THE ROLE OF COGNITIVE INHIBITION AND METACOGNITION ON THE MATHEMATICS PERFORMANCE OF MIDDLE SCHOOL STUDENTS

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THE ROLE OF COGNITIVE INHIBITION AND METACOGNITION ON THE MATHEMATICS PERFORMANCE OF MIDDLE SCHOOL STUDENTS

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DECLARATION OF ORIGINALITY

I, Fatma Acar, certify that

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ABSTRACT

The Role of Cognitive Inhibition and Metacognition

on the Mathematics Performance of Middle School Students

Considering the contribution of both inhibition as an executive function and metacognition as a meta-level construct to mathematics performance, the relationship between inhibition and metacognition was investigated in this study. The aim was to investigate to understand whether metacognition or inhibition was more predictive when considering mathematics performance. The study was conducted with two-hundred and thirty-four middle school students in grades 7 and 8. For mathematics performance, a test of mathematics problems chosen as suitable for leading students to answer intuitively and Mathematics achievement scores in report cards were used. Measuring metacognition was executed through a Likert-type metacognitive skill inventory. As another metacognitive measure, calibration scores as prediction and evaluation judgement of the students before and after the problem test were also computed. Inhibition was measured with a numerical Stroop-like test on computer. Findings showed that there was not a significant relationship between metacognition and cognitive inhibition. While observing the significant relationship between metacognition and both mathematics performance measures, inhibition was only associated with mathematics achievement scores with a low coefficient. Regression analysis indicated that metacognition had a greater role on mathematics performance than inhibition. The results emphasized the major role of metacognition as an analytic thinking structure in mathematics performance.

ÖZET

Ortaokul Öğrencilerinin Matematik Performansında

Bilişsel İnhibisyon ve Üst-Bilişin Rolü

Bu çalışmada, üst biliş ve zihindeki yürütücü işlevlerden biri olan inhibisyonun matematik performansı üzerindeki katkısı düşünülerek, üst biliş ve bilişsel inhibisyon arasındaki ilişki incelenmiştir. Ayrıca, hangi bilişsel yapının (üst biliş, inhibisyon) matematik performansını daha çok yordadığı araştırılmıştır. Çalışma yedinci ve sekizinci sınıf öğrencilerinden oluşan iki yüz otuz dört kişi ile yürütülmüştür. Öğrencilerin matematik performanslarını belirlemek için öğrenciyi sezgisel cevap vermeye yönlendiren problemlerden oluşan bir problem testi ve karnedeki matematik başarı notları kullanılmıştır. Öğrencilerin üst bilişini ölçmek için Likert tipi bir üst biliş envanteri uygulanmıştır. Diğer bir üst biliş göstergesi olan kalibrasyon da öğrencilerin problem testindeki performansına dayanan tahmin ve değerlendirmelerinden yola çıkılarak ölçülmüştür. İnhibisyon ise bilgisayar ortamında uygulanan Stroop tipi sayısal bir test ile ölçülmüştür. Sonuçlar, üst biliş ile inhibisyon arasında anlamlı bir ilişki olmadığını göstermiştir. Üst biliş ile her iki matematik performans göstergesi arasında anlamlı bir ilişki gözlemlenmiştir. Ancak, inhibisyonun problem çözme performansı yerine sadece matematik başarı notlarıyla düşük katsayılı bir anlamlı ilişki içinde olduğu görülmüştür. Regresyon analizi üst bilişin inhibisyona göre matematik performansında daha büyük bir rolü olduğunu göstermiştir. Sonuçlar, analitik bir süreç olan üst bilişin matematik performansı üzerindeki başlıca rolünü vurgulamıştır.

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Dedicated to my lovely parents, Fevzi and Şifa Acar

and to my awesome brothers, Abdussamed and Ebubekir Acar

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CHAPTER 1

INTRODUCTION

Doing mathematics comprises essential mental processes such as cognitive and metacognitive processes, working memory and other executive functions. Mental activities during learning mathematics like problem solving and reasoning are important domains studied to investigate cognitive processes functioning both consciously and unconsciously during mathematical tasks. Both useful, contributing mental processes and interfering mental practices during various mathematical performance have been discovered. These processes are not always clearly observable through the output from the mathematical activity. To investigate the hidden thinking practices in performing mathematical tasks, a variety of questions emerge such as what kind of reasoning students use, which thinking processes are integrated, which associations are used, why particular mistakes are made or why particular solutions are chosen. Literature in both mathematics education and psychology presents different studies about cognitive processes including metacognition and executive functions to clarify these mental processes in learning mathematics.

Dual process theories developed separately in different fields of study such as learning, reasoning, memory, social cognition, and decision making describe the human mind in two different processes such as fast/automatic and slow/analytic processes (Evans, 1989; Kahneman & Frederick, 2002; Sloman, 1996). Automatic processes in these theories are described mostly as fast, heuristic, intuitive, and effortless processes while analytic processes are characterized mostly as effortful, slow and controlled processes (Kahneman & Frederick, 2002). It is stated that heuristics processes are used more than analytic processes in argumentation because they are fast and effortless compared to the analytic ones (Evans, 2008; Sloman, 1996).

Mathematics educators make use of the studies in cognitive psychology about intuitions, heuristic biases, automatic thinking processes in reasoning and problem-solving tasks (e.g., Attridge, & Inglis, 2015; Christou, 2015; Gilmore, Keeble, Richardson, & Cragg, 2015; Gomez, Jimenez, Bobadilla, Reyes, & Dartnell, 2015; Thomas, 2015). There are studies that focus on students' mistakes and misconceptions resulting from the intuitive processes (e.g., Babai, Shalev, & Stavy, 2015; Lem, 2015; Thomas, 2015). According to cognitive psychologists, errors and misconceptions appear as undesirable yet inevitable attributes of human mind (Evans, 2008; Stanovich & West, 2000). Mathematics educators view students' mistakes which reveal a student's state of mind as "normal and acceptable" (p. 268) in the learning process (Leron & Hazzan, 2009). However, some frequently encountered errors are explained by students' intuitions developed through the associations that they created with previously learned contexts and existing cognitive schemata (Christou, 2015; Fischbein, 1999; Vamvakoussi, Van Dooren, & Verschaffel, 2012).

There are various examples of errors resulting from the intuitive responses in mathematical problem solving or reasoning processes. For example; the belief that multiplication and addition always result in bigger quantities and subtraction and division result in always smaller quantities (Bell, Fischbein, & Greer, 1984; Vamvakoussi et al., 2012) are examples of erroneous representations occurring through intuitions. Similarly, expressions like "more than" and "less than" cause intuitive associations with addition (more) and subtraction (less) operations in verbal arithmetic problems (De Corte, Verschaffel, & Pauwels, 1990; Vinner, 1997). Students usually prefer to add the numbers when they observe the word “more” in an arithmetic word problem or automatically carry out a subtraction when they notice the word “less” even though they are not correct solutions of the problems. In a problem requiring students to compare the perimeters of two polygons, the area component in the problem rather than the perimeter can interfere with the logical answer as a visually salient variable of the problem. In another example, the areas of polygons represented as salient in a word problem can interfere with logical answer of students when they are required to compare the perimeters (Babai et al., 2015). In other words, students compare the perimeters of polygons according to their visible magnitude of area. This kind of reasoning causes them to make mistakes in problems as they assume that larger area means larger perimeter. Such common examples of students’ erroneous reasoning and problem-solving processes led mathematics educators to investigate the mental processes underlying these mistakes and find ways for improving student’s performance on mathematical tasks.

