A MODEL STUDY TO EXAMINE THE RELATIONSHIP BETWEEN METACOGNITIVE AND MOTIVATIONAL REGULATION AND METACOGNITIVE EXPERIENCES DURING PROBLEM SOLVING IN MATHEMATICS

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Dedicated to
my beloved family
for all their love and support

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ABSTRACT

A MODEL STUDY TO EXAMINE THE RELATIONSHIP BETWEEN METACOGNITIVE AND MOTIVATIONAL REGULATION AND METACOGNITIVE EXPERIENCES DURING PROBLEM SOLVING IN MATHEMATICS

The main aim of the study was to investigate students' poor problem solving performance within a self-regulation framework. The relations between students' metacognitive experiences, metacognition and motivational regulations were thought to be an appropriate point of view to approach the problem of mathematical problem solving. Students' feelings of difficulty, familiarity and understanding, estimated effort and predicted solution correctness factors were examined under metacognitive experiences. Self-efficacy and effort were indicators of motivational regulation factor. Awareness, self-checking, evaluation and use of cognitive strategies were included as the indicators of metacognitive regulation factor. The relationships were investigated and the proposed model was tested with the data of 406 students obtained from eight grade students from public (N=252) and private (N=154) schools. Convenient sampling method was used in the data collection process of the study.

The data provided empirical evidence for the proposed model on the framework. The results demonstrated significant relations between metacognitive and motivational regulation, metacognitive experiences and mathematical problem solving performance. A significantly high correlation was found between metacognitive and motivational regulation. Although motivational and metacognitive experience had direct effects on student's problem solving performance, metacognitive regulation did not. On the other hand, metacognitive and motivational regulation had indirect effects on problem solving performance through the mediation of metacognitive experiences. Type of school differences were evident for most variables, whereas gender differences were not.

ÖZET

ÖĞRENCİLERİN PROBLEM ÇÖZMEDE BİLİŞÜSTÜ VE MOTİVASYONA İLİŞKİN DENETİMLERİ İLE BİLİŞÜSTÜ DENEYİMLERİ ARASINDAKİ İLİŞKİYİ AÇIKLAYICI BİR MODEL ÇALIŞMASI

Bu çalışmanın temel amacı öğrencilerin problem çözmedeki başarısızlığının bir özdenetim modeli çerçevesinde incelenmesidir. Problem çözmede karşılaşılan sorunların irdelenmesi bağlamında öğrencilerin bilişüstü deneyimleri ile bilişüstü ve motivasyona ilişkin özdenetimleri arasındaki ilişkilerin ele alınmasının yerinde olacağı düşünülmüştür. Öğrencilerin problem çözerken çektiklerini düşündükleri zorluk, probleme aşina olma hisleri, anlayıp anlamayacaklarına ilişkin öngörüleri problemi özebilmek için gereken tahmini çaba ve doğru çözüme ulaşmaya ilişkin tahmin becerileri bilişüstü deneyimler başlığı altında incelenmiştir. Öğrencinin farkındalığı, öz-kontrolü, değerlendirmesi ve bilişsel stratejilerin kullanımı bilişüstü denetim faktörünün göstergeleri olarak bu çalışmaya dahil edilmiştir. Bunun yanında öz-yeterlik ve azim motivasyona ilişkin denetim faktörünün göstergeleri olarak ele alınmıştır. Devlet (N=252) ve özel (N=154) okullarda okuyan 8.sınıf öğrencilerinden kolay ulaşılabilen örneklem yoluyla elde edilen veriler ile önerilen model sınanmış ve değişkenler arası ilişkiler incelenmiştir.

Belirtilen çerçevede elde edilen veriler önerilen model için deneysel bulgular sağlamıştır. Sonuçlar bilişüstü ve motivasyona ilişkin denetim, bilişüstü deneyimler ve matematik problem çözme performansı arasında anlamlı bir ilişki olduğu yönündedir. Bilişüstü ve motivasyona ilişkin denetim arasında anlamlı bir ilinti olduğu ortaya çıkmıştır. Motivasyona ilişkin ve bilişüstü deneyimlerin problem çözme performansına doğrudan etkisi olduğu görülürken, bilişüstü denetimlerin dolaylı bir etkisi olduğu görülmüştür. Birçok değişkende devlet ve özel okullar arası fark net olarak görülürken, cinsiyet farkı net olarak gözlemlenmemiştir.

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1. INTRODUCTION

Throughout their education, students work on many mathematical questions and problems in school. A number of studies demonstrated that many students fail to comprehend the basic concepts of mathematics and have difficulties in problem solving (Cummins, 1992; Hegarty, 1995; Koedinger and Anderson, 1998). Students may be able to recite algorithms, but only a few students understand what they are really doing, how they are doing and why they are performing the given activities (Campione *et al.*, 1989). The problems they solve often become unsolvable for them if the format or wording of the question changes.

Turkish students' performances on mathematical tasks are alleged to be under a desired level. Their poor performance in math problem solving have been observed in some cross-national studies like PISA (2006) and TIMSS (2007) exams; in the central standardized examinations conducted by the Ministry of Education (i.e. OKS and SBS exam); and in the ones conducted as research studies (Karataş and Güven, 2004; Soylu and Soylu, 2006).

The results of the international comparisons such as the Program for International Student Assessment (PISA) and the Trends in International Mathematics and Science Study (TIMSS) caused a lot of concern about the mathematics education in Turkey. Both international benchmarking studies indicated that the Turkish students' performances in mathematics were significantly below the averages of many developed countries (OECD 2004, 2007; Gonzales *et al.*, 2008). As the results of the PISA 2006 study were examined, it was seen that 52 per cent of the students were below the baseline level of math proficiency for future development and use of mathematics. The vast gap among the Turkish schools in terms of performance is another matter of great importance that should be taken into consideration (OECD, 2007).

Apart from the international comparison studies, standardized central exams conducted by the National Ministry of Education (MEB) also revealed low scores in mathematics performance. A central exam for acceptance into competitive high schools called as Secondary Education Entrance Examination (Ortaöğretim Kurumları Öğrenci Seçme ve Yerleştirme Sınavı- OKS) was a high-stakes assessment for eighth grade students. The scores in OKS 2007 demonstrated serious findings about students' performances in mathematics. The results of the exam revealed that the average score for mathematics and geometry was 3.35 (with a standard deviation of 5.2) in 25 questions, whereas it was 13.79 (with a standard deviation of 5.86) for the Turkish language questions (MEB, 2009d).

The poor scores of the Turkish students in the national and international assessments in fact led to a change in national curriculum. As a result, the new curriculum started to be implemented nation-wide in the 2005-2006 academic year for the grades 1-5. The curriculum development process for primary and middle schools gradually continued until it was implemented in 8^{th} grades in 2008 (TTKB, 2005).

The new curriculum based on the constructivist approach was parallel to the curriculum reform movements in other countries. In line with the constructivist approach, the themes of curricula and the modes of instruction were changed from a teacher-centered model to a student-centered one (TTKB, 2005). The essence of the constructivist approach was depicted by Airasian and Walsh (1997) as, constructing knowledge as a result of interaction between one's existing knowledge, beliefs and new ideas. They also pointed out that constructivism concerns how people attain, develop and use cognitive processes. Teachers are expected to support their students' efforts to understand a consistent curriculum by engaging them in rich mathematical experiences. Students are urged to reason mathematically, to explain and justify their reasoning and construct mathematical knowledge through problem solving (Pape and Smith, 2002). Based on the constructivist theory, the vision about learning was altered as something happening by the students rather than something happening to the students (Op't Eynde *et al.*, 2007). According to the principles of the new curriculum, learning should be accomplished by the students themselves. In other words, students should regulate their own cognition, motivation and behavior to be effective learners, as pointed out by Zimmerman (1989).

There is a broad consensus today that self-regulation and metacognition play an important role in effective learning of mathematics. Self-regulation was originally defined as the regulation of cognition resulting by the emphasis of higher order processes and metacognition (Flavell, 1976). Metacognition is defined as knowing what you know and thinking about thinking (Costa, 1984). In that respect, metacognition involves both awareness and monitoring, and control of cognition. Self-regulated learning mostly arises from the impact of student's self-generated thoughts, feelings, skills, strategies and behaviors (Schunk and Zimmerman, 1998). At a more general level, the related literature points out self-regulated students as active learners who are able to select a variety of strategies and to monitor their progress in using the selected strategies with the aim of attaining a goal. Self-regulated learners set clear and realistic goals, use appropriate cognitive strategies for learning, remembering and understanding the material, plan, monitor and modify their mental processes consistently, manage and control the allocated time and effort on academic tasks and have high motivational beliefs on the task as their distinctive features (Pintrich and De Groot, 1990, Pintrich, 1995; Kitsansas, 2002).

Many studies were conducted in the area of metacognition and self-regulation. Based on its sophisticated relations with other contents, metacognition might be assessed as a dependent or independent variable. If metacognition is considered as a dependent variable, it is affected by motivational and cognitive variables. On the other hand, it affects behavior and affective variables as an independent variable (Efklides, 2001). A number of studies have been conducted to demonstrate the relationship between metacognition and achievement. Although many studies have demonstrated positive relationship (Kitsansas, 2002; Rysz, 2004), some revealed contradictory findings (Kuyper *et al.*, 2000; Ader, 2004; Hong and Peng, 2008).

The nature and functions of metacognition could not fully covered by the researchers. The way how people define metacognition based on its sophisticated nature and content, the difficulty to assess cognitive processes with available instruments, and the close cyclic relations of metacognition with other contents such as cognition, motivation and affect might be among the reasons in that dilemma. One more reason stated by Efklides (2001) for the hardships in understanding metacognition was focusing on the particular aspects of metacognition instead of the holistic conceptualizations by the researchers for years.

Mathematics educators are currently focusing on self-regulation and metacognition especially throughout the implementation of reforms in the math classrooms. Pape and Smith (2002) argue that the implementation of such reforms make the development of self-regulated learners possible. They also claim that the reforms in turn oblige developing of self-regulated learners.

Metacognitive involvement might be different for the different sub domains of mathematics. In the subject of arithmetic operations, metacognitive involvement might be less than other specific areas such as problem solving. Arithmetic operations mostly require automatic processes, and practiced and repeated knowledge. On the other hand, problem solving requires more complex processes in addition to arithmetic operations. Students have to find the connections between variables and create meaningful strategies through the solution implying metacognitive processes (Lucangeli and Cornoldi, 1997).

The role of self-regulation and metacognition in problem solving seems to be a relevant issue of research to explain individual differences in mathematics achievement. Problem solving as an indispensable portion of mathematics education stands as an essential issue in which self-regulation is mostly apparent. Within the content of mathematical problem solving, self-regulation refers to careful decoding of the problem text, analyzing the relationships between components and monitoring the solution process toward a goal (Pape and Smith, 2002). Successful problem solvers easily fit the information given in the problem together. When they do not have a schema for a particular problem type, regulatory skills or metacognition serves to facilitate the problem solving process (Schoenfeld, 1983).

Metacognitive experiences are described as the feelings and judgments or estimates regarding cognitive processing. As being the interface between the self and the task, they reflect present experiences that arise as a result of a cognitive activity (Gombert, 1993). As such, metacognitive experiences serve the monitoring and control of the learning process. They provide an intrinsic context and future motivation towards learning (Desoete and

Veenman, 2006). A study related with metacognitive experiences was carried out by Efklides *et al*. (2006). The study stressed the significant role of present metacognitive experiences while working on a task, as opposed to metacognitive knowledge about such experiences or relevant information from the past. Metacognitive experiences have close relationships with cognitive, motivational and metacognitive knowledge. In turn, metacognitive experiences are influenced by these factors.

In the nature of metacognitive experiences, feelings are their only component that does not show a difference. It points out that metacognitive experiences are personal and subjective that occurs during the cognitive processes. Metacognitive experiences are not something that the person knows from the past. In addition, they are not from the sources related to or out of the person's own experiences (Efklides, 2001). Metacognitive feelings are present before, during and after the problem solving process as regarding one's response to the actual processing of the task (Efklides *et al*., 2006).

Another relevant aspect of problem solving is motivation. The concept of self-regulated learning has expanded over the years and comprised motivational, affective and volitional components as well (Op't Eynde *et al*., 2007). As Mayer (1998) declared, only focusing on teaching problem solving skill and metacognition, in other words the ability to control and monitor cognitive processes would be incomplete. He stated the motivational aspects of cognition to be the third prerequisite for successful problem solving. The role of motivation in problem solving has been an important topic of educational psychology for many decades. The three theories of motivation (i.e. the interest theory, attributional theory and self-efficacy theory) all share a cognitive view of motivation.

Self-efficacy and effort have been the focus of many studies relating self-regulation and math achievement (Hong *et al*., 2005). As a cognitive view of motivation based on self-efficacy, the self-efficacy theory suggests that students work harder on learning tasks when they judge themselves as capable, than when they lack confidence in their ability to learn. This view has been supported by research evidence (Pintrich and De Groot, 1990; Zimmerman and Martinez-Pons, 1990; Schunk, 1991). Students have been found to understand the material better when they had high self-efficacy. Moreover, it has been shown that when the students' self-efficacy is improved, their success in learning to solve problems also improves (Schunk and Hanson, 1985). As far as motivational regulation is concerned, making an effort and being persistent in completing tasks require special attention. Effort and persistence have been found to identify math achievement differences across countries (Chiu and Xihua, 2008). Effort regulation and persistence have been previously shown to be related with academic performance and it has been shown to increase the accuracy of assessments and performance (Neuberg, 1989; Volet 1997; Obach, 2003).

Gender differences in mathematics performance have attracted the attention of many researchers. Research studies show that gender differences vary for different skills and across age (Halpern, 2000; Hong *et al.,* 2005). Studies investigating gender differences in self-regulation are relatively few (Zimmerman and Martinez-Pons, 1990; Ablard and Lipschultz, 1998; Hong *et al.*, 2005) Conflicting results of many studies call for new research studies.

The focus of this particular study was to investigate the relationship between students' motivational and metacognitive regulation, and metacognitive experiences applied in mathematical problem solving situations. At a more general level, this study aimed to clarify the role of metacognition and motivation in self-regulation and to what degree they are related with problem solving performance. Metacognition was investigated more holistically by taking its multiple forms of metacognitive experiences and regulatory facets such as self-checking, evaluation, cognitive strategy use and awareness into account. A hypothesized structural model to explain the variance of these constructs in students' problem solving performances was tested.

In this study, use of cognitive strategies, evaluation, awareness and self-checking constructs formed students' metacognitive regulation. Motivational regulation of the students was pointed out by their effort and perceived self-efficacy levels. Students' feelings of familiarity, understanding, difficulty and their prediction about solution correctness and estimated effort were tapped as students' metacognitive experiences. Students' performances in problem solving were assessed through three mathematics problems. Beside the main goals of the study declared above, gender and school differences in relation with the given variables was also examined.

2. LITERATURE REVIEW

2.1. Problem Solving in Mathematics

As an integral part of mathematics, problem solving plays an important role in the teaching and learning of mathematics. Almost every job in today's society requires mathematics and mathematical thinking. Employers are looking for people who are able to solve problems that they have never encountered before.

The mathematical concepts can be covered in math problems. Many concepts and principles in mathematics can be transferred to the students through problems that are familiar to the students in their daily life and previous learning. The council of teachers of mathematics (NCTM), an organization in the United States, which provides vision, leadership and guidance in the development of mathematics education, has emphasized mathematical problem solving as a central theme of all mathematics instruction since 1989. The NCTM's Principles and Standards for School Mathematics (PSSM) declared ten content and process standards that specify what students should able to know and do in mathematics from pre-kindergarten to grade 12 (NCTM, 2003). According to NCTM Principles and Standards for School Mathematics (2003, p. 52), "students should build new mathematical knowledge through problem solving, solve problems that arise in mathematics and in other contexts, apply and adapt a variety of appropriate strategies to solve problems, and monitor and reflect on the process of mathematical problem solving". Problem solving is the first of five process standards, which is a tool through which children develop mathematical ideas.

Problem solving has been defined in many ways. The two common characteristics seem to be the goal and the constraints of the problem. The aim of the problem solver is to deal with the constraints and to reach the intended goal. The problem specifies a goal, but the way to the goal may be blocked through lack of resources or knowledge (Kahney, 1993). These attributes can be used as a basis to define the concepts of problem and problem solving. Smith and Ragan (1999) defined problem solving as the skill to solve un-encountered problems through utilization of previous learned principles, cognitive strategies, and knowledge gained. Sarver (2006) stated that problem solving had two common characteristics. The first one is thinking directed towards achieving a goal and the second one is awareness and management of mental processes to direct the intended goal-directed thinking.

Problem solving requires that students are mentally active and that they reflect on the ideas they already have to construct new ideas and increase understanding (Van de Walle, 2003). As it was declared in Sarver's study (2006), good problem solvers focus on the structural facets of a problem rather than its surface characteristics. They are more aware of their strengths and weaknesses. They monitor and evaluate the problem solving process more consistently compared to poor problem solvers. To be a successful problem solver, students have to possess the cognitive, metacognitive and motivational components. Among these three components, metacognition has prominent role because it coordinates motivation and cognition (Mayer, 1998).

2.2. Problem of Mathematical Problem Solving

The drastic findings of the international comparisons such as TIMSS and PISA caused a lot of concern about the mathematics education in Turkey. These concerns led to changes in the mathematics curricula. Beside assessments conducted by Turkish Ministry of Education (like OKS and SBS exams), cross-national studies carried out to make comparisons between countries such as PISA and TIMSS also demonstrated that students had deficiencies in math problem solving (OECD 2004, 2007; Gonzales *et al.*, 2008).

PISA 2003 results indicated that Turkish students had poor problem solving skills in mathematics. The results obtained in PISA 2006 were also similar to the first one. The main theme was mathematics education in the former one and the main theme was science education in the PISA 2006 study. Hence, PISA 2003 results gave more detailed information on students' math related constraints. According to the latter study, the mean score of Turkish students' performance in mathematics was 424 while the average mean of OECD countries was 498. Based on the mentioned mean, the rank of Turkey on the mathematics scale was 29 in 30 OECD countries.

In PISA studies, students' performances in mathematics were evaluated over levels of proficiency that began to ascend from "Level 1" to "Level 6". The report also presented the percentage of students who were below Level 1. The accepted baseline level of mathematics proficiency on the PISA scale was Level 2. Students at this level can employ basic algorithms, formulas, procedures and can make direct reasoning on the results. Level 2 tasks require having literacy skills that enable students to actively use mathematics, which are considered fundamental for future development and use of mathematics (OECD, 2007). PISA 2006 results showed that, 52 per cent of the students did not perform well enough to reach Level 2 in Turkey. The percentage of students below level 2 was 21 per cent in the OECD area. The ratio of the students in our country who did not have adequate skills and competence in using mathematics was more than twice of the OECD average. In line with PISA 2006 results, there was no significant difference on students' math performances in PISA 2003 (MEB, 2007). The percentages of Turkish students' average at each level of proficiency on the mathematics scale can be seen in Table 2.1. OECD averages corresponding to each level are also given in the same table.

