you have been teaching

- Numeric, therefore no coding is necessary
- May consider grouping by spans of 5 or more years as data analysis proceeds

Question 30 – Please describe your type of teacher preparation experience

- Education degree fulfilling requirements for certification = 0 (labelled as reference group for comparison purposes)
- Degree in other field + course work as required by certifying agency = 1
- Bachelors degree in Mathematics = 2
- Masters degree in Education or Math Education = 3
- Masters degree in Mathematics = 4
- Ph.D. in Mathematics = 5
- Ph.D. in Education, Ph.D. in Mathematics Education, or Ed.D. = 6

Question 31 – Please provide the number of years of your post-secondary education

- Numeric, therefore no coding is necessary
- May consider grouping by spans of 5 or more years as data analysis proceeds

Question 32 – Please select all of the degrees you have earned (Coded as Degrees in Math, Education, Both, or Neither)

- Education = 0 (labelled as reference group for comparison purposes)
- Both Math and Education = 1
- Math = 2
- Neither Math nor Education = 3

Question 33 – Please describe any interruptions in your teaching experience

- No Interruptions = 0 (labelled as reference group for comparison purposes)
- Single interruption < one year (such as a maternity or sick leave) = 1
- Single interruption 1-5 years = 2
- Single interruption 6-10 years = 3
- Single interruption greater than 10 years = 4
- Multiple interruptions = 5