Studies on students’ incorrect responses resulting from intuitions and automatic thinking processes focus on cognitive inhibition phenomena referring to the ability of suppressing automatic and quick interference resulting from task-irrelevant variables (Clayton, & Gilmore, 2015). These studies assert that cognitive inhibition is associated with mathematics scores (Bull & Scerif, 2001; Gilmore, Attridge, Clayton, Cragg, Johnson, Marlow, Simms, & Inglis, 2013). The performance on a Stroop Task which is used for measuring inhibitory control is generally found to be associated with performance on various mathematical tasks such as fraction comparisons (Gomez et al., 2015) and arithmetic operations

(Gilmore et al., 2015) featuring the interference of intuitive/automatic thinking processes.

Along with the studies on the role of cognitive inhibition in mathematical tasks, there are studies examining the role of metacognition in shifting from automatic to analytic thinking processes in reasoning tasks including mathematical problems (e.g., Thompson, Prowse, Turner, & Pennycook, 2011). Metacognition was defined by Flavell (1979) as the awareness and regulation of cognitive processes. There are various categories of metacognition such as metacognitive knowledge which refers to the awareness of the individual about self, the task and the strategy (Efklides, 2009); metacognitive skills which involve the actions for regulation of cognition such as planning, control and monitoring (Veenman & Elshout, 1999); and metacognitive experiences which are defined as the judgements and feelings resulted by the monitoring of a cognitive process (Efklides, 2006). Thompson and his colleagues (2011) found that metacognitive experiences mediate the transition from automatic (quick) to analytic (effortful) thought processes. The role of metacognitive experiences appears as important in the domain of psychology by referring to the conflict between two separate thinking processes (automatic and analytic) in this study. Metacognition is already a significant phenomenon studied broadly in mathematics education literature and presented as a critical variable in mathematics performance (Desoete & Veenman, 2006; Jacobse & Harskamp, 2012).

The erroneous thinking processes originating from intuitions in various mathematical tasks seem to require the control processes such as inhibitory control and metacognitive control according to the studies on automatic and analytic thinking. In order to understand the associations, the students make during their thinking processes, which cause them to make mistakes, or the processes, which give them the ability of resisting the interfering irrelevant answers, it is important to discover the significant cognitive variables affecting their mathematics performance. In this context, cognitive inhibition as an executive function and metacognition as a slow thinking process can be considered as independent variables which have significant roles on mathematics performance.

The differential role of these two processes, cognitive inhibition and metacognition, in their action in significant reasoning and problem-solving tasks in mathematics was the starting point of this study. Their roles in mathematical tasks lead to the examination of relationship between the two. The current study aimed to search for a relationship between inhibition and metacognition of middle school students regarding their mathematics performance. The associations of inhibition and metacognition as two cognitive processes, with the students' mathematics performance was investigated. Examining whether a relationship between students' inhibitory skills and metacognitive skills exists was one of the aims of the study. Furthermore, the predicting roles of inhibition and metacognition on mathematics performance was investigated.

CHAPTER 2

LITERATURE REVIEW

Starting point of this study was dual process theories indicating there are two different thinking processes as automatic, fast and analytic, slow. In mathematics education literature automatic processes were represented by intuitive thinking which reflects the common erroneous reasoning of students in learning mathematics or problem solving situations. Students' common errors, automatic thinking processes, fast and slow thinking processes, control function in cognition and metacognition aspects emerged as important framework in this study in order to understand the relationships in mathematics performance. All these concepts in the cognitive system serve for the understanding of the hidden affairs in students' mathematics performance. Literature review is presented by starting from dual process theories and continuing with other important cognitive processes to understand the path leading to the aim of this study.

2.1 Dual process theories

In the beginning of the 1900s, experimental psychology focused on the study of behavior which is asserted as an observable indicator of learning (Miller, 2003). The experiments about unconscious, automatic and associative processes of human mind which link physical stimulus with response emerged as studies of theorists such as Wundt, Watson, Pavlov, and Skinner (Frankish & Evans, 2009). Through the cognitive revolution, cognitive psychologist such as Reber, Piaget, and Vygotsky studied the cognitive processes such as reasoning, problem solving, learning, and memory (Miller, 2003). For example, Reber's study on implicit learning was an important contribution to the idea of “cognitive unconscious” that is expressing some cognitive processes occurring independently of conscious manner (Frankish & Evans, 2009). Reber (1993) asserted that implicit learning occurs automatically without intention and conscious awareness.

After 1950s, there appeared a focus on human capacity limits of information processing (Hammar, 2012; Schneider and Shiffrin, 1977), bringing about a theory that divided information processing into two parts which were controlled and automatic processing. They asserted that automatic processing proceeds automatically without requiring attention and control as being learned sequences of items in long term memory whereas control processing is a “temporary activation” (p. 50) of elements in sequence that are not experienced before, and it requires attention and short-term capacity (Schneider & Shiffrin, 1977).

The studies of Wason and Evans in 1970s on reasoning showed that logical processes are competing with non-logical biases on different reasoning tasks (Frankish & Evans, 2009). Through this study, Wason and Evans (1975) were the first to use the terms type1 and type 2 processes for unconscious and conscious processes respectively. A decade later, Evans developed a new theory upon heuristic biases and reasoning errors named as heuristic-analytic theory of reasoning (Frankish & Evans, 2009). In this theory, it is assumed that reasoning advances in two processes: one is representational heuristics and the other is logical analysis (Evans, 1989). Evans (1989) asserted that representational heuristics comes before the logical analysis and directs it for acting on determined sides in the problem. In this theory, analytic process refers to logical responses on reasoning tasks rather than rationalization of unconscious bias effect (Frankish, 2010).

Dual process theories, influenced by the experimental studies in psychology, proceeded with the studies of social psychologists in attitudes, perceptions, social behaviors, and stereotyping (Frankish & Evans, 2009; Evans, 2008). Although they have roots in the automaticity and implicit memory studies in cognitive psychology, there is not much connection with the dual process theories of reasoning and decision making (Evans, 2008). For example, there is the heuristic-systematic model of Chaiken about people's processing of persuasive messages (Chen & Chaiken, 1999), and Bargh (2006) has studies on automaticity and unconscious processes on social behavior. Chaiken (1980) stated that people exert a high cognitive effort to understand and evaluate the message through argumentation in systematic processing whereas they use minimal cognitive effort to judge the validity of the message and trust more on accessible information in heuristic processes.