Table 2.1. A comparison of Turkish students' math proficiency level and OECD average in PISA 2006 survey

PISA 2006	Mean Score	Below Level- 1 (%)	Level- 1 (%)	Level- 2 (%)	Level- 3 (%)	Level- 4 (%)	Level- 5 (%)	Level- 6 (%)
Turkey	424	24	28.1	24.3	12.8	6.7	3	1.2
OECD average	498	7.7	13.6	21.9	24.3	19.1	10	3.3

Trends in International Mathematics and Science Study (TIMSS) is another international assessment study, which is used to measure and compare the mathematics and science knowledge and skills of fourth and eighth grade students. A total number of 58 countries and provinces attended the last TIMSS study, which was conducted in 2007. It was the fourth one realized. Turkey took part in TIMSS twice; first in 1999 and then in 2007. Turkey participated for only eighth graders, not for fourth grade students' assessment. According to TIMSS 2007, Turkish eighth-graders' average mathematics score was obtained as 432 points while the TIMSS average was 500. The study pointed out similar results with PISA 2006 (Gonzalez *et al.*, 2008). A related study with TIMSS results indicated that Turkish students were weak in algebra, probability and statistics. Moreover, the study revealed that they had poor profiles in skills such as applying rules in algebra, approximation, estimation, solving open-ended problems, recognizing patterns and relationships, and mathematical literacy (Dogan and Tatsuoka, 2007).

Apart from the international benchmarking studies, a number of studies conducted in Turkey to examine students' performance in math problem solving skills exposed similar results to the international assessments. In a study conducted by Soylu and Soylu (2006), it was found that Turkish elementary students did not have difficulty in exercises, which required arithmetical operations, whereas they had deficiencies in the problems, which required conceptual understanding rather than operational knowledge. Similar results were declared in the study conducted on 8^{th} grades by Karataş and Güven (2004).

The mathematics achievement of Turkish students assessed by the Secondary Education Entrance Examination (OKS) was lower when compared to other learning domains. In 2008, the average score for mathematics and geometry was 3.7 (standard deviation of 6.87) in 25 questions, whereas the average score of Turkish language questions was 15.95 (standard deviation of 6.14) (MEB, 2009a). OKS was a high-stake testing for all eighth grade students in the country and 905,930 students took the examination (MEB, 2009b).

In 2006 the national curriculum was renewed based on the constructivist approach and has begun to be implemented gradually. A newly implemented central assessment exam, "Level Assessment Test" (Seviye Belirleme Sınavı- SBS) that replaced OKS has begun to be taken at the end of each academic year from grade six to eight. The results of the SBS exams revealed similar results with the former one. According to the 2009 results for seventh grade students, the mean and standard deviation for 25 math questions was declared as 2.4 and 3.84, respectively (MEB, 2009c).

PISA studies provided well-matched data set to investigate students' performance differences based on the inequality in educational quality (Dinçer and Kolaşin, 2009). Another striking finding according to PISA 2003 results was the vast gap among schools in terms of performance. The results showed that the variation in students' math performance between Turkish schools was more than twice the average variation of OECD countries. While the OECD average was 33 per cent, the variation in Turkey was around 68 per cent that took Turkey to the top of the list, as possessing the highest percent of variation in mathematics (OECD, 2004). This indicated large differences in quality among different schools.

2.3. Self-Regulated Learning

Many years ago, the ideal aim of education was stated as the creation of the power of self-control (Dewey, 1998). The prominent role of self-regulation in education was tapped nearly half century ago. Currently, many researchers are still seeking to understand the role of self-regulation in learning and instruction. For years, educational researchers have tried to contribute to the understanding and developing of self-regulatory processes such as planning, goal setting, help seeking, use of cognitive strategies, awareness, self-evaluation, self-efficacy, intrinsic motivation, time and effort management, and self-checking (Kitsansas, 2002). Most of the researchers emphasized the key feature of self-regulated learning as the systematic use of metacognitive, motivational and behavioral strategies to attain the desired goal (Zimmerman, 1990; Tobias and Everson, 2002). The well-developed self-regulation involves self-observation, self-judgment and self-reaction (Reis, 2004).

What self-regulation of learning involves is not only detailed knowledge of a skill, but also the self-awareness, self-motivation and behavioral skill to construct the knowledge appropriately. Moreover, self-regulation of learning involves the selective use of specific self-regulatory processes that must be personally adapted to each learning task. These self-regulatory processes are goal setting, adapting appropriate strategies, monitoring, restructuring context compatible with the goals, managing time and effort, self-evaluating and adapting the methods (Zimmerman, 2002).

Self-regulated students are able to plan and check their work through the solution. They are aware of their thought processes. Among a variety of cognitive strategies, they can select proper ones they believe to accomplish the task. Moreover, these students display high effort and are persistent to accomplish the task (Malpass *et al.*, 1999; Kitsansas, 2002).

Self-evaluation attributes to the comparison of performance outcomes with a goal (Zimmerman, 2000). Highly self-regulated learners have powerful self-evaluation skills. They attribute their poor performances as strategy deficiency rather than lack of ability and they experience greater self-satisfaction in comparison to poorly self-regulated learners (Kitsansas, 2002).

Self-regulation is important not only for student's academic achievement, but also for acquiring life-long learning skills. Self-regulated students can view their futures more optimistically because of gained adaptable learning methods, intrinsic motivation and process monitoring ability (Zimmerman, 2002). In self-regulation research, many studies have been conducted in high-stakes testing conditions by assuming that students are highly motivated to perform (Kitsansas, 2002; Ader, 2004; Hong and Peng, 2008). Actually, in real life students face with thousands of "low-stake" situations. Self-regulation and motivation are also important predictors of performance and behavior in these situations (Sundre and Kitsansas, 2004).

At the end of several studies, Montague (2003) declared a seven-phase modeling on math problem solving processes and strategies with specific self-regulation components. According to her modeling, the problem solving processes were in order of reading, paraphrasing, visualizing, hypothesizing, estimating, computing, and checking. Beside, each of the seven processes thought was specified by a "Say, Ask and Check" routine as specific components of self-regulation. "Say" was the self-construct phase that helps students to direct in problem solving process; "Ask" was the self-questioning phase to systematically analyze the problem information and regulate cognitive processes; and "Check" as the self-monitoring strategy to monitor performance throughout problem solving process (Montague, 2008).

Mayer (1998) discussed the requirement of cognitive, metacognitive, and motivational skills in problem solving. According to Mayer's study, successful problem solving has three components in common: skill, metaskill, and will. Skill points out the domain-specific knowledge, that is, the basic problem-solving skills. Metaskill (or metacognitive knowledge) represents the knowledge of when to use, how to coordinate or monitor skills in various problem-solving conditions. The will component as a last requirement for successful problem solving indicates students' feelings and motivation based factors as self-efficacy, interest and attributions. The will component partly depends on how students interpret the problem solving situations.

2.4. Metacognitive Regulation

Many research studies on metacognition have been conducted in the field of education since more than three decades. The term "metacognition" was mainly conceptualized by John H. Flavell (1976) and many researchers share it in their studies (Veenman *et al.*, 2000; Desoete and Veenman, 2006). Flavell (1976) defined metacognition as the knowledge and active regulation of one's own cognitive processes. Although there are many definitions of metacognition in the literature, all definitions have conceptualized around controlling and monitoring of one's cognition, and self-regulating the solution processes (Mevarech *et al.*, 2006).

As can be understood from the definitions, metacognition has two functions: cognitive monitoring and cognitive regulation. Flavell (1979) referred the two functions of metacognition that were monitoring and regulatory functions. The cognitive monitoring function refers to the one's knowledge and cognition about cognitive phenomena. On the other hand, the regulatory function refers to the use of this knowledge to control and modify the cognition (Flavell, 1979; Efklides, 2001).

Metacognition can be used in different situations as children try to consider their own and other's thoughts, feelings, goals. Individual's own thinking and considering what his/her friends might be thinking and feeling when playing with each other can be examples of where metacognition takes place (Flavell and Hartman, 2004). We experience metacognition when we have a dialogue inside our brain and thus we are to evaluate our decision-making or problem solving steps. In addition, we experience metacognition at the time we realize that we are reading a passage but the words give no meaning to us. As it is realized, we return to the passage and seek the point where we left the words, and go on reading (Costa, 1984). Students use their metacognitive ability while studying for exams. They have to determine in which topic they have difficulty and to evaluate whether they understand well at the end. During the exams, at first glance, determining which question is easier to do and which is more difficult requires metacognitive skills as well.

In a three-year-longitudinal study with children from preschool to 2nd grade (Annevirta and Vauras, 2006), it was shown that students' metacognitive knowledge was the main precursor of independent self-regulatory ability. The finding was parallel to Flavell's notion that learners must have enough metacognitive knowledge internalized in their own performance before they are able to become self-regulated. On the other hand, the second finding of the same study tapped that metacognitive knowledge does not guarantee the development of cognitive regulation, which was referred as metacognitive skills

For being qualified in mathematics, students must make use of cognitive resources in the sense of awareness and control over what to do and how to do it (Lucangeli and Cornoldi, 1997). Metacognition is supplemental in challenging tasks in mathematics. Although metacognition is not as effective as cognitive capacity and skills (Carr and Jessup, 1995), it allows students to use the acquired knowledge or procedures in a more meaningful, effectual way (Lucangeli *et al.*, 1998a). Metacognition takes part in mathematical problem solving, especially when students build an appropriate representation of the problem and checking the outcome of the calculations (Verschaffel, 1999). Metacognition contributes to successful problem solving by allowing an individual to identify the problem and work strategically on it (Davidson and Sternberg, 1998). Previous knowledge and gained skills is not enough for successful problem solving. Instead, students should benefit from metacognitive components such as when to use and how to use the skills and previous knowledge (Mayer, 1998).

Metacognitive skills refer to the procedural knowledge that is required for regulation and control of one's cognitive activities (Flavell, 1979; Veenman *et al.*, 2000). Task orientation, planning, monitoring, evaluating and self-checking can be given as behavioral manifestations of metacognitive skills (Lucangeli and Cornoldi, 1997; Veenman *et al.*, 2000).

There are many cognitive strategies that student may use to regulate their cognition. The strategies can be best measured in domain-specific contents that might be a course or a specific task in the course. Similarly, regulation of motivation and of affective variables should also be measured in domain and content specific areas (Pintrich, 2004).

Some students may not be able to use appropriate metacognitive skills. As declared by Veenman *et al.* (2000), it might be because of either availability or production deficiencies. Students who have availability deficiency do not have metacognitive skills and thus do not know how to plan or monitor their actions. On the other hand, student with production deficiency have metacognitive skills, but they do not know when to plan and monitor their actions for a particular task.

2.5. Metacognitive Experiences

The monitoring phase of metacognition occurs through the interactions of four distinct facets that are metacognitive knowledge, metacognitive experiences, tasks, and strategies. Metacognitive experiences and metacognitive knowledge were classified as two segments that formed partially overlapping sets in their content and functions (Flavell, 1979).

Metacognitive knowledge was described as the declarative stored knowledge regarding goals one follows in cognitive efforts, persons, tasks and strategies (Desoete and Veenman, 2006). Metacognitive experiences were defined as any conscious cognitive and affective experiences emerging in any intellectual enterprise (Flavell, 1979).

Metacognitive experiences might be called as self-initiated metacognition. Metacognitive feelings, online metacognitive knowledge (also referred as online task-specific knowledge) and metacognitive judgments are the forms that metacognitive experiences might be seen (Efklides, 2001).

Metacognitive experiences are conscious experiences. They help students to control and direct behaviors occurred in present and in future by means of integrating information about the self and the experiences. Metacognitive experiences are products of working memory. They are closer to actual cognitive processing, and they monitor online processes of cognition (Efklides, 2001).

Flavell (1979) clarified metacognitive experiences as follows:

> "Metacognitive experiences are especially likely to occur in situations that stimulate a lot of careful, highly conscious thinking: in a job or school task that expressly demands that kind of thinking; in novel roles or situations, where every major step you take requires planning beforehand and evaluation afterwards; where decisions and actions are at once weighty and risky; where high affective arousal or other inhibitors of reflective thinking are absent" (Flavell, 1979, p.908).

2.6. Motivational Regulation

The interdependence of self-regulation and motivation is illustrated in Zimmerman's (1989) definition that conceptualized self-regulated learners as metacognitively, motivationally and behaviorally active participants in the learning process. The relation between motivation and self-regulation had previously emphasized in many studies (Pintrich and De Groot, 1990; Malpass *et al.*, 1999; Sundre and Kitsansas, 2004; Hong and Peng, 2008).

Self-regulation and motivation are closely related. Taking only one of them into account in the studies would not reveal powerful predictions for achievement and learning. A student might possess a great number of self-regulated strategies, but lack of motivation may block to use these strategies. On the other hand, a student who has higher motivation but lacks of self-regulated strategies might not be successful in performing tasks (Sundre and Kitsansas, 2004). Students' motivation to learn is an important component to be considered in self-regulation models to understand how students become self-regulated learners and come to use of cognitive strategies (Pintrich and De Groot, 1990)

To use self-regulation strategies, students must be motivated. Deriving from this principle, Pintrich and De Groot (1990) adapted self-regulatory strategies into a general expectancy – value model of motivation. The model comprised three motivational components that could be linked to three different components of self-regulated learning. The *expectancy component* included students' beliefs about their ability to succeed at a task. The *value component* included students' goals and beliefs about the importance and their interest of a task. The *affective component* included students' emotional reactions to the task.

In a study conducted with undergraduate psychology students, the results showed that self-regulatory strategies and motivational factors (self-efficacy and outcome expectation) explain 24 per cent of total variance in the first test and 14 per cent in the second (Kitsansas, 2002). Üredi and Üredi (2005) pointed out that 30 per cent of the total variance of mathematics achievement in eighth grade students could be predicted by students' self-regulating strategies and motivational beliefs. The study also demonstrated that the prediction power of self-regulating strategies and motivational beliefs were higher for the boys than for the girls.

Students' self-efficacy beliefs have a prominent role in the selection of appropriate learning strategies and their use. They are also important to encourage continuous strategy use when faced with unfamiliar tasks. Self-efficacious people have tendency to set high goals. When compared to the others, they are able to self-monitor and evaluate the process and be persistent when they faced with difficulties (Kitsansas, 2002). As expected, the literature indicated that effort regulation and persistence are positively related to academic performance (Volet, 1997; Obach, 2003; Hong and Peng, 2008)

Effective self-regulatory skills are effective in stronger self-efficacy and academic achievement in various learning areas (Pajares, 2002). Besides, self-efficacy is positively related to cognitive engagement and performance (Pintrich and De Groot, 1990).

Malpass *et al.* (1999) examined the effects of self-regulation, self-efficacy and gender on mathematics achievement of high school students. In the study, metacognition and effort were combined into a single higher order "self-regulation" factor. Student's cognitive strategy use, awareness, self-checking and planning factors were grouped in measuring metacognition. The findings of the study showed that effect of self-efficacy on mathematics achievement was greater than of metacognition.

Two studies including structural modeling provided appropriate theoretical bases for the conceptualization of the proposed model used in this study. One of them was conducted by Hong *et al.* (2005). In the study, the researchers investigated the relations between gender, worry, self-regulation and math achievement. Metacognition and motivation were specified in the study as the second-order factors of the first-order self-regulatory factor. The researchers also focused on the differences between state and trait measures of self-regulation. In the study, a structural model was tested and confirmed (Figure 2.1).

The results of the study showed that there were no significant direct or indirect effects of gender on mathematics performance, but worry and self-regulation (both state and trait) had significant effects on it. Regardless of gender, students who planned, monitored, expended effort, and had high self-efficacy tended to have high achievement scores in mathematics (Hong *et al.*, 2005).

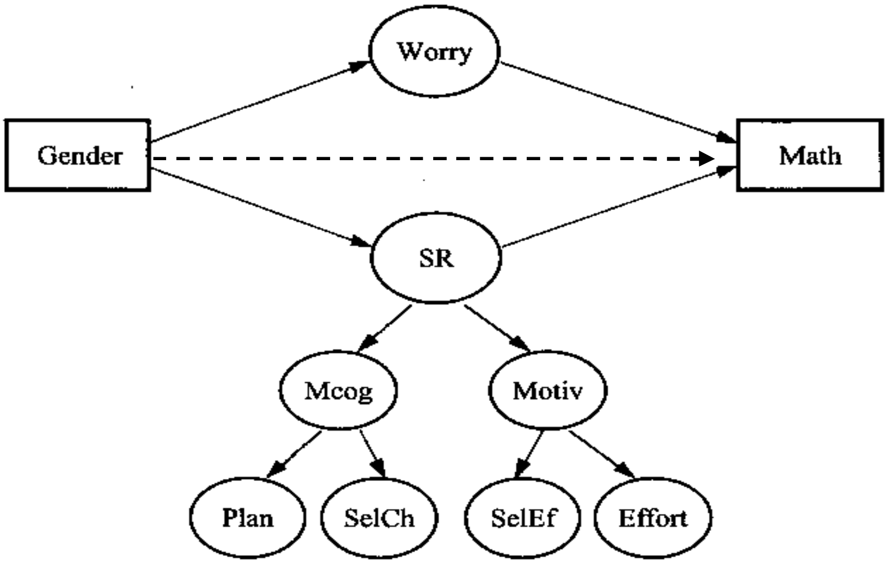


Figure 2.1. A model to explain the relationships between gender, worry, self-regulation and math performance (Hong *et al.*, 2005)

The second study was conducted by Hong and Peng (2008). The study focused on the effects of test value, metacognitive and motivational regulation on mathematics achievement. In this study, the researchers examined the direct effects of test value on test performance and indirect effect through metacognitive and motivational regulation components in test preparation. The researchers demonstrated the standardized path coefficients for grades 7 and 11 (Figure 2.2). In the study, a model with the variables, motivational and metacognitive regulation, and perceived test value and test performance was tested. According to the data obtained, one's perceived test value had a significant direct effect on motivational regulation (β= 0.63 and 0.51 for grades 7 and 11, respectively, ps< 0.001) and metacognitive regulation (β= 0.47 and 0.42 for grades 7 and 11, respectively, ps< 0.001). On the other hand, test value had no direct effect on test performance, but had a significant indirect effect on test performance (β = 0.24, p< 0.001 for grade 7; β = 0.09, p< 0.05 for grade 11).