There is another dual process theory by Epstein (1994) in decision making named as Cognitive-Experiential Self theory (CEST). The theory posits that information processing works by "two parallel, interactive systems: a rational system and an experiential system" (Epstein, Pacini, Denes-Raj, & Heier, 1996, p. 391). Experiential system is regarded as fast, automatic, intuitive, evolutionary old and based on experiences whereas rational system is regarded as slow, logical and deliberate mode which is evolutionarily new (Pacini & Epstein, 1999). In those years, Sloman (1996) presented two systems of reasoning by interpreting the dual nature of human mind over the studies from William James to Evans. He classified two systems as associative and rule-based. By associative system, Sloman (1996) referred to the cognitive processes of reasoning "based on similarity and contiguity" (p.4) while the rule-based system corresponds to processes acting with symbolic structures and logical rules. He argued that both processes work simultaneously, and they work as joint until a conflict occurs. After the conflicting responses from both processes, rule-based system is competing the outcomes of associative system by overruling its response, but associative system is always advantageous because of its speed and efficiency (Sloman, 1996). This framework of Sloman in dual process theories is called parallel-competitive.

The distinction of human reasoning as two systems has continued with the studies of Stanovich on rationality, intelligence, individual differences, and reasoning (Stanovich, 1999; Stanovich & West, 2000). Stanovich called those systems initially as system 1 and system 2 (Frankish & Evans, 2009). System 1 refers to interactional intelligence which is unconscious, automatic process governed by relevance principle and useful for a rapid perception of others' intentions during interaction; System 2 refers to analytic intelligence which is conscious and controlled and requiring cognitive resources (Stanovich & West, 2000). Stanovich and West (2000) argued that system 1 and system 2 mostly act together through the overlapping goals but sometimes system 2 needs to interfere system 1 processing to behave in rational norms. Stanovich explained that the distinctions in thinking styles results from processes inside system 2 rather than the divergent processes of System 1 and 2 (Frankish, 2010). So, there is a new distinction which Stanovich made as tripartite model of mind (Stanovich, 2011). He called type 1 processing as autonomous mind and divided the type 2 processes into two as reflective mind and algorithmic mind.

Kahneman and Frederick (2002) used the labels, system1 and system 2 like Stanovich and West (2000) for the two modes of cognitive processes in decision making and judgment. The roots of their theory go back to the studies of Tversky and Kahneman over intuitive inferences in 1980s. Tversky and Kahneman (1983) demonstrated the conflict among intuitive inferences/heuristics and logical rules in probability judgements in which the subjects make judgements on uncertain events/situations through statistical and probabilistic rules or heuristic inferences. Kahneman and Frederick (2002) signified the characteristics of system 1 as more primitive than system 2, quick, effortless, intuitive, automatic, and associative while System 2 was defined as controlled, effortful, deductive, and slower. They put forward that system 1 submits a quick response to problems beforehand the system 2 then system 2 monitors its answer and tries to override it in the case of conflict (Kahneman & Frederick, 2005).

Dual process theories which define two different processing of human mind, have developed separately in different fields of study such as learning, reasoning, memory, social cognition, and decision making as mentioned above. Concisely, dual process theories or dual system theories claim that there are two different thought processes in human mind. These are type 1 (system 1) and type 2 (system 2) while in some theories, a third one having control function is mentioned separately (e.g., Evans, 2009). There is a variety of characteristics attributed to type 1 and type 2 processes by each dual process framework as mentioned above. In summary, heuristic processes were defined mostly as "automatic, parallel, fast, and undemanding of executive working There is another theoretical framework in mathematics education which differentiates two types of mathematical thinking. Vinner (1997) asserted that there are two types of mathematical processes: one is meaningful and analytical thinking and the other is meaningless, pseudo processes. He classifies pseudo processes as pseudo-conceptual which is occurring in learning situation and pseudo analytic processes which is involved in problem-solving situations. He also explained how pseudo-processes occur and are preferred by the students in his theory. In teaching mathematics, when a domain is presented to the students, there are some exercises following and related with this subject so that the students can internalize and use that information. In this teaching and learning process pseudo-analytical mode of thinking and behavior is developed by the students whose goal is to give the right answers to mathematical problems. For example, in learning the rule of calculating the area of a parallelogram the students may internalize and memorize the knowledge, “two numbers given in the problem will be multiplied” through the repeated problems related with calculation of a parallelogram’s area. Vinner (1997) asserted that this is preferred because the students wish just to give correct answer to the question with the simpler and faster solution.

In pseudo-analytical processes the students focus on the salient irrelevant elements of the problem and solve it by the procedures they use in similar problems. (Gillard et al., 2009a). While solving mathematical problems, some verbal cues that are sometimes useful work as stimuli for some arithmetic operations which may cause the students to get wrong decisions (Vinner, 1997). For example, the word *more* leads the students to do addition operation whereas the word *less* leads them to do subtraction. Vinner (1997) pointed that pseudo processes are “simpler, easier and shorter than true conceptual processes” (p.101) and it is why students mostly prefer them. The work of memory capacity” and analytic processes were defined mostly as “sequential, time-consuming, deliberate, and effortful (Gillard, Schaeken, Van Dooren, & Verschaffel, 2011). It was claimed that people tend to make arguments relying on more heuristic processes rather than analytic ones because of its characteristics of being fast and effortless (Evans, 2008; Sloman, 1996). This differentiation between two cognitive processes of human mind in reasoning, argumentation, and decision-making raises questions in different fields. For example, in the field of mathematics education there is a considerable concern about these theories because of the interest in cognitive processes in mathematical problem solving and learning mathematics overlapping with the ones in experimental studies in psychology about decision making and reasoning.

2.2 Dual thinking processes in mathematics education

Studies differentiating the thinking processes as intuitive thinking/heuristic biases vs. analytical thinking in mathematical problem solving (Fischbein, 1999; Vinner, 1997) show similarities with dual process theories in psychology which state that there are two different thinking processes in reasoning and decision making called Type1 and Type2 (Frankish & Evans, 2009). The relevance of dual process theories and intuitions with mathematics education has been expressed firstly by Leron and Hazzan (2006). They linked the intuitions in mathematics with Type 1 processes; analytic thinking and metacognitive processes with Type 2 (Leron & Hazzan, 2006). However, the roots of the studies about intuitive thinking processes and dual process theories in mathematics education literature are based on Fischbein’s studies about intuition.

The role of intuitive thinking in mathematics education has been studied firstly by Fischbein in 1980s. Fischbein (1982/1999) focused on intuitive thinking and the role and development of intuitive beliefs in mathematics and science education. He interpreted the errors and misconceptions of the students in mathematics and science problems which are resulted from intuitive tendencies and decisions rather than the deficiencies in logical processes (Fischbein, 1999; Stavy & Tirosh, 2000). Intuitive cognition appears as self-evident and direct which means the person has a feeling of not having need for control of his/her answer (Fischbein, 1999). However, accuracy of the answer may be questionable. Fischbein (1987) determined the characteristics of intuitions such as certainty, self-evidence, immediacy, perseverance, coerciveness, and implicitness. He also identified intuitions as implicitly occurring during daily experiences (primary intuitions) and as occurring through instruction (secondary intuitions). For example, children or even adults may have intuitions like *"multiplication always make bigger and division makes smaller"* because of their former experiences with natural numbers (Fischbein, 1999).

Stavy and Tirosh, (2000) continued with the study of intuitive beliefs. They developed the Intuitive Rules Theory which explained students' errors and misconceptions through intuitive reasoning as immediate processes in mathematics and science problem solving They separated intuitive thoughts into groups such as *the more A-the more B* rule, *the same A- the same B* rule and *everything can be divided* rule. For instance, according to the rule, the more A-the more B, students are inclined to think that the larger area of a parallelogram means the longer perimeter it has (Gillard, Van Dooren, Schaeken, & Verschaffel, 2009a). Although these intuitive decisions can lead the students to answer correctly it may also cause them to have an erroneous conclusion (Babai, Shalev, & Stavy, 2015). According to intuitive rules theory, specific external task features such as a salient characteristic of the task which is not yet relevant to the task's specific content determine the students' responses (Stavy &Tirosh, 2000; Babai, Levyadun, Stavy, & Tirosh, 2006). For example, when the students are asked to compare the probabilities of selecting a black ball from two boxes containing both white and black box, they make more mistakes for the boxes which numerically consist of more black ball by focusing on salient numerical property rather than thinking over proportionality (Babai et al., 2006).

There is another theoretical framework in mathematics education which differentiates two types of mathematical thinking. Vinner (1997) asserted that there are two types of mathematical processes: one is meaningful and analytical thinking and the other is meaningless, pseudo processes. He classifies pseudo processes as pseudo-conceptual which is occurring in learning situation and pseudo analytic processes which is involved in problem-solving situations. He also explained how pseudo-processes occur and are preferred by the students in his theory. In teaching mathematics, when a domain is presented to the students, there are some exercises following and related with this subject so that the students can internalize and use that information. In this teaching and learning process pseudo-analytical mode of thinking and behavior is developed by the students whose goal is to give the right answers to mathematical problems. For example, in learning the rule of calculating the area of a parallelogram the students may internalize and memorize the knowledge, "two numbers given in the problem will be multiplied" through the repeated problems related with calculation of a parallelogram's area. Vinner (1997) asserted that this is preferred because the students wish just to give correct answer to the question with the simpler and faster solution.

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Currently, there is an increasing number of studies simultaneously working on the dual process theories and mathematical problem solving and reasoning. The studies and theories about intuitive thinking in mathematics raise the issue of most common intuitive errors of the students in mathematics. For example, there are studies about the most frequent failures of students as a result of intuitive (type 1) processes and heuristic biases in mathematical contents such as natural number bias in comparing rational numbers (Christou, 2015; Van Hoof, Janssen, Verschaffel, & Van Dooren, 2015), poor probabilistic thinking performance (Obersteiner, Bernhard, & Reiss, 2015), proportional reasoning (Gillard, Van Dooren, Schaeken, & Verschaffel, 2009b) and in associating the measure of area with perimeter of polygons (Babai, Shalev, & Stavy, 2015). For example, in studies about natural numbers bias, it was stated that the knowledge of whole numbers which is learned beforehand in the early school years can interfere with the operations with rational numbers and can cause erroneous answers (Christou, 2015; Van Hoof et al., 2015). Similarly, in mathematical problems about proportional reasoning, students used non-proportional reasoning due to inaccurate heuristic processing rather than lack of domain-specific knowledge (Gillard et al., 2009b). Due to the characteristics of type 1 processes as being faster than type 2 processes and requiring less working memory capacity, working memory load, and reaction time measurements are used for determining whether the response was the result of intuitive thinking or analytical reasoning (Lem, 2015).

Dual process theories point out that intuitive and analytic processes take a joint act in reasoning tasks (De Neys, & Glumicic, 2008). It was claimed that intuitive thinking as an immediate and effortless process can override analytical thinking. In the cases, where two systems come with different and conflicting responses, the analytic system should interrupt and suppress the intuitive response tendencies (Stanovich & West, 2000; Stanovich, West, & Toplak, 2014). This introduces the inhibitory control phenomenon in analytical thinking process (type 2) which is an executive function (Miyake & Friedman, 2012).

In mathematics education, to encourage type 2 processes was regarded as an important goal because students need type 2 processes to inhibit and override the inappropriate responses arising from type 1 processes in conflict conditions (Attridge & Inglis, 2015). In these conflicting cases, the answer generated automatically through intuitions contradicts with the logical answer generated through analytic processes. Mathematics educators examine inhibitory control, an executive function, in those processes in which the analytical thinking compete and override the intuitive answer by using slower and effortful process (e.g., Attridge & Inglis, 2015; Van Hoof et al., 2015, Lubin, Simon, Houde, & De Neys, 2015). Further, Vinner (1997) emphasized the absence of control procedure in pseudo-analytical behaviors in which the student chooses the associated solution path in his/her “mathematical problem repertoire” (p. 110). In pseudo-analytical process there is no intention to investigate automatic associations or checking the rightness of the response of the problem (Vinner, 1997). This also highlights the “control” notion in such cognitive processes containing automatic or intuitive thought. The studies about automatic thinking, pseudo-analytical behaviors or heuristic biases in mathematics education literature raise the issues of both control processes and inhibition concept in mathematics performance.

2.3 Inhibition

Inhibition, a broad construct expressed in various behavioral and cognitive aspects, (Dempster, 1993) was explained through two separate units as behavioral inhibition and cognitive inhibition (Harnishfeger, 1995). Behavioral inhibition refers to control processes of behavior like control of explicit pleasure and impulses and inhibition of motor-behavior (Luria, 1961). However, cognitive inhibition refers to the control of cognitive processes like deleting irrelevant inferences and other information from working memory during memory retrieval (Harnishfeger & Bjorklund, 1993). Harnishfeger (1995) explained inhibition as a cognitive act as a suppression of prior cognitive processes. In addition, Macleod (2007) defined cognitive inhibition as "stopping or overriding of a mental process, in whole or in part with or without intention" (p. 5) and he preferred to use the term "cognitive inhibition" for separating it from "neural inhibition".

In some psychological theories, inhibition was expressed together with the concept of interference (i.e., Interference Theory, Dempster, 1992). In these studies, interference implies the negative effect of irrelevant information on performance (Dempster & Corkill, 1999). Resisting to interference of the irrelevant information on behavior refers to inhibition mechanism. Dempster and Corkill (1999) indicated that the terms inhibition and interference are "closely related empirically and theoretically" (p.4). Besides, Harnishfeger (1995) stated that resisting to interference and inhibition are not the same construct, but they are used as substitute terms with each other in literature. For example, the Stroop Task (Stroop, 1935) which is a kind of interference test is used for measuring inhibitory control of subjects and it is also called Stroop interference or Stroop effect (MacLeod, Dodd, Sheard, Wilson, & Bibi, 2003; Stroop, 1935).