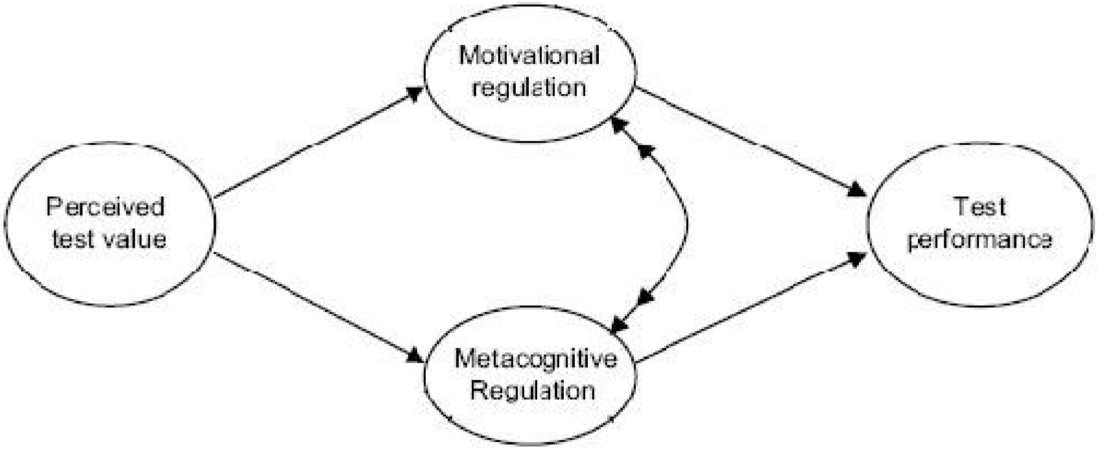


Figure 2.2. A model to explain the relationships between test value, performance, and metacognitive and motivational regulation (Hong and Peng, 2008)

As far as the effects of motivational and metacognitive regulation are concerned, the results indicated that motivational regulation had a significant direct effect on test performance (β = 0.38, $p < 0.001$, for grade 7; β= 0.18, $p < 0.05$, for grade 11). Metacognitive regulation did not show a significant effect in both grades. Metacognitive and motivational regulation had a significant relation with a correlation value of ($r = 0.74$ and 0.56 for grades 7 and 11, respectively, ps< 0.001)

Within the context of self-regulation, the above-mentioned models that mainly focused on self-regulatory factors and the related literature about self-regulatory, motivational, and metacognitive features led us to propose and test a structural model (Figure 2.3). The proposed model intended to give meaningful explanations to students' poor problem solving performances by focusing self-regulatory and metacognitive factors more holistically. Students' metacognitive and motivational regulation, metacognitive experiences and problem solving performances were taken as the main variables in the proposed model study.

Students' metacognitive regulation was formed by the use of cognitive strategies, evaluation, awareness and self-checking constructs. Motivational regulation of the students was pointed out by their effort and perceived self-efficacy beliefs. Students' feelings of familiarity, understanding, difficulty and their prediction about solution correctness and estimation of effort were tapped as students' metacognitive experiences. Students' performances in problem solving were assessed through open-ended math problems.

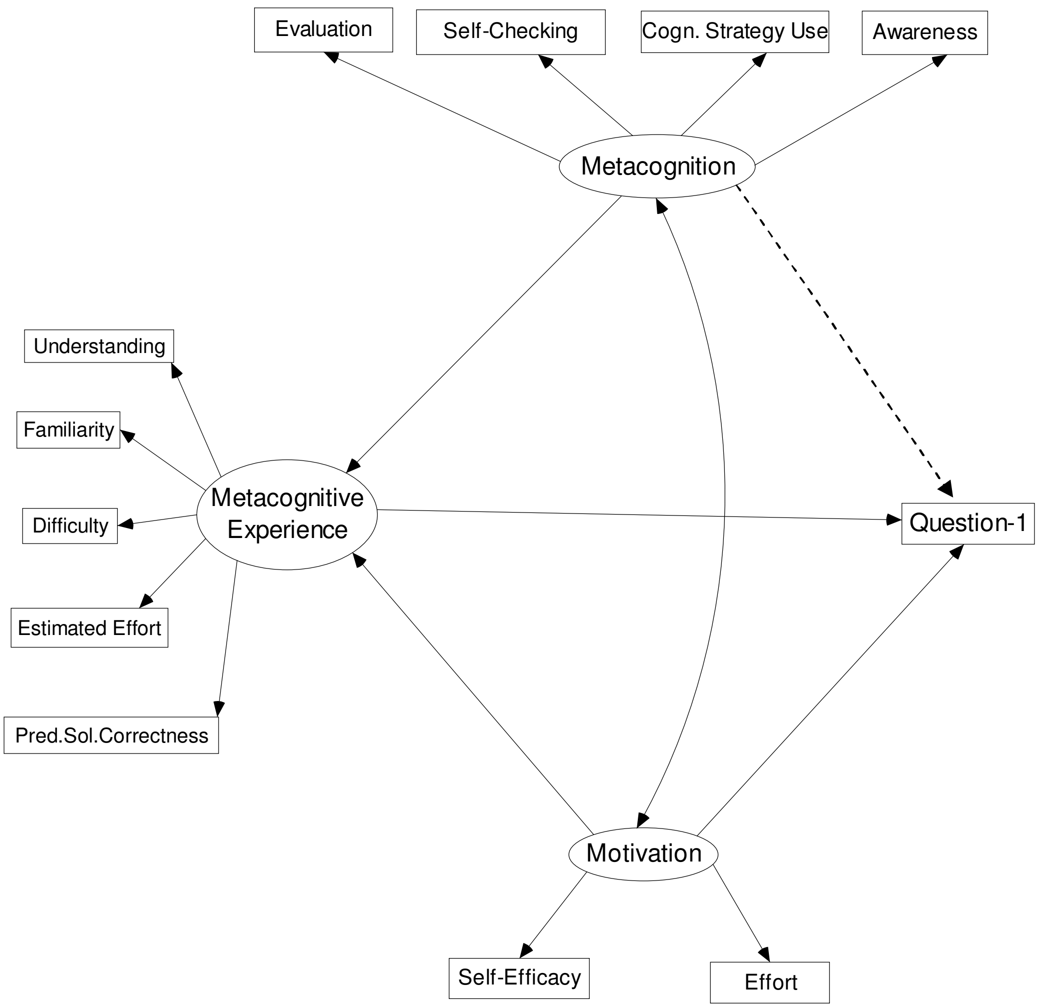


Figure 2.3. The hypothesized model

3. STATEMENT OF THE PROBLEM AND RESEARCH QUESTIONS

3.1. Statement of the Problem

The problem of mathematical problem solving has been considered as one of the most important issues in math education. The poor performance of Turkish students in international comparison studies has been thought to be worth investigating. The self-regulation perspective was considered to be one of the appropriate points of view to approach the problem of the grim results due to Turkish students' poor performance.

The effect of self-regulation on mathematics performance is highly complex and requires simultaneous evaluation of many relevant variables to develop a comprehensive understanding of the diverse findings in the literature (Hong *et al.*, 2005). Moreover, significant research studies have been conducted to figure out the relationship between metacognition and academic achievement. Nevertheless, there is no consensus about their correlations. Some studies have demonstrated a positive relationship between metacognitive strategies and academic achievement (Eme and Rouet, 2001; Kitsansas, 2002). On the other hand, some other research studies have demonstrated no significant relationship (Kuyper *et al.*, 2000; Schraw, 1997).

Metacognitive experiences on the other hand, have not been examined deeply in the area of metacognition. A few studies have been conducted in the related field and in most of them; they demonstrated a relationship between problem-solving performance and metacognitive beliefs (Lucangeli *et al.*, 1997).

This study sets out to give meaningful explanations to two main questions. Firstly, it was searched if the issue in question could be investigated considering the relationships between students' motivational and metacognitive regulation, and metacognitive experiences in problem solving situations. Secondly, it was thought if one could hypothesize and test a structural model to explain the variance in problem solving performances of Turkish children who did so poorly in international tests.

The purpose of this research was to investigate students' problem solving performance within the framework of a hypothesized model of metacognitive experiences, metacognitive and motivational regulation. Taking all into account, this study might be useful to demonstrate the relationships among variables and to contribute to the literature in the context of education, especially in the part of metacognitive experiences.

3.2. Research Questions

This study focused on four main research questions.

1. Are there significant relationships between the variables: metacognitive regulation, motivational regulation, metacognitive experiences and performance in mathematical problem solving?
2. Are there gender differences in the variables: metacognitive regulation, motivational regulation, metacognitive experiences and performance in mathematical problem solving?
3. Are there school differences in the variables: metacognitive regulation, motivational regulation, metacognitive experiences and performance in mathematical problem solving?
4. Will the data fit a model explaining the relationships between the variables: metacognitive regulation, motivational regulation, metacognitive experiences and performance in mathematical problem solving?

4. METHOD

In the study, four research questions were explored. The study was carried out in two phases. In the first phase, measuring instruments were developed and tested in a pilot study. The research questions were investigated in the second phase during the main study.

4.1. Variables and Operational Definitions

The variables investigated in this study were metacognitive experiences, metacognitive regulation, motivational regulation and math problem solving performance. The operational definitions of these variables were:

- Metacognitive experiences were defined as the scores on the Metacognitive Experience Scale.
- Metacognitive regulation was defined as the score on the Metacognitive Skills Inventory.
- Motivational regulation was operationalized as the score on the Motivation Scale.
- Math problem solving performance was assessed through the Problem Solving Performance Test that had three math problems. The scoring of the Problem Solving Performance Test ranged from 0 to 4 for each question.

4.2. Sample

The pilot study was conducted with two sub samples. The first sub sample was used to assess the psychometric properties of the instruments and the math problem solving performance test. The second one was used to re-assess the math problem solving performance test, which was edited according to the first implementation results. The third sample was the main sample. Data from the main sample was used to explore the research questions, especially to test the hypothesized model to explain the relationship between metacognitive experiences, metacognitive and motivational regulation and problem solving in mathematics.

4.2.1. Sample for the Pilot Study

Sample for the Assessment of the Psychometric Properties of the Instruments and the Math Problem Solving Performance Test. A total of 57 students who were enrolled in the 8th grade in a public school in Istanbul took part in the sample to assess both the psychometric properties of the instruments and the math problem solving performance test. The gender distribution was as 24 female (42 per cent) and 33 male (58 per cent) students (Table- 4.1). The data obtained from six of the students were extracted because of their considerably missed or unfilled responses.

Sample for the Re-assessment of the Math Problem Solving Performance Test. A total of 40 students who were enrolled in the 8th grade in a public school different from the one in the first study in Istanbul took part in the sample to re-assess the math problem solving performance test. 19 of the students (48 per cent) were female, and the remaining 21 students (52 per cent) were male (Table 4.1). The test was edited after the first implementation results.

Table 4.1. Gender distributions of the pilot studies

		1st part of the Pilot Study		2nd part of the Pilot Study	
		n	%	n	%
GENDER	Female	24	42.1	19	47.5
	Male	33	57.9	21	52.5
	TOTAL	57	100.0	40	100.0

4.2.2. Sample for the Main Study

The main sample was chosen among the 8th grade 14 year-old-students from both public and private schools. Convenient sampling was used in the study. At the end of the data collection process, the main sample consisted of 419 students. During the preparation of the data for the model testing, 13 students were eliminated because of their substantially incomplete data. Therefore, the final sample for the study consisted of 406 participants. Of these, 48 per cent were female (n=195) and 52 per cent were male (n= 211) (Table 4.2).

252 of the students came from public schools and the remaining 154 students were attending private schools. During the selection of the main sample, nearly one-third of the total number of participants was attempted to be chosen from private schools (38 per cent) and the rest came from public schools (62 per cent). Students' distributions according to gender and type of school were shown in Table 4.2.

Table 4.2. Gender and type of school distribution of students in the main sample

N_{total} = 406		Main Study	
		n	%
GENDER	Female	195	48
	Male	211	52
SCHOOL	Public	252	62
	Private	154	38

The private schools that took part in this study were among the most well known schools for their high academic standards. The public schools in case of achievement and socio-economic background did not have similar characteristics. The different characteristics of the schools came out as a result of the kind of the choice of sample. Nevertheless, it was thought to be positive in the sense that this situation seemed to increase the variability of the sample in terms of socio-economic status and general achievement. This situation was thought to increase the representativeness of the sample. The study was conducted in the middle of the second semester of the 2008 / 09 academic year.

4.3. Instruments

Besides a demographic information form, a different instrument was used to measure each variable in the study. Student’s metacognitive experiences were assessed by the Metacognitive Experiences Scale, which included five questions related to students’ metacognitive feelings and judgments. The same questions had been used previously in Efklides *et al.* (2006) study. Metacognitive Skills Inventory had been developed by Çetinkaya (2000). The Motivational Regulation Scale was developed for this study by the researcher within two main contexts: self-efficacy and effort. Performance in math problem solving was assessed through a test, which included three open-ended mathematics questions.

4.3.1. Demographic Form

The demographic form was used to gather information about the students on gender, type of the school they were enrolled (private or public), and their first semester mathematics’ grades.

4.3.2. Metacognitive Experiences Scale

Metacognitive Experiences Scale was used to assess student's present metacognitive feelings and judgments on mathematics problem (Appendix A). There were five items in the Metacognitive Experiences Scale. The items focused on reflecting students' feelings of knowing, feelings of familiarity, feelings of difficulty, estimated effort, and predicted solution correctness. The students should give response to the items before they actually solved the problem.

Metacognitive Experiences Scale was implemented separately as soon as each of the three math problems was presented to the students before solving the related problems. Students' metacognitive experiences were measured with the following items: "How familiar is the problem to you?"; "How well do you understand what it requires you to do?"; "How difficult do you feel the problem is?"; "How much effort do you think you have to exert in order to solve the problem?"; How correctly do you think you can solve the problem?".

All questions were presented in a four-point Likert type format. The responses were scored as 1 point for "not at all", 2 points for "a little", 3 points for "quite", and 4 points for "very". The items indicating feeling of difficulty and estimated effort were the reverse items. Through the nature of the study, each feeling was assessed as a separate variable in the hypothesized model. Therefore, there was no need to recode the reverse items and to sum the scores of student's feelings for each problem. For the feelings of familiarity, understanding and predicted solution correctness, higher scores indicated positive feelings on the related problem. For the feeling of difficulty and estimated effort, lower scores indicated positive feelings.

Metacognitive Experiences Scale could be used in a prospective and retrospective manner through problem solving process (Efklides *et al.*, 2006). In this study, only students' prospective metacognitive experiences before solving the problem were assessed. Therefore, only the prospective questions were written in Turkish by the researcher. The coherency and appropriateness of the questions for the Turkish language were checked by an expert who was working as a linguist in the field of education. Small changes were edited based on the recommendations of the expert.

4.3.3. Metacognitive Skills Inventory

The metacognitive regulation of the students was assessed by the Metacognitive Skills Inventory (Çetinkaya, 2000) (Appendix B). The scale comprised of four dimensions: self-checking, awareness, cognitive strategy use and evaluation. The items below each dimension can be seen in Appendix C. There were 32 items in the scale and all items were four-point Likert-type, scaling from 1 (never) to 4 (always).

The reliability analysis of the inventory had been conducted with one hundred and eleven sixth grade students of a private high school and the alpha coefficient had been calculated as 0.87. The corrected item total correlations had ranged between 0.18 and 0.60 with an average correlation coefficient of 0.38. The reliability analysis indicated acceptable internal consistency for the entire scale (Çetinkaya and Erktin, 2002).

Beside judgmental ratings, a factor analysis had been carried out to examine the validity of the Metacognitive Skills Inventory. To see how items grouped together under each domain, a principal component analysis with varimax rotation had been applied on the domain items grouped as a result of judgmental ratings. The result showed overlapped domains and factors as an evidence of construct validity (Çetinkaya and Erktin, 2002).

Acceptable internal consistency for the Metacognitive Skills Inventory was also obtained during the pilot study of this research. The pilot study was conducted with ninety-one 8^{th} grade students who were enrolled in two public schools. The Cronbach's alpha reliability value of the scale was obtained as 0.92. The corrected item total correlations ranged between 0.31 and 0.66 (Appendix D). In both studies, the reliability analysis indicated acceptable internal consistency for the entire scale.

4.3.4. Motivational Regulation Scale

4.3.4.1. Preparation and Implementation of the Motivational Regulation Scale. The Motivational Regulation Scale was prepared to measure students' motivational regulation in mathematics. The scale was developed by the researcher for this study. The questionnaire consisted of 24 items. It mainly comprised of two dimensions: self-efficacy and effort. Participants responded to the items on the four-point Likert-type scale, scaling from 1 (strongly disagree) to 4 (strongly agree).

The "self-efficacy" items were developed based on the literature. There were twelve items related with self-efficacy in the Motivational Regulation Scale. Eight of the items were developed by considering student's actual self-efficacy beliefs. The actual self-efficacy beliefs, which were referred as online self-efficacy, were focusing on student's confidence in being able to accomplish a math task in school circumstance. Four items were developed by taking student's confidence to accomplish a task related with mathematics in a wide time interval. That is to say, perceived self-efficacy or person's belief of ability to succeed a task in the future.

Perceived self-efficacy is concerned not with the number of skills you have, but with what you believe you can do with what you have under a variety of circumstances (Bandura, 1994). Students with higher self-efficacy set higher goals and expend more effort toward the achievement of these goals (Zimmerman *et al.*, 1992).

The "effort" items were adapted from Trait Thinking Questionnaire (TTQ) (Hong *et al.*, 2005) and modified to characterize mathematics situations. There were eight items in the effort subscale. The Trait Thinking Questionnaire, which included the effort items, was used in more than ten studies and effort subscale indicated acceptable Cronbach's alpha coefficients between 0.77 and 0.91. Principal components factor analysis with varimax rotation was performed on the items for the validity studies of the questionnaire (Hong *et al.*, 2005).

Based on the two dimensions, 30 items were generated by the researcher at the beginning of the questionnaire development process. There were four reverse items in the scale. Two of the reverse items (3 and 23) were later categorized into effort items and the other two (5 and 9) corresponded to self-efficacy items. After the responses of the test were coded into numerical values, the reversed items were recoded.

In order to assess the psychometric properties of the instrument a pilot study was conducted with 91 eight-grade students in a public school. Series mean estimation method for replacing missing values was used by aiming not to narrow the pilot data. The means and standard deviations for the items are shown in Table 4.3.

4.3.4.2. Reliability of the Motivational Regulation Scale. The initial Cronbach's alpha reliability value for the scale was obtained as 0.94. The corrected item total correlations varied between 0.27 and 0.74 (Table 4.4).

Table 4.3. Initial means and standard deviations of the items in the Motivational Regulation Scale

Item Number (N= 91)	Mean	Standard Deviation
Item 1	2.73	.908
Item 2	2.54	.779
Item 3	2.96	.855
Item 4	3.08	.885
Item 5	2.99	.960
Item 6	1.85	.930
Item 7	2.87	.792
Item 8	2.60	.801
Item 9	2.90	.978
Item 10	2.69	.974
Item 11	2.64	.837
Item 12	2.87	.806
Item 13	2.97	.737
Item 14	2.62	.769
Item 15	1.92	.734
Item 16	2.53	.835
Item 17	2.81	.842
Item 18	2.97	.795
Item 19	3.09	.694
Item 20	2.10	1.033
Item 21	2.31	.784
Item 22	2.99	.796
Item 23	3.02	1.011
Item 24	2.56	.858
Item 25	2.63	.852
Item 26	2.07	1.063
Item 27	2.85	.815
Item 28	2.91	.877
Item 29	2.59	.943
Item 30	3.18	.877

Table 4.4. The initial item-total correlations of the items in the Motivational Regulation Scale

Item Number (N= 91)	Item-Total Correlation
Item 1	.740
Item 2	.653
Item 3	.361
Item 4	.481
Item 5	.512
Item 6	.606
Item 7	.602
Item 8	.570
Item 9	.512
Item 10	.545
Item 11	.729
Item 12	.702
Item 13	.628
Item 14	.599
Item 15	.344
Item 16	.581
Item 17	.577
Item 18	.274
Item 19	.609
Item 20	.628
Item 21	.578
Item 22	.646
Item 23	.464
Item 24	.476
Item 25	.663
Item 26	.622
Item 27	.303
Item 28	.623
Item 29	.601
Item 30	.600

4.3.4.3. Validity of the Motivational Regulation Scale. To confirm the construct validity of the scale, expert judgments were obtained. Experts were asked to determine to what extent, items belonged to sub-dimensions under which they were placed. Depending on the judgments of experts, six items (1, 4, 11, 23, 27 and 29) were excluded from the scale.

Item 23 was the reverse item and hence, the number of reverse items remaining in the scale was three.

Table 4.5. The final factor loadings according to the factor analysis carried out on the Motivational Regulation Scale

Item Numbers	Component			
	1	2	3	4
Item 22	.755			
Item 13	.755			
Item 12	.710			
Item 25	.604			
Item 17	.562			
Item 5		.711		
Item 9		.684		
Item 16		.660		
Item 2		.593		
Item 14		.543		
Item 10		.484		
Item 15		.481		
Item 21		.439		
Item 20			.809	
Item 26			.760	
Item 6			.746	
Item 24			.536	
Item 18				.841
Item 28				.574
Item 19				.569
Item 3				.555
Item 8				.485
Item 30				.429
Item 7				.406

As evidence for the validity of the scale, a confirmatory factor analysis was carried out on the data. As a result of the confirmatory factor analysis, each factor was found to consist of items representing one of the domains of the motivational regulation scale. The factor loadings of the items were shown in Table 4.5.

<u>4.3.4.4. The Final Form of the Motivational Regulation Scale.</u> Considering the results of the factor analysis, the Motivational Regulation Scale reached its final form after six items were deleted from the initial scale (Appendix E). Items 1, 4, 11, 23, 27 and 29 were excluded from the scale. The Cronbach's alpha coefficient for the final form of the scale was 0.92. Internal consistency estimates of the subscales of the Motivational Regulation questionnaire were effort (0.85), persistence (0.82), self-efficacy for future life (0.83), and online self-efficacy (0.84). The item-total correlations of the items varied between 0.27 and 0.69 (Appendix F). The estimates were considered acceptable for the current research.

As initial distribution of the items, self-efficacy category contained 12 items and the remaining twelve items belonged to the effort category. As a sub-category of the self-efficacy category, online self-efficacy dimension had eight items, and self-efficacy for future life decisions had four items. As distributions of the items into effort category, five of the items were categorized under "effort" and the remaining seven items belonging to "persistence". The distribution of the items according to categories is shown in Table 4.6.

Table 4.6. Distribution of the items in Motivational Regulation Scale

		Item numbers
Self-Efficacy	Self-efficacy for future life decisions	6, 20, 24, 26
	Online self-efficacy	2, 5, 9, 10, 14, 15, 16, 21
Effort	Effort	12, 13, 17, 22, 25
	Persistence	3, 7, 8, 18, 19, 28, 30

The following items are examples of these domains. *Self-efficacy for future life decisions*: (Item 20) I can work on advanced mathematics related fields in the future. *Online self-efficacy*: (Item 10) I can be the best in my mathematics class. *Effort*: (Item 22) I put forth my best effort on tasks. *Persistence*: (Item 7) Gives up making an effort if s/he cannot solve a problem in a short time.

4.3.5. Problem Solving Performance Test

To assess students' performance in math problem solving, three math problems were presented to the students (Appendix G). Two of the problems were taken from 7th grade course book, which was published by the Turkish Ministry of National Education (MEB). The variables in the questions were edited and some modifications were made on the questions. The third problem was developed by the researcher based on the national math curriculum. The coherency and appropriateness of the math problems for the Turkish language were checked by an expert who was working as a linguist in the field of education. Two mathematics teachers also checked the questions in terms of appropriateness of the questions for student's comprehension.

The first problem was taken from the 7th grade text book and was used without editing. It was about solving equations. In order to solve the problem, the students had to form an algebraic expression, then put it into an equation and solve the equation to find the result of the first part of the problem. Again using the equation and their findings in the first part, they had to solve the second part of the problem.

The second problem was also in the 7th grade text book and was about drawing a pie graph according to given data. It was edited and was turned into an arithmetical operation problem requiring calculation of percentages.

The third problem was developed by the researcher. It was on the topic of fractions. The problem included algebraic equations, as well. In this problem, what was attempted to be measured was the performance of the students in solving algebraic equations with fractions.

Each question was scored by taking the Holistic Scoring Rubric into account (Appendix H). The Holistic Scoring Rubric was developed by the Center for Research on Evaluation, Standards, and Student Testing (CRESST) in 1995 (Aschbacher *et al.*, 1995). The CRESST mission focuses on the development of scientifically based evaluation and testing techniques, improvement of educational quality and exploring technological applications to improve assessment and evaluation practice in U.S. (CRESST, 2009).

Within the rubric, student's work in each problem was considered as a whole and one score was assigned to each problem. To be consistent in each solution, the rubric describes the criteria of the response for each scale point (Aschbacher *et al.*, 1995). The same rubric was also advised as the best teaching practices by the Schreyer Institute for Teaching Excellence at Penn State University in 2007. A similar rubric had been used in the study that was conducted by Efklides *et al*. (2006).

In the Holistic Scoring Rubric, student's performance was scored on a scale, ranging from 0 to 4 for each question. Briefly, 0 = totally wrong or no answer at all; 1= an incomplete and/or incorrect solution providing evidence in attempt to solve the problem; 2= incorrect solution by selecting appropriate strategies; 3= selecting appropriate procedures/ strategies to solve the problem; however the solution was not entirely correct; 4= totally correct solution. The assessment rubric for the study was given in Appendix H.

4.4. Procedure

After the demographic information form and the instruments were developed and prepared for the study, the initial implementation study was conducted with 57 participants to assess the psychometric properties of the instruments and to check over the math problems for comprehensibility and consistency. After obtaining the first set of data, the mathematics questions were edited and wording changes were done.

The second implementation study was conducted with 40 students to check over the math problems' comprehensibility and consistency. Consequently, the data demonstrated that the questions were ready to present for the main study. At the end of the second implementation study, the psychometric properties of the instruments were assessed. The reliability and validity analyses indicated satisfactory results.

After the instruments were developed and psychometric qualities were evaluated, the data were collected through the above-mentioned instruments from five different schools. The teachers or the researcher directed carrying out of the instruments in the classrooms. While the researcher was not in the classroom during data collection, the responsible teachers were informed in advance about the implementation and timing of the instruments. The duration for the implementation of all measures was a class hour, which is 40 minutes. No extra credit was provided for participating in the study. Responses were kept confidential to protect the identities of the students and the schools.

At the end of the data collection period, the data were coded and entered into SPSS version 17 (Statistical Package for the Social Sciences), a statistical analysis program. In order to test a hypothesized model of the relations between metacognitive experiences, motivational and metacognitive regulation in problem solving, the data were analyzed using AMOS version 17 (Analyses of Moment Structures), a structural equation modeling program.

4.5. Statistical Analysis

For investigating the relationships between variables, bivariate correlational analysis was used in this study. For the gender and type of school differences in the variables, independent samples t-test analysis was carried out. These analyses were conducted by using statistical analysis software, SPSS version 17.0. The hypothesized model testing of the study was conducted by AMOS version 17.0 software that is a structural equation modeling (SEM) program. AMOS is a program for visual structural equation modeling (Arbuckle and Wothke, 1999).

Structural equation modeling (SEM) was defined by Byrne (2001, p.3) as "a statistical methodology that takes a confirmatory, i.e. hypothesis testing, approach to the analysis of a structural theory bearing on some phenomenon". The term *structural equation modeling* (SEM) refers to a family of related procedures rather than a single statistical technique. *Covariance structure analysis, covariance structure modeling,* or *analysis of covariance structures* have been also used in the literature to classify these various techniques under a single label (Kline, 1998).

SEM is a large-sample technique, however it is difficult to determine how large a sample is large enough. Some guidelines are offered related with sample size. Sample sizes less than 100 could be considered as “small”. The sample between 100 and 200 subjects is labeled as “medium” and over 200 could be considered as “large” (Kline, 1998).

In structural equation modeling, single-headed arrows represent linear dependencies- regression weights. On the other hand, double headed-arrows represent the correlations with each other. The observed variables in path diagrams are shown as rectangles and the latent variables are represented by circle or ellipse. Dependent variables that have single-headed arrows pointing to them in the path diagram are called as endogenous variables. On the other hand, independent variables in a regression setting that do not have arrows pointing at them are called as exogenous variables (Arbuckle and Wothke, 1999).

In structural equation modeling as well as the observed variables, the researchers can be interested in theoretical constructs, which cannot be observed directly. These unobserved variables such as intelligence, motivation, self-concept, personality and health condition are termed as *latent variables*, or *factors*. Moreover, the observed variables such as income, test scores, self-report responses to an attitudinal scale and weight can be also termed as *manifest* variables. Since the latent variables are not observed directly, they cannot be measured directly. In that case, the researcher has to link the latent variable with observed variables to make it measurable (Byrne, 2001). In practice, the characteristics of a latent variable can be partially measured by a linear combination of some manifest variables (Lee, 2007).

Structural equation modeling programs provide a lot of information to the researcher related to which variables are assumed to affect other variables and the direction of these effects. If the model is given at the beginning of the analysis and whether the model is supported by the data is the main question, the SEM could be viewed as confirmatory. However, if the model is not consisted with the data, the researcher might abandon the model or can modify it. In case where the model is modified and tested again, it is regarded as exploratory technique (Kline, 1998).

As the schematic representation of a model, path diagram provides visual portrayals of relations among the variables. A path diagram is actually the graphical equivalent of its mathematical representation whereby a set of equations relates dependent variables to their exploratory variables (Byrne, 2001).

5. RESULTS

In this part of the study, firstly demographic characteristics of the students are presented. Secondly, the range, means and standard deviations of the scores obtained from the instruments used to measure the variables are revealed. Thirdly, the correlation coefficients between the variables are calculated and presented in the tables. Lastly, the hypothesized model testing results based on the related variables in the study are discussed.

5.1. Demographic Data

The demographic data included students' gender, type of school and their first semester grades. Data on gender and school were presented previously in the method section. When the students' grades which were taken at the end of the first semester of 2008/09 academic year were analyzed, the mean of the grades was calculated as 3.75 (S.D.= 1.29) within the range 1 to 5. The distribution of the grades showed that 63 per cent of the students got grades over the mean. The data of the students' grades were not normally distributed as shown in Figure 5.1. 156 students (38 per cent) among 406 had highest grades at the end of the first academic semester. On the other hand, 37 of them (9 per cent) got the lowest grades.

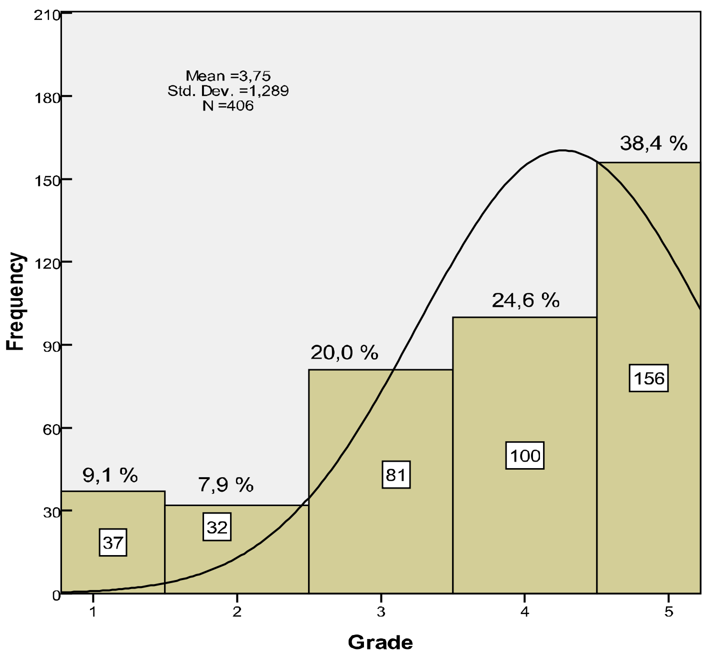


Figure 5.1. Histogram for students' grades

The significant difference was shown in students' grades based on which type of school they enrolled (Figure 5.2). The range of possible students' grades at the end of the first semester was from 1 to 5. The mean for students who were studying in public school was 3.44 (S.D.= 1.38), whereas it was calculated as 4.27 (S.D.= 0.93) for students in private schools. The percentage of students who got the highest grade in public schools was 29 per cent with 73 students among 252. On the other hand, it was 54 per cent in private schools with 83 students among 154 participants, which represented nearly twice of public school students' percentage as much. In private school sample, only one student (less than one per cent) got the lowest grade contrary to 36 students (14 per cent) in public school. The findings indicated higher achievement in mathematics in favor of private schools.

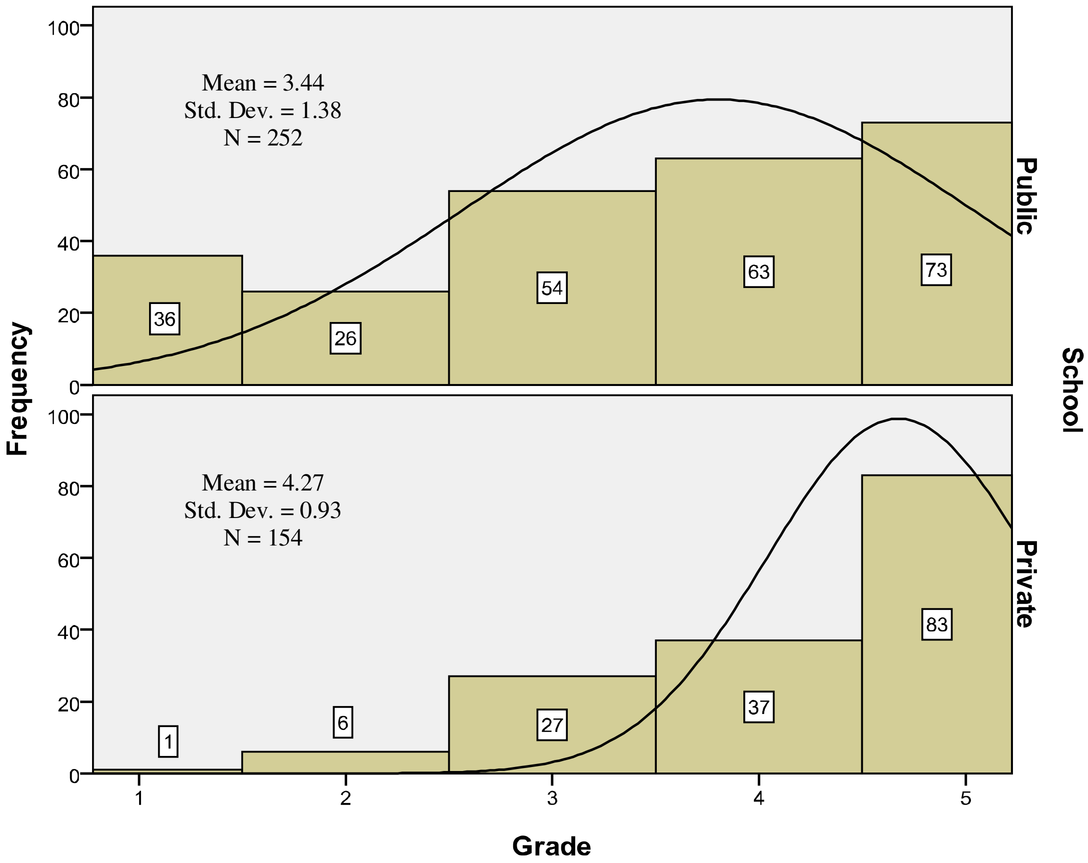


Figure 5.2. Histogram for students' grades based on type of school

The mean for female students was 3.92 (S.D. = 1.19), whereas it was calculated as 3.6 (S.D.= 1.36) for male students. The number of female students who got higher grades was a bit more than the number of male ones. Moreover, it was observed that there were more male students than females who got low grades.