In a part of the Stroop test, the subjects are asked to name the color of written words as soon as possible in two different conditions; one is the color of the word is congruent with what the word says, and the other condition is the color of the word is incongruent with what is written. For example, “yellow” is written in blue font color (incongruent) or in yellow font color (congruent). Reading the word itself is a dominant, automatic, and faster response condition than saying the color of the word (Macleod, 2015). Because of its automaticity, reading the word itself interferes with naming the color and it causes slower performance in incongruent conditions (Cohen, Dunbar, & McClelland, 1990). In this condition, to be able to suppress the tendency of giving the automatic response (i.e uttering the color of the written word) implies inhibitory control in this task (Miyake, Friedman, Emerson, Witzki, Howerter, & Wager, 2000). In short, during a cognitive task, focusing on relevant information while restraining self-driven and intense interference of irrelevant ones implies inhibition process (Clayton & Gilmore, 2015).

Inhibition process is explained in general as being incorporated into central executive of working memory. Various models of working memory have influenced the interpretation of the construct of central executive. One is the working memory model of Baddeley and Hitch (1974) proposing that central executive is one of three components of working memory and its task is controlling and regulation of cognition (Miyake et al., 2000). Central executive is linked to the frontal lobes anatomically (Baddeley, 1996) and functionally it is responsible for attentional control of working memory (Baddeley & Della Sala, 1996). Another model which is influential for explaining executive functions (i.e central executive) is supervisory attentional system (SAS) proposed by Norman and Shallice in 1980 (as cited in Bull, Johnson, & Roy, 1999). SAS has various functions controlled by central executive sub-serving for the regulation of action (Baddeley, 1986). As a function under the central executive, inhibitory mechanism is serving for implementing goal-directed behavior by preventing the dominant goal-irrelevant inclinations (Diamond, 1989). Logan and Cowan (1984) called inhibition of thought and actions as an act of control in executive functions which is meaningful in both motor control and cognitive control. Because of its control function, inhibition mechanism is also called inhibitory control in the related literature. Dempster (1992) stated that inhibitory control is an executive function mechanism suppressing the automatized and unwanted responses to get an expected result in a task.

Miyake and his colleagues (2000) incorporated inhibition mechanism with shifting and updating as three major executive functions. Through factor analysis, they separate executive functions into three as “shifting between mental sets or tasks, updating and monitoring of working memory contents and inhibition of prepotent responses” (p. 86). They identified inhibition as suppressing automatically generated dominant responses when they are goal-irrelevant. To measure inhibition skill, they asserted stop-signal task (Logan, 1994) and Stroop task (Stroop, 1935). In Stroop task, the subjects try to inhibit or suppress the response which is more automatic and dominant as quickly as possible (Miyake et al., 2000). Similarly, in stop-signal task the subjects respond as quickly as possible in case of “go task” while they need to inhibit the response in case of randomly appearing stop-signal (Logan, Van Zandt, Verbruggen, & Wagenmakers, 2014). In both tasks, the reaction time is regarded for measuring inhibitory control of subjects (Dempster, 1992; Logan & Cowan, 1984).

Hasher, Zacks, and May (1999) assumed inhibitory mechanism acts together with excitatory mechanism within attentional control processes which direct the individual to behave or respond in parallel with his/her goals. Accordingly, first activation occurs automatically with the links between the stimuli in the environment and the representations in memory. After this first activation, excitatory mechanism helps the individual to follow goal-relevant information while inhibitory mechanism provides him/her to prevent activation of goal-irrelevant information (Hasher et al., 1999). Hasher and his colleagues (1999) separated inhibition mechanism into three functions as “access, deletion and restraint” (p. 654). It was explained that inhibitory mechanism controls which information will be activated in working memory as being goal-relevant and which will be deleted or suppressed as being goal-irrelevant by use of the functions, access and deletion. Inhibitory mechanism also gives a chance for less probable responses in a task by stopping the high probable goal-irrelevant responses by restraint function.

Some cognitive developmental theories used inhibition mechanism to explain the individual differences in cognitive tasks regarding the ages. For example, Bjorklund and Harnishfeger (1990) proposed the theory of inefficient inhibition claiming that younger children are less able to suppress task-irrelevant information during cognitive processing in comparison with the older ones. It was explained that younger children have inefficient inhibitory mechanism because their working memory is more occupied with irrelevant information, so it does not have enough space for processing of relevant issues (Harnishfeger & Bjorklund, 1993). The model of Hasher and Zacks (1988) emphasized the inhibition mechanism in aging by explaining it as repression of irrelevant information during cognitive processes as well. Their claim was that inhibitory efficiency in elderly people is not good as much as younger ones during retrieval from working memory. In both approaches, they used memory experiments to measure the inhibitory mechanism of individuals by observing their intrusion errors.

There are other developmental models examining individual differences on cognitive task with respect to aging by measuring inhibitory efficiency (i.e., resistance to interference and Fuzzy Trace Theory). Brainerd and Reyna (1993) proposed Fuzzy-Trace Theory in which the term "interference" is emphasized. Interference was explained as a "central processing by-product that disrupts efficient processing" (p.180) in this model (Harnishfeger, 1995). In this theory, inhibitory mechanism assessed by the construct "interference sensitivity" which is claimed as a developmental change decreased by age and developed the cognitive performance (Harnishfeger, 1995). Similarly, Dempster (1993) proposed the term "resistance to interference" for explaining developmental changes in cognitive tasks as well. He incorporated the term interference into inhibitory processes. Regarding interference in these models, various tasks were used to measure inhibition mechanism by use of shifting attention and competition among stimuli and responses such as the Wisconsin Card Sorting Test and selective attention tasks (Harnishfeger, 1995).

Executive processes such as organization of action, inhibition of behavior, suppressing the interference and control of response have an important role on various cognitive tasks (Bull et al., 1999; Bull & Scerif, 2001; St Clair-Thompson, & Gathercole, 2006). Inhibition was found to be related with general academic attainment involving the domains like language, mathematics and science (St Clair-Thompson, & Gathercole, 2006). Research about reading comprehension put forward that inefficient inhibitory mechanism is related with failure in comprehension because the individuals with weak inhibitory skills are not good at restraining irrelevant meanings of words in a text (Borella, Carretti, & Pelegrina, 2010; Cain, 2006; Gernsbacher & Faust, 1991).

There is an increasing attention on the links between inhibition and mathematics performance. Inhibition is generally examined as an executive function with other two functions shifting and updating in the research investigating the effect in academic achievement or mathematics performance (e.g., Bull & Scerif, 2001; St Clair-Thompson et al., 2006). Bull and Lee (2014) proposed that inhibition may have an important role in case of need to restrain any strategy or irrelevant information in mathematical tasks such as interfering whole number representations when studying on fractions and incorrect strategies deduced from the irrelevant information in a word problem (i.e. using subtraction while the correct strategy is doing addition). Bull and Scerif (2001) found a significant relationship between inhibitory control measured by Stroop task and mathematics scores of third grade students. Further, Gilmore and colleagues (2015) demonstrated the relationship between mathematics achievement and inhibitory skills by use of the numerical part of Stroop task and procedural skills of children in arithmetic rather than conceptual understanding. Inhibition was emphasized as activating analytical thinking processes and preventing giving incorrect responses when intuition conflicts with mathematical reasoning in mathematical tasks (Attridge & Inglis, 2015). So, the inhibition process, the student has during mathematical tasks, increases the likelihood of giving correct answers by overriding the intuitively given incorrect answers (Obersteiner et al., 2015).