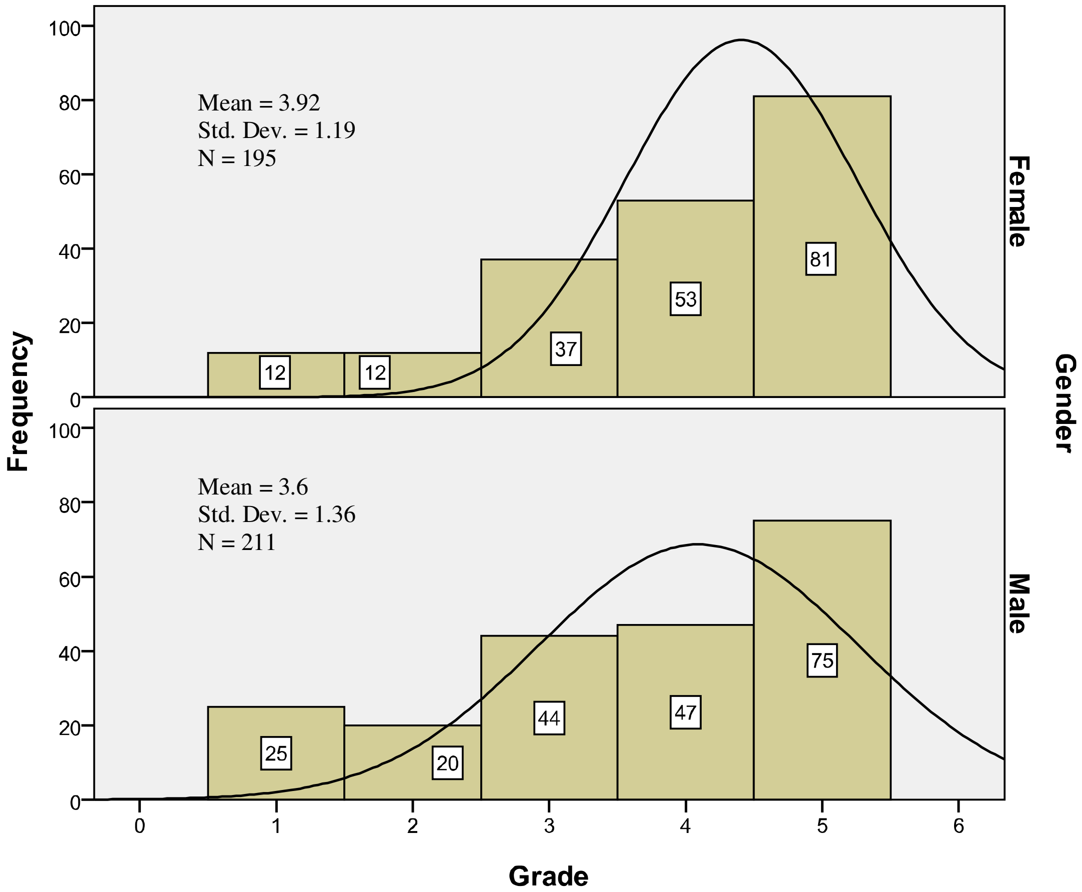


Figure 5.3. Histogram for students' grades based on gender

5.2. Descriptive Characteristics of the Data

The range, means and standard deviations of the scores from the scales used to measure the variables are shown on Table 5.1. During the development of the Motivational Regulation Scale, the items were generated within two dimensions: self-efficacy and effort. In the development of self-efficacy items, students' perceived self-efficacy beliefs both for actual performance and for future were considered. On the other hand, because of their overlapping meanings in their content and function, effort and persistence were evaluated under the same dimension that was "effort". The descriptive statistics of the dimensions were presented in Table 5.1.

Table 5.1. Descriptive statistics of the measures

N_{total} = 406	Range	Mean	Standard Deviation
METACOGNITIVE REGULATION			
Self-Checking	14 – 40	30.13	5.26
Cognitive Strategy	6 – 24	18.31	3.27
Evaluation	10 – 32	21.86	4.49
Awareness	11 – 32	25.00	4.13
MOTIVATIONAL REGULATION			
Self-efficacy	15 – 48	32.01	6.91
Online Self-efficacy	11 – 32	22.15	4.33
Self-efficacy Future	4 – 16	9.86	3.11
Effort	14 – 44	34.17	5.58
Effort	6 – 20	15.53	2.74
Persistence	6 – 24	18.65	3.17

The problem solving performances of the students were analyzed by a set of three mathematics questions. The means, standard deviations and range for each question are shown on Table 5.2. Beside, frequencies and percentages of the scores for each question were also given on the same table.

The scoring range for all three mathematics problems was between 0 and 4. When we compared the means of the problems, the mean for the second question was higher than the other problems. For the first and the third questions, the means were close (1.77 versus 1.87). In the second question, students had to use arithmetic operations by focusing on proportions. In the first and third questions, students had to solve equations to find the solutions. The mean for the second mathematics problem, which required using arithmetic operations, was higher than the means of the other two problems focusing algebra.

Table 5.2. The range, means, standard deviations and score distribution for each math problem

	Math Problem – 1		Math Problem – 2		Math Problem – 3	
Scoring Range 0 – 4						
Means	1.77		2.06		1.87	
Standard Deviations	1.339		1.904		1.804	
Scores	n	%	n	%	n	%
0	78	19.2	168	41.4	168	41.4
1	121	29.8	29	7.1	38	9.4
2	90	22.2	8	2.0	23	5.7
3	51	12.6	12	3.0	31	7.6
4	66	16.3	189	46.6	146	36

The findings indicated that algebra questions were more difficult as expected. A paired sample t- test revealed significant difference between algebra and arithmetic questions (Table 5.3). The results of the paired sample t- test results indicated this difference as Question-1 and Question-2 ($t= -3.7$; $p < 0.01$) and as Question-2 and Question-3 ($t= 2.1$; $p< 0.05$). On the other hand, there was no significant difference between the Question-1 and Question- 3 ($p< 0.17$), which were both algebra questions.

Table 5.3. Paired Sample Statistics of the Questions

		t (df= 405)	Sig. (2-tailed)	Correlation	Sig.
Pair 1	Q-1 and Q-2	-3.650	.000	.549	.001
Pair 2	Q-2 and Q-3	2.144	.033	.551	.001
Pair 3	Q-1 and Q-3	-1.389	.166	.556	.001

Distribution of students' metacognitive experiences for each question is demonstrated in Table 5.4. The feeling of familiarity scores had mean values around 3, which indicated that over 50 per cent of the items in each of the math problem were familiar to the students. Especially the Math Problem – 3 was more recognizable when compared to the other two. Except for Math Problem – 3, the feeling of familiarity scores had the highest values for the standard deviation, which means that the scores varied on a large scale. Therefore, the feeling of familiarity scores did diverge less than the other two.

The mean of feeling of understanding scores was near to a complete score, 4.00 for each of the problem. To a great extent, students felt that they understood the parts of each problem. The standard deviation values of feeling of understanding were the highest for the Math Problem – 2, which points out that the students' answers, considering that problem and feeling of understanding part differ from each other more.

Feeling of difficulty and estimated effort items were the reverse items. The scores were lower than other feelings. Predicted solution correctness, on the other hand displayed more similar results to the feelings of understanding and familiarity.

Table 5.4. The means and standard deviations of metacognitive feelings and judgments based on each problem

	Math Problem – 1		**Math Problem – 2**		**Math Problem – 3**	
	Mean	Sd.	Mean	Sd.	Mean	Sd.
Feeling of Familiarity	2.98	.849	2.93	.855	3.32	.776
Feeling of Understanding	3.42	.734	3.25	.825	3.41	.724
Feeling of Difficulty	1.68	.636	1.97	.721	1.81	.749
Estimated Effort	2.03	.649	2.24	.720	2.01	.717
Predicted Solution Correctness	3.20	.803	3.04	.838	3.19	.810

5.3. Correlational Analysis

The first part of the research focused on the relationships between the variables included in the study. It is important to keep in mind that this part only describes the correlations, not causal relationships between variables. Correlation is a statistical technique that shows at what degree two variables are related to each other. In another sense, it explains the degree of association between two variables. All correlational analyses were conducted by the use of the Pearson Product Moment correlation coefficients.

In relation to the first research question "Are there significant relationships explaining a relation between the variables: metacognitive regulation, motivational regulation, metacognitive experiences and performance in mathematical problem solving?", the correlation coefficients between these variables are shown in Table 5.5. High values of metacognitive experiences indicate positive experience. "Estimated effort" and "Feeling of Difficulty" items were the reverse items. Metacognitive experiences were defined as the sum of the indicators for practical purposes for the correlation analysis. The reversed items were recoded to show positive direction. All correlations are significant at the 0.01 level.

Table 5.5. The correlation coefficients between metacognitive and motivational regulation, metacognitive experiences, and problem solving performance

	Motivational Regulation	Metacognitive Regulation	Metacognitive Experiences	Problem Solving Performance	Grade
Motivational Regulation	1	.710**	.560**	.473**	.535**
Metacognitive Regulation		1	.547**	.396**	.409**
Metacognitive Experiences			1	.526**	.479**
Problem Solving Performance				1	.581**
Grade					1

** Correlation is significant at the 0.01 level (2-tailed).

The findings indicated that all main variables in the study had significant correlations with each other. Needless to say, grade had the highest correlation to problem solving performance ($r = .581$, $p< 0.01$). As the two main components of self-regulation, the motivational components had the highest correlation with metacognitive regulation ($r = .71$, $p< 0.01$). Metacognitive experiences expressed as the sum of its components showed higher correlations than metacognitive ($r = .396$, $p< 0.01$) and motivational regulation components ($r = .473$, $p< 0.01$) with problem solving performance.

These significant relationship coefficients were accepted as justification to put the related variables in a model to be tested on the data.

5.4. Group Comparisons

In relation to the second research question "Are there gender differences in the variables: metacognitive experiences, metacognitive regulation, motivational regulation and performance in mathematical problem solving?", gender differences in the main variables of the study were investigated (Table 5.6). No significant differences were found in male and female students' motivational regulation, metacognitive regulation, metacognitive experiences and their performance in problem solving. The only significant gender difference were found for the grades ($t(404)= 2.49$, $p<0.01$). Females' grades were higher.

Table 5.6. The independent sample t-test results of the main variables based on gender

VARIABLE	MEAN		S.D		t- value	df	Significance (two-tailed)
	Male	Female	Male	Female			
Motivational Regulation	66.5	65.83	11.24	11.76	-0.58	404	n. s.
Metacognitive Regulation	94.14	96.57	14.97	15.19	1.62	404	n. s.
Metacognitive Experience	40.79	40.10	3.71	3.67	-1.88	404	n. s.
Problem Solving Performance	5.55	5.87	4.26	4.22	0.77	404	n. s.
Grade	3.60	3.92	1.36	1.19	2.49	404	0.01

Then, group comparisons were made for the components of the variables. For the exploration of the gender differences in student's metacognitive regulation and motivational regulation and metacognitive experiences, independent sample t- test analyses were conducted. Means and standard deviations according to the gender and t-test results are shown in Table 5.7.

When the impact of gender differences on metacognitive experiences over three math problems were examined, significant differences were found for the students' predicted solution correctness (t(404)= -2.61, p< 0.01) and slightly for the estimated effort (t(404)= -1.92, p< 0.05). No significant differences were found in feeling of familiarity, feeling of understanding and feeling of difficulty.

Table 5.7. The independent sample t-test results of the indicators of metacognitive and motivational regulation, and metacognitive experiences based on gender

<table>
<tr><th colspan="2" rowspan="2"></th><th colspan="2">Mean</th><th colspan="2">S.D</th><th rowspan="2">t-value (df= 404)</th><th rowspan="2">Significance (two-tailed)</th></tr>
<tr><th>Female</th><th>Male</th><th>Female</th><th>Male</th></tr>
<tr><td rowspan="4">Metacognitive Regulation</td><td>Self-checking</td><td>30.72</td><td>29.59</td><td>5.36</td><td>5.12</td><td>2.19</td><td>0.05</td></tr>
<tr><td>Cognitive Strategies</td><td>18.39</td><td>18.24</td><td>3.33</td><td>3.21</td><td>0.46</td><td>n. s.</td></tr>
<tr><td>Evaluation</td><td>21.83</td><td>21.90</td><td>4.54</td><td>4.46</td><td>-0.15</td><td>n. s.</td></tr>
<tr><td>Awareness</td><td>25.62</td><td>24.42</td><td>3.93</td><td>4.24</td><td>2.96</td><td>0.01</td></tr>
<tr><td rowspan="2">Motivational Regulation</td><td>Self-efficacy</td><td>31.25</td><td>32.71</td><td>7.19</td><td>6.58</td><td>-2.13</td><td>0.05</td></tr>
<tr><td>Effort</td><td>34.58</td><td>33.79</td><td>5.53</td><td>5.61</td><td>1.43</td><td>n. s.</td></tr>
<tr><td rowspan="5">Metacognitive Experiences</td><td>Feeling of Familiarity</td><td>9.09</td><td>9.36</td><td>1.96</td><td>1.99</td><td>1.37</td><td>n. s.</td></tr>
<tr><td>Feeling of Understanding</td><td>10.00</td><td>10.14</td><td>1.93</td><td>1.83</td><td>0.78</td><td>n. s.</td></tr>
<tr><td>Feeling of Difficulty</td><td>5.57</td><td>5.33</td><td>1.65</td><td>1.61</td><td>-1.46</td><td>n. s.</td></tr>
<tr><td>Estimated Effort</td><td>6.43</td><td>6.11</td><td>1.73</td><td>1.65</td><td>-1.92</td><td>0.05</td></tr>
<tr><td>Predicted Solution Correctness</td><td>9.68</td><td>9.14</td><td>2.00</td><td>2.21</td><td>-2.61</td><td>0.01</td></tr>
</table>

When gender differences for the indicators of the metacognitive regulatory variables were examined, significant differences were found for the awareness ($t(404)= 2.96$, $p< 0.01$) and for the self-checking dimensions ($t(404)= 2.19$, $p< 0.05$) in favor of females. On the other hand, for the dimensions of motivational regulation, only self-efficacy indicator demonstrated significant gender difference in favor of males ($t(404)= -2.13$, $p< 0.05$). No significant gender differences were found for the other metacognitive and motivational regulatory dimensions of evaluation, cognitive strategies, and effort. In the dimensions of metacognitive experiences, only students' estimation of their effort ($t(404)= -1.92$, $p< 0.05$) and their predictions to be able to solve the problem correctly ($t(404)= -2.61$, $p< 0.01$) demonstrated significant gender difference in favor of female (Table 5.7).

In relation to the third research question "Are there school differences in the variables: metacognitive regulation, motivational regulation, metacognitive experiences and performance in mathematical problem solving?", group differences were assessed for different type of schools.

When the impact of the type of the school on the variables of the study was examined, except from metacognitive regulation, significant difference were found for all main variables at the significance level of 0.01 (Table 5.8). The students who studied at the private schools scored higher on achievement as measured by both grade and problem solving performance, motivational regulation and metacognitive experiences.

Table 5.8. The independent sample t-test results based on type of school

VARIABLE	MEAN		S.D		t- value	df	Significance (two-tailed)
	Public	Private	Public	Private			
Motivational Regulation	64.72	68.56	12.42	9.33	-3.54	404	0.01
Metacognitive Regulation	94.36	96.85	15.78	13.85	-1.61	404	n. s.
Metacognitive Experience	39.75	41.61	4.08	2.59	-5.64	404	0.01
Problem Solving Performance	4.27	8.05	3.92	3.65	-9.64	404	0.01
Grade	3.44	4.27	1.38	0.93	-7.21	404	0.01

5.5. Model Testing

The fourth research question "Will the data fit a model explaining the relationships between the variables: metacognitive regulation, motivational regulation, metacognitive experiences and performance in mathematical problem solving?" pertained to the testing of a model.

The hypothesized model to examine the relationship between metacognitive and motivational regulation, metacognitive feelings and problem solving was given in Figure 5.4. The measurement model mainly consists of four factors: metacognitive experiences, motivational and metacognitive regulation, and students' problem solving performance.

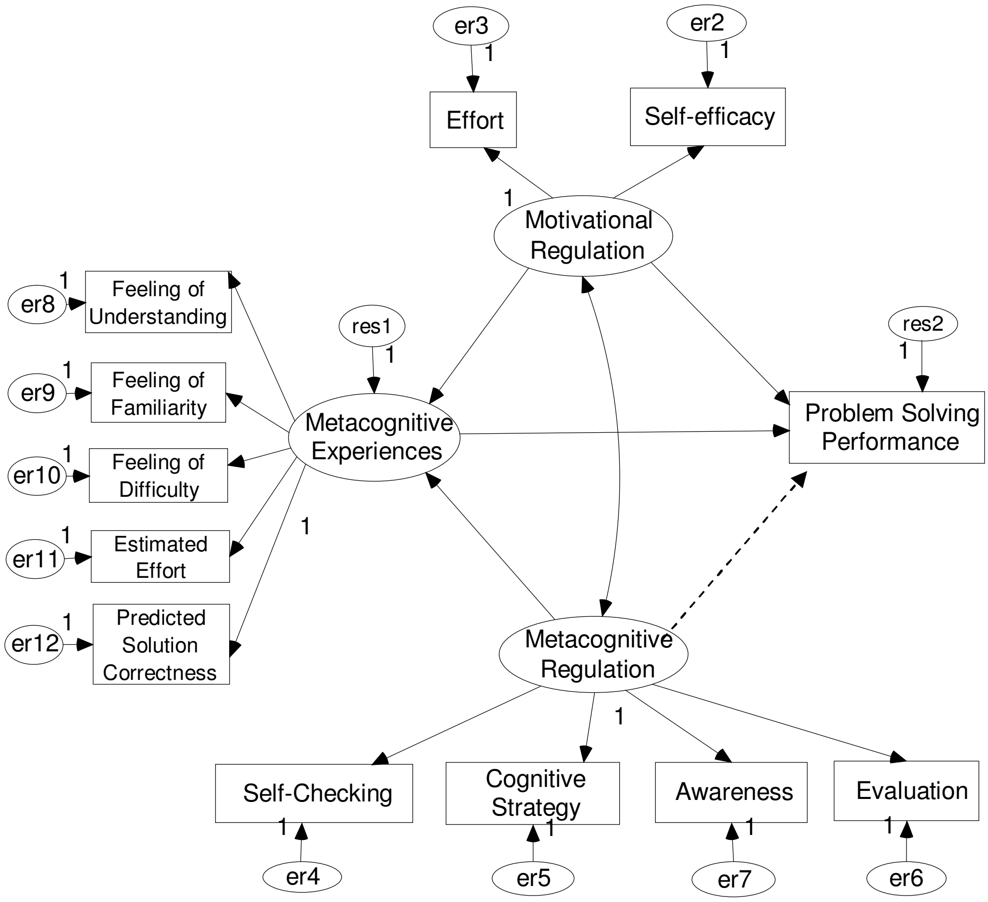


Figure 5.4. The hypothesized model

In the hypothesized model metacognitive experiences, motivational and metacognitive regulation factors are the latent variables. Problem solving performance is the observed variable, which is based on students' scores obtained from each math problem. The indicators that were linked to unobserved variables can be directly observed. The observed variables in path diagrams are shown as rectangles and the latent variables are represented by circle or ellipse. The latent variables in the hypothesized model were linked with indicator variables as follows: metacognitive experiences with 5 indicators (feeling of understanding, feeling of familiarity, feeling of difficulty, estimated effort and predicted solution correctness), metacognitive regulation with 4 indicators (self-checking, cognitive strategies, awareness and evaluation), and motivational regulation with 2 indicators (effort and self-efficacy). Each indicator has an error variable linked by one-headed arrows pointing toward them. Error represents not only the random fluctuations in the scores of the variable due to measurement error, but also other variables that were not included in the model, but might have effect on scores. An estimated measurement error was linked to every observed variable and represented by "er"s. Residual errors were linked to the latent variables.