Beside the importance of inhibitory process for intuitive errors in mathematics performance there is also an interest in intervention studies which are focusing on how to improve the inhibitory processes and how to prevent intuitive errors in mathematical tasks (e.g., Attridge & Inglis, 2015; Babai et al., 2015). Babai et al. (2015) remarked the possibility of decreasing students' errors resulting from intuitive interferences during problem solving by the "simple, focused, task-specific interventions" (p.742) such as a warning of a teacher about an irrelevant yet salient variable in the problem. For example, stimulating the students for an intuitive erroneous answer and then falsifying it in a learning environment can be used for increasing the students' awareness about their intuitive answers as well (Christou, 2012). This also raises the issue of awareness of the teacher about students' intuitive answers which cause them to make mistakes during problem solving. People's awareness about their own intuitions, and the need of control mechanism for inhibiting the incorrect prepotent responses highlight the issue of metacognition as a construct in meta level.

2.4 Metacognition

Research on metacognition has gathered around the concept of metamemory which was brought up by Flavell (1970) and it refers to one's knowledge about his/her own memory skills and strategies (Brown, 1978). Beside the general knowledge about the memory, memory monitoring in which the individuals assess their memory for the particular items regarding whether they are retrievable or not in that time, brought the term feeling of knowing as a personal state (Wellman, 1977). Feelings about cognitive performance experienced during a learning process or after finishing a cognitive task such as "feeling of knowing", feeling of difficulty", and "feeling of confidence" (p. 77) were explained as metacognitive feelings (Efklides, 2009). Monitoring what one knows, having an accurate feeling of knowing and deciding on the required strategies for an effective study is regarded as metacognitive phenomenon (Butterfield, Nelson, & Peck, 1988). In this way, metacognition was defined as the knowledge of the person about his/her cognitive activities and regulation of these cognitive processes in learning situations by Flavell (1976) and Brown (1978).

Metacognition was divided into two sub-components as “knowledge of cognition” and “regulation of cognition” (Baker & Brown, 1984 p. 353). Knowledge of cognition was explained as the awareness about cognitive activities (Schraw, 2001), and knowledge or sense about the cognitive factors affecting those processes such as “person, task and strategy” (Flavell, 1979, p. 907). Knowledge of cognition consists of three kinds of knowledge which are declarative knowledge, procedural knowledge, and conditional knowledge (Brown, 1987). Knowledge “about” things refers to *declarative knowledge*; awareness of “how” to do things refers to *procedural knowledge*; knowing the answers of the questions “why” and “when” for cognitive activities indicates *conditional knowledge* (Schraw & Moshman, 1995). Regulation of cognition refers to controlling activities of the learning process by the learner (Schraw, 2001). Regulation of cognition consists of several activities such as planning, monitoring, and evaluating of cognitive processes and products (Baker & Brown, 1980). Planning indicates determining the strategies regarding which are the most suitable ones for the particular task and allocating the necessary and effective potentials of individual; monitoring indicates individual’s current awareness of his/her performance during a task; and evaluating indicates assessing the process and the product of learning (Schraw & Moshman, 1995).

Metacognition was also explained in three subcategories as metacognitive knowledge, metacognitive experiences, and metacognitive skills (Efklides, 2009). Metacognitive knowledge was explained as awareness of the individual about the all factors regarding the self, the task, and the strategy. Metacognitive experiences are all indications resulting from monitoring of a cognitive process including metacognitive feelings, judgments (i.e feeling of knowing, feeling of confidence etc.) and current knowledge about task (Efklides, 2006). Metacognitive skills involve the specific actions and abilities for controlling of cognition such as planning, monitoring, controlling and adjustment of task (Veenman & Elshout, 1999). Research showed that individuals may not perform the skills and strategies well although they have metacognitive knowledge about their learning and performance (Schraw, 1994). Metacognitive knowledge itself is helpful for performance while it is not enough by its own to apply the required strategies and to implement the cognitive task successfully (Whitebread, 1999). A cooperation between metacognitive regulation and knowledge is required for implementation successfully of a cognitive task (Brown, 1978).

Pintrich (2002) asserted that learners who know how they learn easily, which strategies they should use in various tasks, and what their weaknesses are, can control and manage their learning process cognitively well. It was asserted that learning processes are facilitated by cognitive monitoring (Paris & Winograd, 1990). Regulation of cognitive processes as a metacognitive activity is a personal factor improving various academic tasks (Narang & Saini, 2013; Schraw, 1998). Metacognitive monitoring and control skills of students were indicated as important predictors of their performance on learning tasks (Schneider & Artelt, 2010), especially on higher order, unfamiliar cognitive ones (Van der Stel & Veenman, 2010; Veenman, Prins, & Elshout, 2002).

Schoenfeld (1987) asserted that students' monitoring of problem solving process and awareness of when and why to use specific strategies provide them to decide correct strategies to use in mathematical tasks. Carr and Jessup (1995) showed that there is a positive relationship between metacognition and the performance on mathematics. Desoete (2008) stated that there are four metacognitive skills studied as being important for mathematics performance which are predicting, planning, monitoring, and evaluating. For example, predicting ability of students as a metacognitive skill provide them to discriminate the difficult tasks from the easier ones in mathematics and manage the process such as focusing more and persisting on the challenging tasks (Desoete, 2008). Narang and Saini (2013) stated that metacognition has an important role on students' getting better results on a variety of academic tasks.

In a mathematics education context, there are numerous studies investigating the role of metacognition in particularly mathematical problem solving. These studies showed that metacognitive level of students have a significant role on their mathematical problem-solving performance (Artzt & Armour-Thomas, 1992; Pennequin, Sorel, & Mainguy, 2010; Swanson, 1990). Swanson (1990) found that the students with high metacognitive skills, regardless of aptitude, rely more on deductive reasoning and evaluation strategies and show higher performance on problem solving. Research indicated that successful learners showed their difference by using metacognitive knowledge which is guiding them to carry out the accurate strategies during problem solving task (Chi, Bassok, Lewis, Reimann & Glaser, 1989). In addition, efficient monitoring helps the students to regulate the solution strategies and to follow current cognitive processes (Nietfeld, Cao, & Osborne 2005).

Kuhn (2000) asserted that development of metacognition in early years sets the ground for higher order thinking processes generating better cognitive performance. In those years, pedagogical interaction contributes to metacognitive development of children (Whitebread & Coltman, 2010). Hence, parent-child interaction gains importance considering development of metacognitive behaviors and learning (Thomas & Anderson, 2013). The studies investigated the relationship of family characteristics such as socio-economic status (SES) and education level with both mathematics achievement (e.g., Hernandez, 2014; Wang, Li, & Li, 2014) and metacognition (e.g., Akyol, Sungur, & Tekkaya, 2010; Pappas, Ginsburg, & Jiang, 2003; Topçu, & Yılmaz-Tüzün, 2009). It is stated that high socio-economic status contributes to mathematics achievement (McConney, & Perry, 2010; Wang et al., 2014) and metacognition (Topçu, &Yılmaz-Tüzün, 2009). These findings emphasize supporting the development and teaching of metacognition in early years with pedagogical interaction (Whitebread & Coltman, 2010). Furthermore, there are other studies investigating metacognitive training in classrooms (i.e., Mevarech, 1999). They demonstrated that the students show better performance on learning mathematics and problem solving when they are instructed by a new method prompting students' metacognition (Mevarech & Fridkin, 2006).