Residual errors associated with the regression of metacognitive experiences on both motivational and metacognitive regulation and the regression of problem solving performance on all other three main variables are fixed to "1". The regression weight of one single-headed arrow pointing away from each unobserved variable should be fixed to unity "1". Thus, because of each *error* has only one single-headed arrow pointing away, *error* has weight of one in the prediction of corresponding indicator variables. Such constraints are important in order to make the model identified, and it is one of the necessities of the model to communicate with AMOS (Arbuckle and Wothke, 1999).

On the path diagram of the hypothesized model, the correlational relationship between metacognitive and motivational regulation were represented by the double-headed arrow. Moreover, single-headed arrows between metacognitive regulation and metacognitive experiences, motivational regulation and metacognitive experiences, motivational regulation and performance, metacognitive regulation and performance represented the causal relationships.

Metacognitive experiences represent students' feelings and judgments for the problem represented to him/her. Students declared their feelings and judgments separately for each problem. Depending on this, it is not the case that to take the sum of each feeling for all three math problems. Hence, the model was tested separately for each question.

At the beginning of the model analysis, firstly confirmatory model analyses for each variable were conducted to determine whether or not the data confirm the hypothesized model. If the theory of the model is confirmed; then path coefficients, direct and indirect effects of the variables, and total effects of the variables should be determined. If the model is not confirmed by the data, exploratory model analysis is conducted and the model should be modified based on the modification indices and correlation and regression estimates.

5.5.1. The Initial Model

The initial hypothesized model was analyzed by taking students' feelings, judgments and performances on the first mathematics question into account. The model was tested for each problem separately.

In order to check whether the hypothesized model was confirmed or not, chi-square statistics and goodness of fit indices were used for assessing the fit of the model. Focusing on the first set of fit statistics into the AMOS output, CMIN (minimum discrepancy) is at the beginning of the results. CMIN represents the likelihood ratio test statistics commonly expressed as a chi-square (χ^2) statistics. The chi-square statistics represent the discrepancy between the unrestricted sample covariance matrix and the restricted covariance matrix that is the hypothesized model covariance matrix. "*P*" is the probability value associated with x^2, which represents the likelihood of obtaining a χ^2 value that exceeds the χ^2 value when null hypothesis (H_0) is true (Byrne, 2001). The higher probability associated with χ^2, the closer is the fit between the hypothesized model (under H_0) and the perfect fit (Bollen, 1989a as cited in Byrne, 2001).

However, the chi-square statistics are sensitive to the sample size. Large sample provides unrealistically large chi-square values and in case, have led to problems of fit that are widely known. Therefore in studies with large sample, rather than considering probability value associated with chi-square, the value of chi-square divided by degrees of freedom (χ^2 / df) is considered (Byrne, 2001, p.81). If the χ^2/df value is in the range of 2-1 or 3-1 are indicative of an acceptable fit between the hypothetical model and the sample data (Carmines and McIver, 1981). Sample sizes over 200 could be considered as large samples (Kline, 1998). Additionally to χ^2/df value, various goodness-of-fit-indices were taken into account during the analysis.

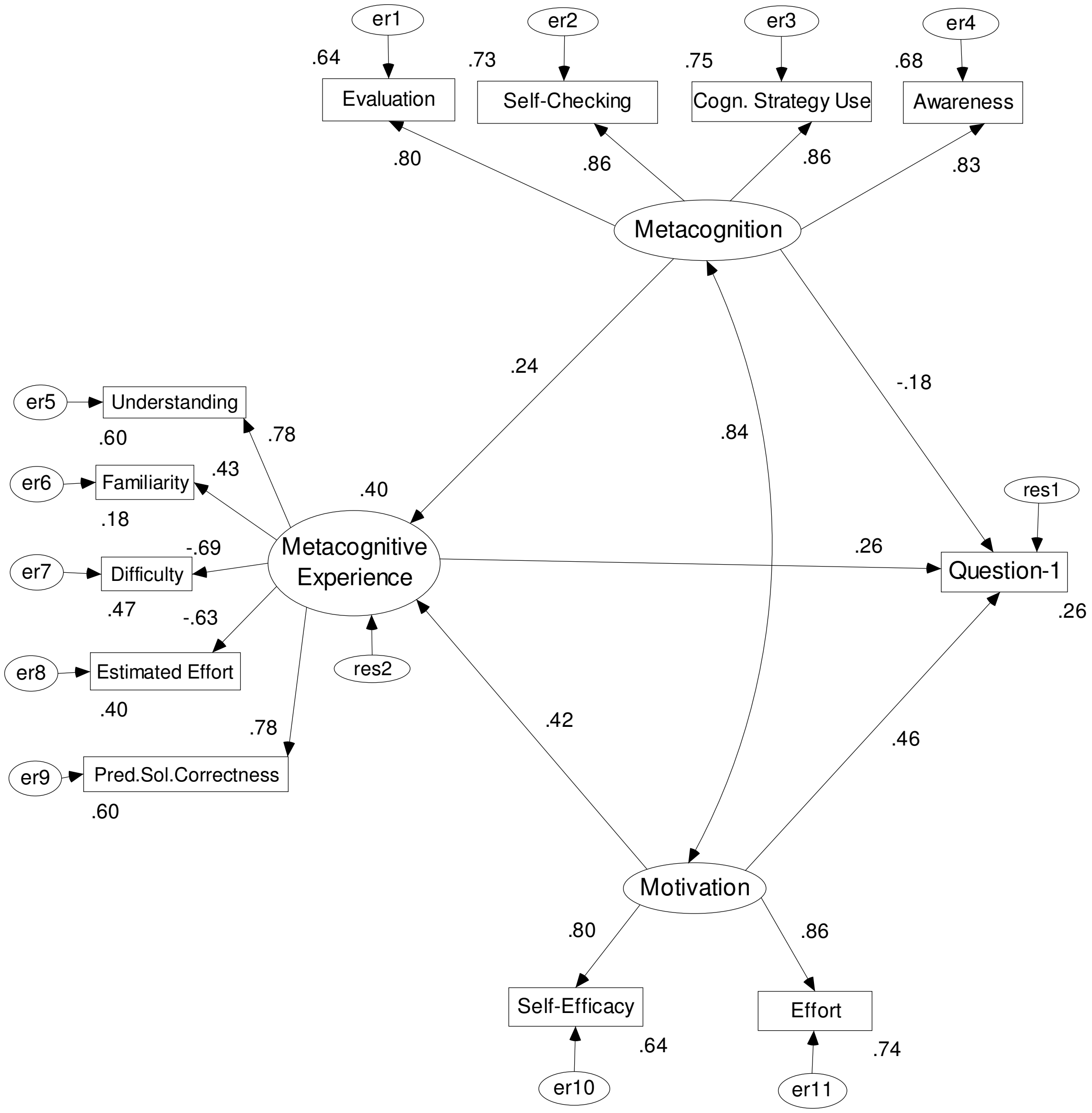


Figure 5.5. The initial model for the 1st math problem

For the initial model, the obtained initial chi-square value (χ^2) was 164.2 with 49 degrees of freedom. The CMIN/df value in our study 3.35 (<3), which indicates that the fit was not acceptable for the initial model. As a result of confirmatory modeling, the hypothesized model and its parameters were shown in Figure 5.5. The initial model was also tested for the other two questions. Since, the x^2/df values were obtained as 4.17 and 3.62, respectively. The χ^2/df values for all three questions did not confirm the initial model.

The Goodness of Fit Index (GFI) is a measure of the relative amount of variance and covariance in the sample covariance matrix that is jointly explained by the restricted covariance matrix. The Adjusted Goodness of Fit Index (AGFI) differs from the Goodness of Fit Index (GFI) only in the fact that AGFI adjusts for the number of degrees of freedom in the specified model (Byrne, 2001). The range for both indices is between 0 and 1. The value closer to one indicates good fit. Values over 0.90 are regarded as an indication of good fit for both indices (Kline, 1998). The GFI value for the initial model based on the first question was 0.936 and AGFI index was found as 0.898. The initial model represented adequate fit to the data.

Another important fit index is Bentler and Bonett's Normed Fit Index (NFI) and Comparative Fit Index (CFI). CFI is the revised version of NFI by taking sample size into account. Both CFI and NFI are derived from the comparison of a hypothesized model with the independence model. The range is between 0 and 1. Although values greater than 0.90 can be accepted as a well-fitting model, values close to 0.95 have been adviced by Hu & Bentler in 1999. Bentler suggested that CFI should be the index of choice (Byrne, 2001). Based on the CFI and NFI values, which were 0.954 and 0.936 respectively, we can conclude that the initial model fits the sample fairly well.

The incremental index of fit (IFI) is also used to evaluate the goodness of fit of the initial model. IFI addresses the issue of parsimony and the sample (Byrne, 2001). IFI values close to 1 indicate a very good fit. Similar to CFI and NFI, IFI values close to 0.95 represents good fit of the model (Arbuckle and Wothke, 1999). For the initial model, IFI value was obtained as 0.954, which indicates that the initial model fits the sample data farily well.

The root mean square error approximation (RMSEA) was another index of model fit, used to evaluate the goodness of fit of the initial model. The RMSEA takes the error of approximation in the population with unknown but optimally chosen variable into account and examine how well the model fit the population covariance matrix if it were available. Values less than 0.05 indicate good fit, hence values greater than 0.08 represent reasonable errors of approximation in the population (Byrne, 2001). MacCallum *et al.* (1996) suggested that values of RMSEA between 0.05 and 0.08 indicate a "fair" fit. The finding of the RMSEA index in the study was found as 0.76, which indicates an adequate fit to the data.

All fit indices except χ^2/df value demonstrated that the model adequately fit the data. However, since the χ^2/df values were more than 3, the model was to be modified and tested again. The confirmatory model testing process did not reach an adequate χ^2/df value for the initial model in spite of getting well fit for the other indices. Therefore, the rest of the study was an exploratory model testing.

5.5.2. Modification of the Model

Although all goodness of fit indices of the initial model indicated adequate fits to the data, the χ^2/df values did not justify the initial model. Therefore, the model had to be revised and modified by taking parameter estimates and modification indices into account. Parameter estimates give the significance of causal and correlational paths included in the model. The parameter estimates of the initial model for the 1st math problem are represented in Table 5.9.

Table 5.9. Estimates for the paths hypothesized in the initial model for the 1st math problem

			Estimate	S.E.	C.R.	P
Metacog. Experiences	<---	Metacog. Regulation	.044	.021	2.063	.039
Metacog. Experiences	<---	Motivational Regulation	.054	.016	3.410	***
Effort	<---	Motivational Regulation	1.000			
Estimated Effort	<---	Metacog. Experiences	-.655	.054	-12.036	***
Feeling of Difficulty	<---	Metacog. Experiences	-.700	.053	-13.179	***
Feeling of Familiarity	<---	Metacog. Experiences	.578	.072	8.000	***
Awareness	<---	Metacog. Regulation	1.000			
Performance Question-1	<---	Metacog. Experiences	.553	.150	3.690	***
Self-efficacy	<---	Motivational Regulation	1.150	.066	17.526	***
Evaluate	<---	Metacog. Regulation	1.053	.057	18.584	***
Self-checking	<---	Metacog. Regulation	1.322	.064	20.553	***
Predicted Sol.Correctness	<---	Metacog. Experiences	1.000			
Feeling of Understanding	<---	Metacog. Experiences	.914	.062	14.802	***
Cognitive Strategies	<---	Metacog. Regulation	.828	.040	20.787	***
Performance Question-1	<---	Motivational Regulation	.128	.035	3.631	***
Performance Question-1	<---	Metacog. Regulation	-.072	.045	-1.603	.109
	Correlational Path					
Metacog. Regulation	<-->	Motivational Regulation	13.690	1.277	10.722	***

One of the main themes in the study was to examine whether there was a relationship between metacognitive regulation and performance. If not, the indirect effect of metacognitive regulation on performance through metacognitive experiences would be assessed. According to the results of path analysis for the initial model of the 1st question, two causal relationships warned the researcher for their degrees of significance. Only one causal relationship was identified as non-significant, which is the direct effect of metacognitive regulation on performance in the 1st question. The direct effect of metacognitive regulation on metacognitive experiences that had a value of 0.039 was identified as significant at the 0.05 level. Therefore, the causal relationship of metacognitive regulation on performance was excluded from the model, but the one from metacognitive regulation to metacognitive experiences was not. The same procedure was conducted for the other two problems and it could not be shown that there was a significant direct effect of metacognitive regulation on problem solving performance. Hence, the causal relationship of metacognitive regulation on performance was extracted from the model for all three mathematics problems. Thus, the results clarified one of the main themes of the study that metacognitive regulation did not have a direct effect on problem solving performance for all three mathematics problems.

After the direct effect of metacognitive regulation on problem solving performance was excluded, the model was tested again. The chi-square value was obtained as 166.87 with 50 degrees of freedom. The χ^2/df value for the first question (3.34) did not change significantly when compared with the confirmatory model testing result (3.35). For the second and third problems, the χ^2 values remained as 205.48 (χ^2/df = 4.11) and 177.93 (χ^2/df = 3.56) respectively. The results indicated that after the causal relationship of metacognitive regulation on performance was deleted, the model still did not show fit with the data. As a next step, modification indices, which represent the AMOS program suggestions on the inclusion of causal and correlational paths into the model, were inspected.

According to Pedhazur (1982, as cited in Kısa, 2008) explanations of the causes do not come from structural equation modeling, they come from the theory, which the model is based on. Thus, rather than adding causal relations between the indicators of latent variables into the model, modifying the model by taking correlational relations into account were considered as better manipulations. The hypothesized model mainly based on unobserved variables. Hence, the modification indices suggested correlations between the error variables as seen in Table 5.10.

In the modification indices estimates, a modification index (M.I.) and an expected parameter change (Par Change) is shown for each path. The value of the modification index (M.I.) of a path represents the expected drop in overall x^2 value if the parameter were to be freely estimated in a subsequent run and the expected parameter change (Par Change) value represents the predicted estimated change for each fixed parameter in the model in either positive or negative direction. The latter one gives important information about the sensitivity of the evaluation of fit to any re-parameterization of the model (Byrne, 2001).

Table 5.10. Error covariance table based on the hypothesized model for the 1st math problem

			M.I.	Par Change
er2	<-->	res2	15.601	-0.344
er5	<-->	res1	4.899	0.068
er7	<-->	res1	5.869	0.070
er8	<-->	er2	6.609	0.209
er8	**<-->**	**er7**	**16.923**	**0.053**
er9	<-->	er6	5.057	-0.050
er3	<-->	res2	5.971	0.130
er1	<-->	Metacognition	4.343	-0.723
er1	<-->	Motivation	6.828	1.342
er4	<-->	er1	7.216	-0.980
er10	<-->	MC	4.678	-1.190
er10	<-->	res2	8.339	0.383
er10	<-->	er2	11.595	-2.447
er10	<-->	res1	6.094	0.678
er10	<-->	er5	8.528	-0.361
er10	**<-->**	**er9**	**17.954**	**0.572**
er10	<-->	er1	17.968	2.890
e11	<-->	res2	6.201	-0.248
e11	<-->	er2	13.194	1.964
e11	<-->	res1	4.538	-0.439
e11	<-->	er5	4.532	0.198
e11	<-->	er9	5.829	-0.246

In reviewing the error covariance, two correlation paths with higher value of modification indices were included in the model. Adding these two error correlations to the model testing did not have inconsistency with the theory. The modified model was tested and the results of the path analysis indicated that every causal and correlational relation was significant. The other important goodness of fit indices for the final version of the model was as: GFI = 0.952 (>0.90), AGFI = 0.922 (>0.90), NFI = 0.951 (>0.95), χ^2 (48) = 126.8 (p<0.01), χ^2/df = 2.64 (< 3). All goodness of fit indices of the hypothesized model was confirmed. Additionally, similar values were obtained when model testing was conducted by considering the other two mathematics problems. The related models with standardized estimates are shown in Appendix I and Appendix J.

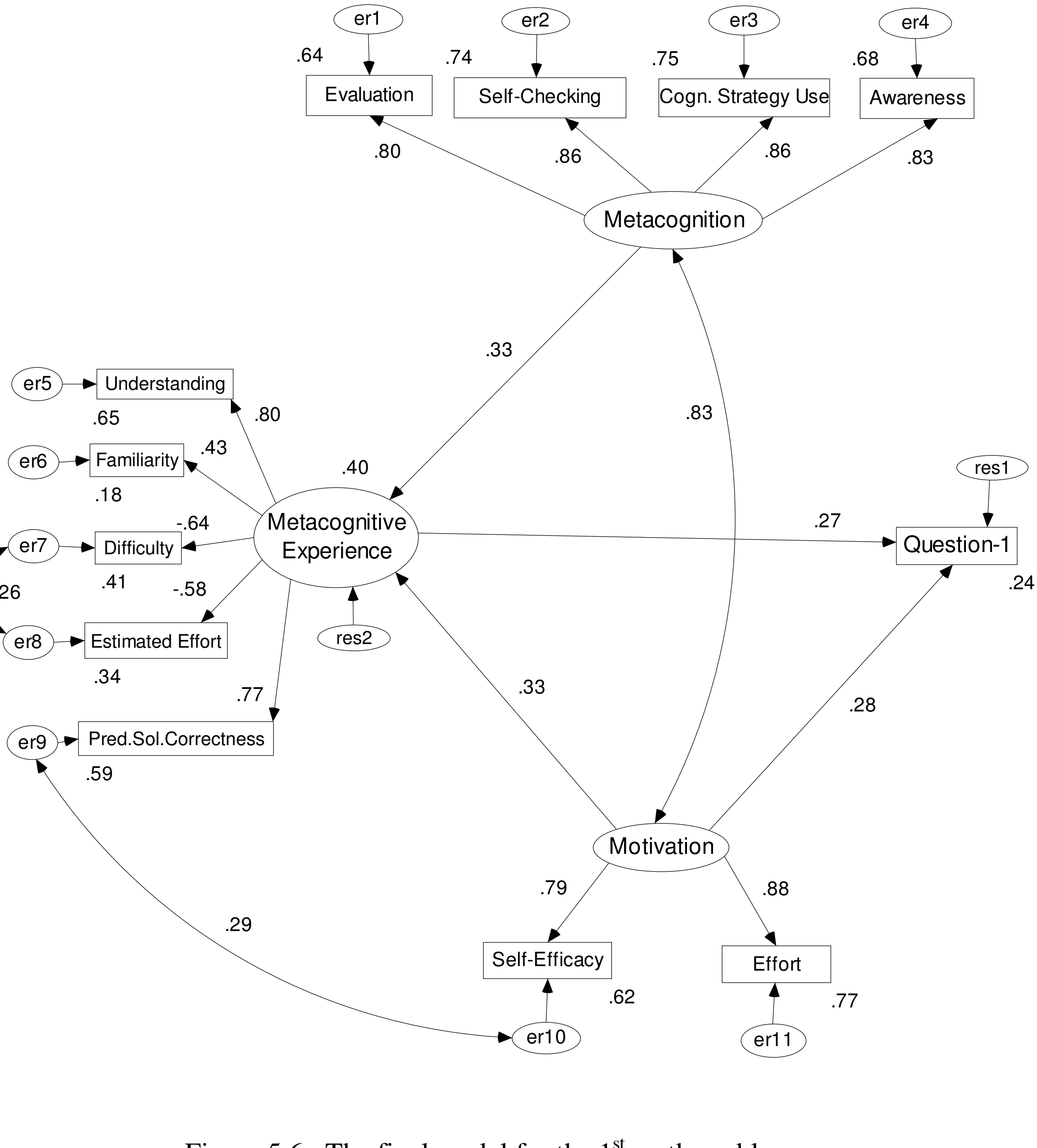


Figure 5.6. The final model for the 1st math problem

As a result of the above-mentioned modifications, the self-regulation model explaining students' problem solving performance in relation with metacognitive and motivational regulation, and metacognitive experiences reached its final form shown in Figure 5.6. The final model explained 24 percent of the variance in problem solving performance.

The values corresponding to each path represents the standardized regression and correlation coefficients. The values corresponding to endogenous variables represent the estimates of squared multiple correlations. They are estimated that in what percent the variance of the variable is explained by the predictors. The standardized regression weights for the causal paths and the standardized correlation coefficients for the final model were given in Table 5.11.

Table 5.11. The standardized regression weights and correlation coefficients for the final model

Causal Path			Standardized Regression Weight
Metacognitive Experiences	<---	Metacognitive Regulation	.33
Metacognitive Experiences	<---	Motivational Regulation	.33
Performance (Q-1)	<---	Metacognitive Experiences	.27
Performance (Q-1)	<---	Motivational Regulation	.28
Feeling of Understanding	<---	Metacognitive Experiences	.80
Feeling of difficulty	<---	Metacognitive Experiences	-.64
Feeling of familiarity	<---	Metacognitive Experiences	.43
Predicted Solution Correctness	<---	Metacognitive Experiences	.77
Estimated Effort	<---	Metacognitive Experiences	-.58
Cognitive Strategies	<---	Metacognitive Regulation	.86
Evaluation	<---	Metacognitive Regulation	.80
Self-Checking	<---	Metacognitive Regulation	.86
Awareness	<---	Metacognitive Regulation	.83
Effort	<---	Motivational Regulation	.88
Self-Efficacy	<---	Motivational Regulation	.79
Correlational Path			Standardized Correlation Coefficient
Motivational Regulation	<-->	Metacognitive Regulation	.83
Error 11	<-->	Error 10	.26
Error 2	<-->	Error 12	.29

The final model implies that metacognitive and motivational regulation had same amount of direct effects (β = 0.33) on metacognitive experiences. This means that if metacognitive or motivational regulation goes up 1 standard deviation, Metacognitive experiences goes up 0.33 standard deviations. Metacognitive experiences and motivational regulation had direct effects on problem solving performance (β = 0.27 and β = 0.28, respectively). Motivational regulation also had a significant indirect effect on problem solving performance through the mediation of metacognitive experiences (β = 0.09). As indicated earlier, the direct effect of metacognitive regulation on problem solving performance was not statistically significant. However, the findings indicated that metacognitive regulation had a significant mediator effect on problem solving performance through the mediation of metacognitive experiences (β = 0.09) The direct, indirect and total effects of all variables are shown in Appendix K.

There is only one correlational path regarding main variables between motivational regulation and metacognitive regulation with 0.83 estimates of correlation. Moreover, there are two correlation paths between errors (er10 ⇔ er11 and er2 ⇔ er12) which were added during the modification process of the initial model. Their correlational coefficients were found as 0.26 and 0.29, respectively.

6. DISCUSSION

This study aimed at investigating the relationship between metacognition, motivation and metacognitive feelings and problem solving performance. The rationale for the study was poor problem solving performance of eight grade students observed in cross-national studies. These studies also indicated large school differences in the quality of math education. Moreover, some research studies in the literature pointed toward gender differences in the above-mentioned variables. These concerns led to the research questions of this study.

The research questions were explored by means of correlational techniques and group comparisons on a sample of 406 eight graders coming from different kind of schools. First, the relationships between all the variables were analyzed through Pearson correlation coefficients. Gender and school differences were investigated by group comparison t-test techniques. A structural equation model including the metacognitive and motivational variables and problem solving performance was proposed and tested.

The findings from the data analyses presented evidence for significant relationships between metacognitive and motivational regulation, metacognitive experiences and problem solving performance. The correlation coefficients were considerable. The data showed good fit with the proposed model. The significant gender and school differences were detected in group-comparison analyses.

In relation to the first research question "Are there significant relationships between the variables: metacognitive regulation, motivational regulation, metacognitive experiences and performance in mathematical problem solving?" significant relationships between the variables were found. These results were mostly consistent with the findings emphasized in the literature. As the correlation coefficients were ranked in an order, the highest degree of correlation was seen between metacognitive and motivational regulations.

The motivational regulation demonstrated a significant high degree of correlation with metacognitive regulation. The findings of the study gave parallel results to the previous research studies. Many studies in the literature found strong relationships between motivation and metacognition (Pintrich, 1988; Pintrich and De Groot, 1990; Zimmerman, 2000; Sundre and Kitsansas, 2004; Hong and Peng, 2008).

The metacognitive and motivational regulation and metacognitive experiences had significant moderate degree of correlations with students' problem solving performances. Similar results were seen when students' grades at the end of first semester were considered instead of their actual problem solving performances. In some studies, self-regulation was defined as the combination of metacognition and motivation (Zimmerman, 1995; Hong *et al.*, 2005). By taking the definition of self-regulation in that framework, the results of this study emphasized that self-regulation has significant relation with students' achievement and problem solving performance.

Although a positive relationship between the metacognition and academic achievement has been demonstrated in a number of studies (Eme and Rouet, 2001; Kitsansas, 2002; Sundre and Kitsansas, 2004), contradictory findings also have been found in some others. Some studies examined metacognition - achievement relationship and found no significant relationships (Purpura, 1997; Schraw, 1997; Kuyper *et al.*, 2000; Malpass *et al.*, 1999; Hong and Peng, 2008). The findings of the present study indicated that problem solving performance and grade point average were significantly related to metacognitive regulation through self-checking, evaluation, awareness and using cognitive strategies.

As it was emphasized in previous research studies, the contradictory findings might be because of cultural diversity and the relationship should be investigated in different cultural settings (Hong and Peng, 2008). The findings on the significant relationship between metacognition and achievement among Turkish students emphasized the diversity of literature.

The emergence of expected correlation coefficients set the stage for and justified the structural model to be tested. The results provide evidence for the importance of considering both motivational and metacognitive components in the model studies of academic performance.

As the second research question: “Are there gender differences in the variables: metacognitive regulation, motivational regulation, metacognitive experiences and performance in mathematical problem solving?” was investigated, it was observed that no significant gender difference was found between the first-order self-regulatory constructs such as metacognitive and motivational regulation, and metacognitive experiences. However, within some second-order constructs like awareness, self-checking and self-efficacy significant gender differences were found.

Zimmerman and Martinez-Pons (1990) declared that females demonstrated higher level of monitoring. As parallel to their finding, the results of our study indicated that although males and females demonstrated similar feelings about difficulty, familiarity and understanding of a problem, females’ effort estimation and solution correctness prediction were significantly higher than males in positive direction. In a study, it was found that girls attribute failure to their lack of ability even though their achievement is higher than boys (Nicholls, 1979).

Significant gender difference was observed in students’ grades. Contrary to this, no gender differences were found based on their problem solving performance. Students need to do many works in their classrooms. Homework, active participation, teachers’ individual assessments might be among those. Actually, female students are much careful than the boys in schoolwork. However, their achievement did not give significant difference when pure problem solving performance was considered. Further research might be done in relation to such phenomena.

Students’ metacognitive feelings are closely tied to metacognitive and motivational regulation of learning (Desoete and Veenman, 2006). Although there is a debate about the validity of self-report questionnaire, the results of this study showed similar results with self-report questionnaire results. The assessment of metacognitive experiences was conducted in more task- specific content. The results emphasized the role of metacognition in academic achievement.

The most striking findings of the study were found investigating the third research question: “Are there school differences in the variables: metacognitive regulation, motivational regulation, metacognitive experiences and performance in mathematical problem solving?” The results were parallel to the findings of the PISA study. There were great differences in the problem solving performances of students coming from different type of schools. There were also differences in motivational regulation and metacognitive experiences.

As to the testing of the model, to answer the research question: “Will the data fit a model explaining the relationships between the variables: metacognitive regulation, motivational regulation, metacognitive experiences and performance in mathematical problem solving?” it was observed that the data fit successfully into the proposed self-regulation model. The model suggested relationships between different aspects of self-regulation. The metacognitive experiences’ variables played an important role in explaining self-regulation in problem solving. These results were found relevant to the literature in metacognition in mathematics.

This study aimed at identifying the relations between students’ metacognitive and motivational regulation, metacognitive experiences and problem solving performance in mathematics. The results of the model study provided evidence for the importance of considering both motivational and metacognitive aspects of self-regulated learning components in model studies. Cognitive ability referred to “skill” played a crucial role in academic achievement. Hence, the results of the study emphasized that students needed to have both “metaskill” and “will” components in relation with cognitive ones.

6.1. LIMITATIONS OF THE STUDY

The difficulty of assessment metacognitive factors with self-report questionnaire might be thought as a limitation in the study. Since, there is a debate in the literature about if evaluating students' metacognitive and self-regulatory components through self-report questionnaire is valid or not (Pintrich and De Groot, 1990; Hong *et al.*, 2005; Hong and Peng, 2008). Self- report instruments are practical to implement, since it is difficult to assess students' unconscious beliefs and cognitive processes.

Convenient sampling method was used through the data collection process. This might be a limitation for the generalizability of the findings.

6.2. SUGGESTIONS FOR FURTHER RESEARCH

The results of this study indicated the importance of metacognitive and motivational regulation for problem solving performance. Further studies using different kinds of instruments and different samples will contribute to the area.

The teaching implications of the findings ought to be studied. Classroom practices enhancing metacognitive and motivational regulation should be used in intervention studies to further investigate their effects on problem solving performance and achievement.

The school differences in achievement and metacognitive and motivational regulation variables were apparent in this study. The findings were consistent with cross-national studies, which showed that there were vast differences in schools for Turkish students. The reasons for the large differences in different schools need to be examined. The variables that cause the large differences should be identified. The debilitating effect of such variables should be reduced through intervention studies.

APPENDIX A: METACOGNITIVE EXPERIENCES SCALE

SORU -1

Barış harçlıklarını biriktirerek bir bisiklet almak istiyor. Biriktirdiği paraya bu paranın 2 katından 30 TL fazla para eklerse fiyatı 150 TL olan bir bisiklet alabilecektir.

Buna göre;

- Barış'ın biriktirdiği para ne kadardır?
- Barış biriktirdiği paraya, her gün 2,5 TL eklerse bisikleti kaç gün sonra alabilir?

Daha önce buna benzer bir soru ile karşılaştınız mı?	Hiç ☐	Biraz ☐	Oldukça ☐	Çok ☐
Problemde ne yapmanız istendiğini ne kadar anladınız?	Hiç ☐	Biraz ☐	İyi ☐	Tamamen ☐
Sizce bu problem ne kadar zor?	Hiç ☐	Biraz ☐	Oldukça ☐	Çok ☐
Sizce bu problemi çözmek için ne kadar çaba sarf etmeniz gerekir?	Hiç ☐	Biraz ☐	Oldukça ☐	Çok ☐
Problemi ne kadar doğru çözebileceğinizi düşünüyorsunuz?	Hiç ☐	Biraz ☐	Oldukça ☐	Tamamen ☐

<u>*SORU - 2*</u>

Bir memur 1200 TL olan aylık maaşının %40'ını kiraya, %35'ini gıdaya, %15'ini diğer masraflar için harcayıp geriye kalanını biriktiriyor. Bu memur bir yıl boyunca biriktirdiği paralarla, fiyatı 580 TL olan bir televizyon alıp geri kalan parasıyla da tatile gitmek istiyor. Memurun, tatil için ne kadar parası kalır?

Daha önce buna benzer bir soru ile karşılaştınız mı?	Hiç ☐	Biraz ☐	Oldukça ☐	Çok ☐
Problemde ne yapmanız istendiğini ne kadar anladınız?	Hiç ☐	Biraz ☐	İyi ☐	Tamamen ☐
Sizce bu problem ne kadar zor?	Hiç ☐	Biraz ☐	Oldukça ☐	Çok ☐
Sizce bu problemi çözmek için ne kadar çaba sarf etmeniz gerekir?	Hiç ☐	Biraz ☐	Oldukça ☐	Çok ☐
Problemi ne kadar doğru çözebileceğinizi düşünüyorsunuz?	Hiç ☐	Biraz ☐	Oldukça ☐	Tamamen ☐

<u>*SORU – 3*</u>

Bir sınıftaki kız öğrencilerin sayısı, sınıf mevcudunun 3/4' ünden 13 eksiktir. Sınıftaki kız öğrencilerin sayısı 20 olduğuna göre, erkek öğrencilerin sayısı kaçtır?

Daha önce buna benzer bir soru ile karşılaştınız mı?	Hiç ☐	Biraz ☐	Oldukça ☐	Çok ☐
Problemde ne yapmanız istendiğini ne kadar anladınız?	Hiç ☐	Biraz ☐	İyi ☐	Tamamen ☐
Sizce bu problem ne kadar zor?	Hiç ☐	Biraz ☐	Oldukça ☐	Çok ☐
Sizce bu problemi çözmek için ne kadar çaba sarf etmeniz gerekir?	Hiç ☐	Biraz ☐	Oldukça ☐	Çok ☐
Problemi ne kadar doğru çözebileceğinizi düşünüyorsunuz?	Hiç ☐	Biraz ☐	Oldukça ☐	Tamamen ☐

APPENDIX B: METACOGNITIVE SKILLS INVENTORY

	HİÇ	BAZEN	SIK SIK	HER ZAMAN
Sınavda soruları cevaplarken, nasıl düşündüğümün farkındayım.	□	□	□	□
Bir soruyu cevaplarken, nasıl yaptığımı kontrol ederim.	□	□	□	□
Hangi düşünme biçimini, ne zaman kullanacağımı bilirim.	□	□	□	□
Sınavlarda hatalarımı fark eder, dönüp düzeltirim.	□	□	□	□
Sınav sorularının bildiğim konularla ilgili olup olmadığını anlamaya çalışırım.	□	□	□	□
Sınavlarda soruları cevaplamadan önce ne sorulduğunu anlamaya çalışırım.	□	□	□	□
Sınavlarda gerek görürsem, düşünme ve çözüm yollarımı değiştiririm.	□	□	□	□
Soruları cevaplarken doğru yapıp yapmadığımı kontrol ederim.	□	□	□	□
Hangi konuyu ne kadar anladığımı değerlendirebilirim.	□	□	□	□
Bir sınavdaki başarımı doğru olarak tahmin edebilirim.	□	□	□	□
Bir bilginin benim için önemli olup olmadığını anlar, dikkatimi ona yoğunlaştırırım.	□	□	□	□
Hangi bilgiyi öğrenmemin daha önemli olduğunu bilirim.	□	□	□	□
Kafamdaki bilgileri kolay hatırlayabileceğim bir şekilde düzenlerim.	□	□	□	□
Bir sınavda soruları çözebilmek için belirli yöntemler kullandığımın farkındayım.	□	□	□	□
Fikir sahibi olduğum bir konuyu daha iyi öğrenirim.	□	□	□	□
Öğretmenin benden ne öğrenmemi beklediğini bilirim.	□	□	□	□

Duruma bağlı olarak farklı öğrenme yolları kullanırım.	□	□	□	□
Bir soruyu çözdükten sonra kendime, daha kolay bir çözüm yolu olup olmadığını sorarım.	□	□	□	□
Daha iyi öğrenip, öğrenememem bana bağlıdır.	□	□	□	□
Bir problemle karşılaştığımda bir sürü çözüm yolu düşünür, en iyisini seçerim.	□	□	□	□
Çalışırken hangi yöntemleri kullandığımın farkındayım.	□	□	□	□
Çalışırken kullandığım yöntemlerin işe yarayıp yaramadığını düşünürüm.	□	□	□	□
Bir konuyu anlayıp anlamadığımı bilirim.	□	□	□	□
Bir şeyi anlayıp anlamadığımı kontrol ederim.	□	□	□	□
Hangi yöntemi, nerede kullanırsam daha etkili olacağımı bilirim.	□	□	□	□
Yeni öğrendiğim bir konuyu daha kolay anlayabileceğim bir hale getirmeye çalışırım.	□	□	□	□
Bir konuyu anlayamadığım zaman kullandığım yöntemi değiştiririm.	□	□	□	□
Sınavlarda soruları cevaplamak için gerekli olan süreyi bilir ve kendimi ona göre ayarlarım.	□	□	□	□
Sınavlara hazırlanırken, çalıştığım konuları bölümlere ayırırım.	□	□	□	□
Çalışmayı bitirdiğimde, öğrenebileceğim kadar öğrenip, öğrenmediğimi anlamaya çalışırım.	□	□	□	□
Tam olarak anlamadığım konuyu tekrar ederim.	□	□	□	□
Kafam karıştığı zaman durur ve tekrar okurum.	□	□	□	□

APPENDIX C: DIMENSIONS OF METACOGNITIVE SKILLS INVENTORY

Self-Checking:

Item 2	I check my work while I am answering a question.
Item 8	I check my accuracy as I progress through a test.
Item 13	I organize the information in my mind so that I can easily remember them.
Item 22	I think about the usefulness of the strategies when I study.
Item 24	I check whether or not I understand something.
Item 28	I know the given time for the tests and I organize myself accordingly.
Item 29	When I study for a test, I break down the subjects into smaller chapters.
Item 30	I ask myself if I learned as much as I could have once I finish a task.
Item 31	I go back over new information that is not clear.
Item 32	I stop and reread when I get confused.