Considering the importance of metacognition in mathematics education, it is necessary to have satisfactory instrument to assess metacognition for teachers and researchers investigating the role of metacognition on students' academic performance (Jacobse & Harskamp, 2012). There have been long lasting discussions about the questionable assessment methods of metacognition to find the most appropriate approach (Schellings & Van Hout-Wolters, 2011). There are various assessment procedures applied in metacognition literature. One way of measuring metacognition is the think-aloud technique (Veenman, 2005). In this technique, the students are asked to verbalize their thoughts with simultaneous observation during a cognitive task such as problem solving (Jacobse & Harskamp, 2012). This method is categorized as an online-measurement reflecting cognitive activities currently during a task. It is criticized as being time-consuming and challenging (Azevedo, Moos, Johnson, & Chauncey, 2010). The other method is using self-report inventories in which the students select most corresponding choice among the judgments in a scale expressing their cognitive processes in general (Tobias & Everson, 1996). This is called an offline method examining the self-evaluation scores of students presenting statements about cognitive activities in general (Azevedo et al., 2010).

Another method used for measuring metacognition is assessing performance judgements (Schraw, 2009). In this method, how accurately the participants can judge their performance before or after a task is evaluated (Jacobse & Harskamp, 2012). The process is called calibration. Nelson (1996) stated that there are prospective and retrospective judgements of performance as key components of metacognitive monitoring. Prospective judgements which are the ones about future performance are stated as "*ease-of-learning judgments (i.e., predictions of how easy learning will be), judgments of learning (i.e., predictions made during or at the end of learning that pertain to subsequent recall), the aforementioned feeling-of-knowing judgments (i.e., predictions of subsequent memory performance on currently unrecallable items)*" (p. 108). Judgement of confidence about how certain the individual feels that the given answer is correct was stated as retrospective judgement which is the judgement after performance. These metacognitive judgments are effective for forming strategic behaviors and they set ground for calibration (Alexander, 2013). Accuracy scores measured after performance on each item in a test or after the overall performance on the test are used to measure of metacognitive regulation (Nietfeld, Cao, & Osborne, 2005). This is also regarded as online measuring method because the participants state their judgements simultaneously with task performance as being just before and after the performance.

Metacognitive constructs and processes were investigated in various research areas such as cognitive psychology, mathematics education and problem solving. Cognitive processes which is intersecting phenomenon for all these research areas bring about the diverse yet interrelated studies. For example, there is some research in cognitive psychology focusing on metacognitive constructs while investigating the thought processes people use during reasoning tasks. Thompson (2009) assumed that feeling of rightness (FOR) as an affective variable can promote the responses coming from type 1 processes by causing the individual to ignore analytic processes. It was found that FOR has a mediating role in the relation between intuitive and analytic reasoning processes (Thompson et al., 2011). In addition, Stanovich (2009) mentioned *reflective mind* as a sub-dimension of type 2 processes which is partly acting as a metacognitive construct. All these can be accepted as indicators of the relation and cooperation of different cognitive phenomenon such as metacognition, inhibition, and intuitive and analytic processes in higher order cognitive tasks like mathematical problem solving.

2.5 The relationship between metacognition and inhibition

It was argued that changing a strategy considering its inappropriateness in the current task is a part of inhibitory control (Best & Miller, 2010; Kuhn & Pease, 2010). Further, strategy selection was claimed as prominent to metacognition (Kuhn & Pease, 2010). It was suggested that there is a close relationship among monitoring and resolving the conflict in inhibitory control processes and control and monitoring processes in metacognition (Fernandez-Duque, Baird, and Posner, 2000; Shimamura, 2000). Fernandez-Duque et al. (2000) asserted that inhibitory control can support planning and maintaining the long-term goals by providing focusing on the objectives and preventing the irrelevant feelings as an emotional control for metacognition. Roebers (2017) suggested an integrated framework for both executive functions and metacognition considering common aspects of monitoring and inhibition which provide the person to follow intentions and suppressing or abandoning the goal-irrelevant steps in ongoing cognitive processes.

Studies examining the relationship between executive functions and metacognition mostly did not analyze the relationship between metacognition and inhibition particularly as an executive function component (e.g., Bekci and Karakas 2006; Perrotin, Belleville & Isingrini 2007; Perrotin, Tournelle & Isingrini 2008). In a study conducted with participants over 60 about aging, metacognition used in solving mathematical word problems was seen supported by executive functions (i.e., updating and shifting) yet not particularly by inhibition (Pennequin et al., 2010). In a study examining the relationship of metacognitive monitoring and control skills with executive functions, a relationship was found between inhibitory skills and metacognitive control in a spelling task yet no relationship was found between inhibition and monitoring for eight years-old children (Roebers, Cimeli, Roethlisberger & Neuenschwander, 2012). Recently, monitoring processes was found related with inhibitory control in 5 and 7 year-olds (Bryce, Whitebread & Szcus, 2015).

CHAPTER 3

STATEMENT OF THE PROBLEM

In the previous chapter, the literature related with the selected area of the current study was presented. In this chapter, the purpose of the study, variables, their operational definitions, research questions and hypothesis are presented.

3.1 The purpose of the study

Students go through various cognitive processes such as comprehending the problem and keeping information in working memory, choosing relevant and important content and strategies and using them in their solutions during problem solving (De Corte, Verschaffel, & Op’t Eynde, 2000). Considering these cognitive processes and intuitive errors of students during mathematical problem solving and reasoning, metacognition and cognitive inhibition can be regarded as important constructs to investigate together with mathematics performance of students. Research shows that both skills contribute to mathematics achievement as mentioned above. In a mathematics education context, the contribution of metacognitive skills to performance in mathematics and the role of inhibition on preventing the students from erroneous answers in mathematical tasks directed to examine these two factors together in the same process. Considering the contribution of both inhibition as an executive function and metacognition at meta-level to mathematics performance and their mutual roles during the conflict situations among automatic and analytic processes it was aimed to investigate the relationship between the two. Besides, it was aimed to examine the predictor role of inhibition and metacognition on the mathematics performance of students.

For the aim of the study, mathematics performance of students was determined through both mathematics achievement scores and the performance in a mathematics problem test. Mathematical problems in this test were chosen as suitable for leading the students to intuitive or pseudo processes like the ones in which the students focus on the salient characteristics and cues of the problem rather than the required contents to solve. Such problems were used since they have a potential for interfering with the correct solution ways through students' possible intuitions. Metacognition was measured through both online (calibration) and offline (self-report inventory) procedures. By this way, it was aimed to engage less questionable measures for determining metacognition.