Awareness:

Item 6	I try to understand the test questions before I attempt to solve them.
Item 9	I am a good judge of how well I understand something.
Item 10	I know how well I did once I finish a test.
Item 11	I consciously focus my attention on important information.
Item 12	I know what kind of information is most important to learn.
Item 15	I learn best when I know something about the topic.
Item 16	I know what the teacher expects me to learn.
Item 19	I have control over how well I learn.

Evaluation:

Item 4	I realize and correct my errors in the tests.
Item 7	If necessary, I change my thinking and solving techniques in tests.
Item 14	I am aware that I am using specific strategies for solving the problems in the test.
Item 17	I use different learning strategies depending on the situation.
Item 18	I ask myself if there was an easier way to solve a problem after finishing the task.
Item 20	I use multiple thinking techniques/strategies to solve the test questions and choose the best one.
Item 26	I try to make new information into something I can understand easier.
Item 27	I change strategies when I fail to understand.

Cognitive Strategies:

Item 1	I am aware of my thinking while answering to the questions in the test.
Item 3	I know which and when to use the thinking strategies.
Item 5	I ask myself if the problems in the test are related to what I already know.
Item 21	I am aware of what strategies I use when I study.
Item 23	I know whether or not I understand a topic.
Item 25	I know when each strategy I use will be most effective.

APPENDIX D: ITEM-TOTAL CORRELATIONS OF THE METACOGNITIVE SKILLS INVENTORY

	Corrected Item-Total Correlation
Item 1	,426
Item 2	,492
Item 3	,509
Item 4	,358
Item 5	,554
Item 6	,557
Item 7	,499
Item 8	,606
Item 9	,512
Item 10	,438
Item 11	,423
Item 12	,534
Item 13	,551
Item 14	,579
Item 15	,541
Item 16	,423
Item 17	,561
Item 18	,310
Item 19	,492
Item 20	,357
Item 21	,656
Item 22	,518
Item 23	,541
Item 24	,547
Item 25	,510
Item 26	,521
Item 27	,462
Item 28	,420
Item 29	,559
Item 30	,568
Item 31	,573
Item 32	,479

APPENDIX E: FINAL FORM OF THE MOTIVATIONAL REGULATION SCALE

Matematik problemlerini kısa sürede çözebilirim.	1	2	3	4
Problemi kısa sürede çözemezsem; uğraşmam, çabalamayı bırakırım.	1	2	3	4
Matematikten düşük not aldığımda dert etmem, zaten matematikte yetersiz olduğumu biliyorum.	1	2	3	4
İleride matematikçi olabilecek özelliklere sahibim.	1	2	3	4
Tam olarak anlayamadığım zor bir konu ile karşılaştığımda kolay kolay pes etmem.	1	2	3	4
Matematik ile ilgili daha çok şey öğrenmek için fazladan çalışırım.	1	2	3	4
Matematiği beceremem / yapamam.	1	2	3	4
İstesem matematik dersinde sınıfın en iyisi olabilirim.	1	2	3	4
Çözemediğim problemler ile karşılaştığımda çözmek için çaba sarf ederim.	1	2	3	4
Bir matematik sorusunu çözerken mümkün olduğunca çözdüğüm soruya konsantre olurum.	1	2	3	4
Matematik sınavından düşük not alsam bile bunu sorun etmem, bir sonraki sınavda yüksek alacağıma eminim.	1	2	3	4
Kimsenin yardımı olmadan matematik öğrenebilirim.	1	2	3	4
Bir konuda benzer problemleri çözmemiş olsam bile yeni problemleri çözebilirim.	1	2	3	4
Başkaları itiraz etseler bile bulduğum sonucun doğruluğunu savunurum.	1	2	3	4
Matematikten ne kadar çok ödev verilmiş olsa da, ödevlerimi zamanında bitirmeye çalışırım.	1	2	3	4
Matematikte istediğim notu alamazsam daha fazla çaba harcarım.	1	2	3	4
Gelecekte ileri düzeyde matematik gerektiren bir işte çalışabilirim.	1	2	3	4
Bir konuda benzer problemlerin çözümünü görmemiş olsam bile yeni problemleri çözebilirim.	1	2	3	4
Matematik dersinde elimden gelenin en iyisini yapmaya çalışırım.	1	2	3	4
Derste ve ders kitaplarında matematik ile ilgili öğrendiğim her şeyi günlük hayatta kullanabilirim.	1	2	3	4
Not verilmeyecek olsa bile, bir matematik sorusunu çözmek için çok çalışırım.	1	2	3	4
Üniversitede matematik ile ilgili bir bölümde okuyabilirim.	1	2	3	4
Arkadaşlarım başaramadığımı düşünseler bile aldırmam, çaba göstermeye devam ederim.	1	2	3	4
Ne kadar çok alıştırma yaparsam, matematiğim o kadar iyi olur.	1	2	3	4

APPENDIX F: ITEM-TOTAL CORRELATIONS OF THE MOTIVATIONAL REGULATION SCALE

	Corrected Item-Total Correlation
Item 2	.646
Item 6	.607
Item 7	.604
Item 8	.567
Item 10	.535
Item 12	.686
Item 13	.597
Item 14	.583
Item 15	.372
Item 16	.579
Item 17	.589
Item 18	.273
Item 19	.599
Item 20	.629
Item 21	.594
Item 22	.634
Item 24	.473
Item 25	.646
Item 26	.610
Item 28	.621
Item 30	.566
Item 3	.360
Item 5	.510
Item 9	.526

APENDIX G: PROBLEM SOLVING PERFORMANCE TEST

SORU -1

Barış harçlıklarını biriktirerek bir bisiklet almak istiyor. Biriktirdiği paraya bu paranın 2 katından 30 YTL fazla para eklerse fiyatı 150 YTL olan bir bisiklet alabilecektir.

Buna göre;

- Barış'ın biriktirdiği para ne kadardır?
- Barış biriktirdiği paraya, her gün 2,5 YTL eklerse bisikleti kaç gün sonra alabilir?

SORU - 2

Bir memur 1200 TL olan aylık maaşının %40'ını kiraya, %35'ini gıdaya, %15'ini diğer masraflar için harcayıp geriye kalanını biriktiriyor. Bu memur bir yıl boyunca biriktirdiği paralarla, fiyatı 580 TL olan bir televizyon alıp geri kalan parasıyla da tatile gitmek istiyor. Memurun, tatil için ne kadar parası kalır?

SORU – 3

Bir sınıftaki kız öğrencilerin sayısı, sınıf mevcudunun 3/4' ünden 13 eksiktir. Sınıftaki kız öğrencilerin sayısı 20 olduğuna göre, erkek öğrencilerin sayısı kaçtır?

APPENDIX H: THE HOLISTIC SCORING RUBRIC

This scale evaluates the process employed in response to a problem-solving task. It takes into consideration the level of student knowledge and understanding with respect to the given problem solving task; the selection and implementation of appropriate procedures and/or strategies; and the accuracy of the solution obtained.

4 - Response is characterized by all of the following:
- The student selects and implements relevant concepts and procedures/strategies needed to solve this problem.
- The student considers all constraints of the problem situation.
- The solution and all relevant work is correct; or, there is a mistake due to some minor computational or copying error.

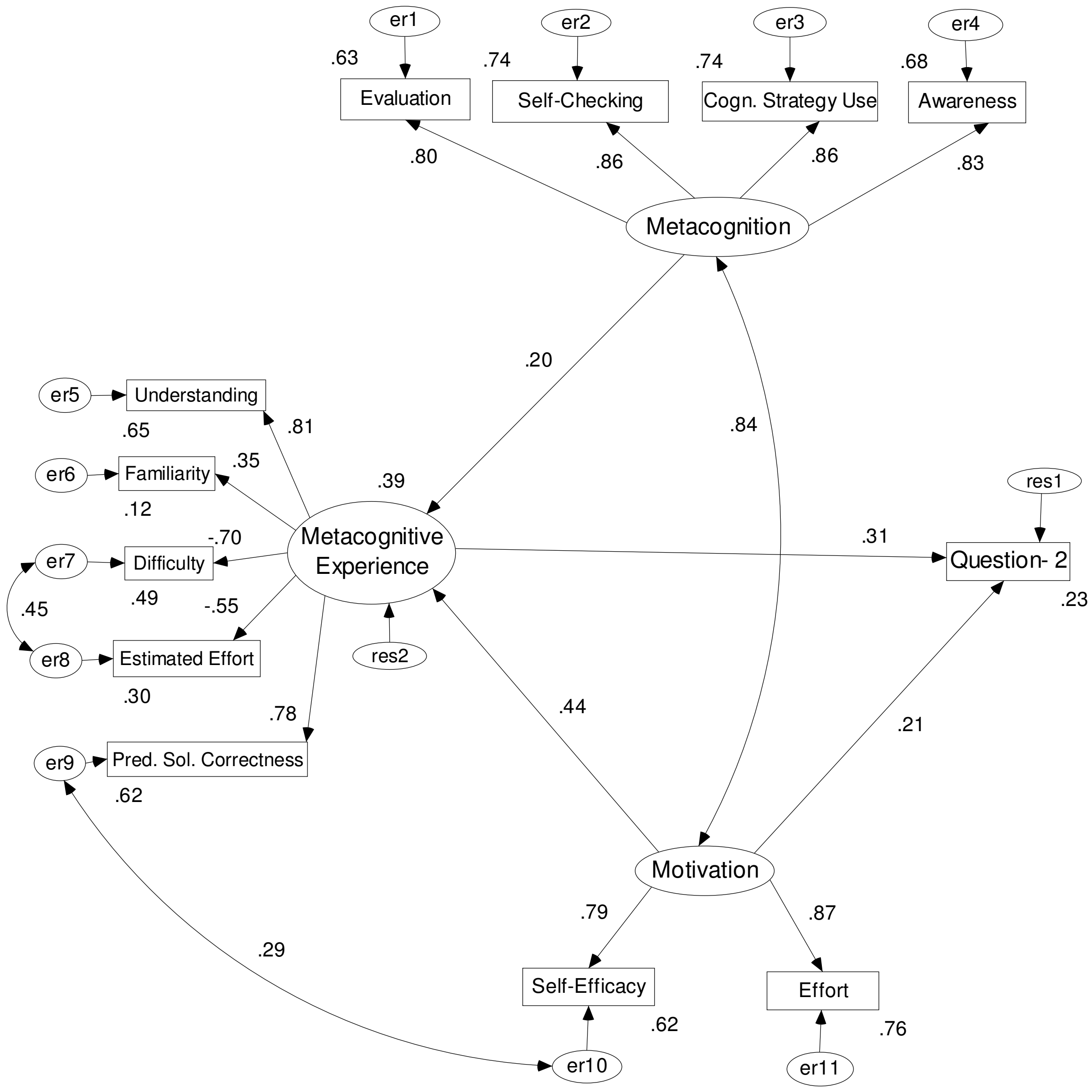
3 - The student selects appropriate procedures/strategies to solve this problem; however, the response/solution is not entirely correct because one of the following is apparent:
- There is evidence the student has a misconception or has failed to consider a relevant concept needed to solve the problem correctly.
- The student fails to consider a constraint of the problem situation.
- The student has considered an irrelevant variable or failed to consider a relevant variable.
- The response/solution is generally correct; however, from the information provided it is not completely clear how the student arrived at this solution.

2 - The student selects appropriate procedures/strategies to solve this problem; however, the response/solution is not correct because one or more of the following are:
- There is evidence that the student has several misconceptions or has failed to consider several relevant concepts needed to solve the problem correctly.
- The student fails to consider several constraints of the problem situation.
- The student has also considered several irrelevant variables or failed to consider several relevant variables.
- The student did not carry the procedures/strategies far enough to reach a solution.
- The response/solution is generally correct; however, there is no information showing how the student arrived at this response/solution.

1 - An incomplete and/or incorrect response/solution is provided evidencing an attempt to solve the problem. In addition, one or more of the following are apparent:
- The student did consider a constraint or variable of the problem situation.
- The student understands some concepts relevant to the problem task.
- The student selected a totally inappropriate procedure/strategy.

0 - Response is characterized by the following:
- It is blank.
- The student response only repeats information in the problem task.
- An incorrect solution/response is given and no other information is shown.
- The solution/response and supportive information is totally irrelevant to the problem task.

APPENDIX I: THE MODEL FOR THE 2nd MATH PROBLEM



Model Fit Summary:

CMIN = 121.056

DF= 48

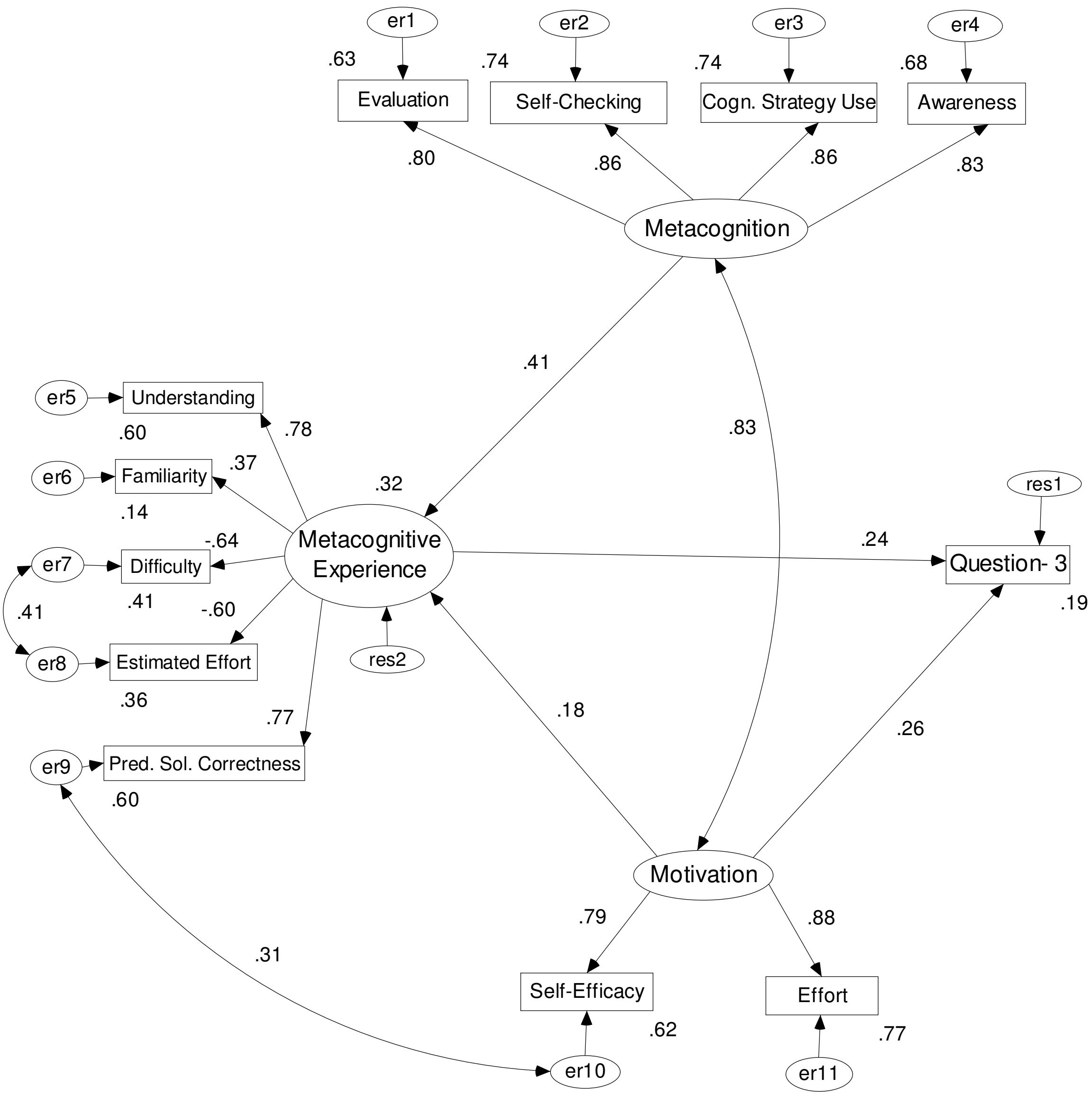
CMIN / DF = 2.522

GFI = 0.953

AGFI = 0.924

CFI = 0.972

APPENDIX J: THE MODEL FOR THE 3rd MATH PROBLEM



Model Fit Summary:

CMIN = 103.003

DF= 48

CMIN / DF = 2.146

GFI = 0.960

AGFI = 0.935

CFI = 0.978

APPENDIX K: STANDARDIZED DIRECT, INDIRECT AND TOTAL EFFECTS

Standardized Direct Effects

	Metacognitive Regulation	Motivational Regulation	Metacognitive Experiences
Metacognitive Experiences	.329	.331	.000
Self-checking	.857	.000	.000
Problem Solving Performance	.000	.280	.267
Feeling of Understanding	.000	.000	.805
Feeling of Familiarity	.000	.000	.429
Feeling of Difficulty	.000	.000	-.644
Estimated Effort	.000	.000	-.583
Predicted Solution Correctness	.000	.000	.768
Use of Cognitive Strategies	.865	.000	.000
Evaluation	.797	.000	.000
Awareness	.827	.000	.000
Self-efficacy	.000	.788	.000
Effort	.000	.879	.000

Standardized Indirect Effects

	Metacognitive Regulation	Motivational Regulation	Metacognitive Experiences
Metacognitive Experiences	.000	.000	.000
Self-checking	.000	.000	.000
Problem Solving Performance	.088	.088	.000
Feeling of Understanding	.265	.267	.000
Feeling of Familiarity	.141	.142	.000
Feeling of Difficulty	-.212	-.213	.000
Estimated Effort	-.192	-.193	.000
Predicted Solution Correctness	.253	.254	.000
Use of Cognitive Strategies	.000	.000	.000
Evaluation	.000	.000	.000
Awareness	.000	.000	.000
Self-efficacy	.000	.000	.000
Effort	.000	.000	.000

Standardized Total Effects

	Metacognitive Regulation	Motivational Regulation	Metacognitive Experiences
Metacognitive Experiences	.329	.331	.000
Self-checking	.857	.000	.000
Problem Solving Performance	.088	.369	.267
Feeling of Understanding	.265	.267	.805
Feeling of Familiarity	.141	.142	.429
Feeling of Difficulty	-.212	-.213	-.644
Estimated Effort	-.192	-.193	-.583
Predicted Solution Correctness	.253	.254	.768
Use of Cognitive Strategies	.865	.000	.000
Evaluation	.797	.000	.000
Awareness	.827	.000	.000
Self-efficacy	.000	.788	.000
Effort	.000	.879	.000

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