The specific objective of this study was to examine the relationship between metacognition of middle school students and their inhibitory skills. Further, the association of these cognitive and metacognitive processes with the students' performance on mathematical problem solving and mathematical achievement levels was investigated.

3.2 Variables and operational definitions

There were three main variables, metacognition, inhibition, and mathematics performance in this study. For determining metacognitive levels, both Metacognitive skill inventory as an offline self-rated scale and calibration scales including prediction and evaluation were used. In measuring inhibitory skills, a numerical Stroop task was used. Mathematics performance was determined by both mathematics achievement scores in report card and performance on a problem solving test. The variables were defined as follows:

- Metacognitive Skills: Self-evaluation scores of students regarding metacognitive skills in Metacognitive Skill Inventory (Çetinkaya & Erktin, 2002)
- Calibration (Prediction): The score on prediction scale assessing the consistency among the students' judgement about their performance before solving the problem and the actual performance.
- Calibration (Evaluation): The score on evaluation scale assessing the consistency among the students' judgement about their performance after solving the problem and the actual performance.
- Inhibitory skills: The difference of the scores obtained from baseline condition and incongruent condition of Stroop task.
- Mathematics achievement: The mathematics grades of the students reflected on report cards of previous school year.
- Problem solving performance: The number of correct answer on a problem solving test.

3.3 Research questions and hypothesis

The relationship between students' inhibitory skills and metacognition was questioned. It was hypothesized that there is a relationship between the students' mathematics performance and their metacognition and inhibition. Based upon the aims of the study, the research questions are as follows:

- Is there a significant relationship between inhibition and metacognition of middle school students?
- Is there a significant relationship between inhibition and mathematics performance of middle school students?

- Is there a significant relationship between metacognition and mathematics performance of middle school students?
- Which independent variable, inhibition or metacognition, is a better predictor for the mathematics performance of students?

CHAPTER 4

METHODOLOGY

In the previous chapter, the statement of the problem, variables, operational definitions, research questions and hypotheses were presented. In this chapter, information about participants of the study, variables and data collection instruments, data collection procedure, and data analyses are explained.

4.1 Participants

Participants of the study were middle school students from seventh and eighth grades in İstanbul. The grade level of the students was chosen purposively. The assessment of metacognitive skills and academic attainment of students was taken into consideration. Research shows that older children are better at metacognitive regulation skills than younger ones (Schraw & Moshman, 1995). The last years of primary education were viewed as proper to assess their metacognition and problem solving performance considering the students' cognitive development and larger domain of knowledge.

The selection of schools in İstanbul was convenient. Availability in the current conditions such as approvals from governmental authorities, and access to the schools was taken into consideration. Two schools were selected. The schools were from different regions in İstanbul. According to Human Development Index Report of INGEV Foundation, both districts, the schools are located in, were listed as the districts with the highest human development in İstanbul based on the indices such as economic, education, health, and social life indicators (Şeker, Bakış & Dizeci, 2018). According to the information which administration of school A has provided, most of the students come from the neighborhood in which the school is located. The administration also indicated that parents enrolling in school council are professional active workers with high profile educational background. Although the school B is in the district with highest human development rate, the school administration stated that the students come from various districts having differing educational and economic backgrounds.

There were 99 students from school A and 135 students from school B (234 as total) in the study. The number and percentages of students according to gender, grade and school type are represented in Table 1. There were 103 seventh graders (44.02%) and 131 eighth graders (55.98%). A hundred and one students (43%) were thirteen years old, 126 of them (54%) were fourteen years old and 7 of them (3%) were fifteen years old (see Table 2). There were 124 female students and 110 male students in total.

4.2 Data collection methods and instruments

In the present study, there were three variables: mathematics performance, metacognition and inhibition. Mathematics performance was assessed through two measures: one was mathematics grades on students report cards of previous school year while the other was students' performances on problem solving test. For measuring metacognition two methods were used as online and offline. Two measuring instruments were used: one was an inventory measuring metacognitive skills of participants including self-ratings of students as offline, the other was calibration instrument including prediction and evaluation scales assessing the consistency between students' judgements and their actual performance on problem solving test. Inhibition of participants was measured by a numerical Stroop-like test on computer. All measures and instruments are explained in the following parts.

Table 1. Distribution of Sample by Grade-Gender-School Crosstabulation

School				Gender		Total
				M	F	
A	Grade	7	Number	27	35	62
			Percentage	27.3%	35.4%	62.6%
		8	Number	23	14	37
			Percentage	23.2%	14.1%	37.4%
	Total		Number	50	49	99
			Percentage	50.5%	49.5%	100.0%
B	Grade	7	Number	23	18	41
			Percentage	17.0%	13.3%	30.4%
		8	Number	37	57	94
			Percentage	27.4%	42.2%	69.6%
	Total		Number	60	75	135
			Percentage	44.4%	55.5%	100.0%
Total	Grade	7	Number	50	53	103
			Percentage	21.3%	22.6%	44.0%
		8	Number	60	71	131
			Percentage	25.6%	30.3%	55.9%
	Total		Number	110	124	234
			Percentage	47.0%	53.0%	100.0%

Table 2. Distribution of Sample by Grade and Age

		Age			Total
		15	14	13	
Grade	7	0	3	100	103
	8	7	123	1	131
Total		7	126	101	234

4.2.1 Problem solving test

To generate a problem solving test (see Appendix A), the literature on intuitions and automatic and analytic processes in mathematics education was reviewed. There were various problems and mathematical questions used to represent the intuitive tendencies of participants in cognitive processes in these studies. Nine problems were chosen from mathematics education and cognitive psychology literature. They were translated and adapted into Turkish. There were both multiple choice and open-ended questions.

Selected problems were formed as to include some leading words (i.e., more, less, and half) for particular operations or having salient components directing misconceptions and automatic answers. The students were expected to make automatically or intuitively some mathematical calculations through associations caused by those characteristics of the problems. For example, in problem 1 (see Appendix A) the word “half” is likely to direct the students to divide the number by two as a solution. However, the amount should be divided by three because one share is double of the other share, so it makes three shares. The problems were formed by translating or adapting the problems. They were chosen because of their characteristics of directing the students to incorrect answers through intuitive processes.

Problems 1 and 2 were taken from the study of Khng and Lee (2009) which is about interferences in algebra word problem solving. Problem 1 contains the word “half” which directs the students to do division by two. However, the required solution should be division by three. It was adapted into Turkish by changing the numbers from 381 to 480. In the original problem, the amount 381 cannot be divided by two without remainders. It was considered that this may cause the students to change their answers or leave it without answering although they think over division by two. Hence, the number, 480, which can be divided by both two and three without remainders was chosen as more appropriate in the current study to observe the students who give intuitive answer without hesitation. In the original problem, it is asked to find the amount for each child. However, one in the current study is asking to find the amount for just one child because it was aimed to have just one arithmetic operation to get a solution and just one correct answer to mark the problem as in the other problems of the test. In problem 2, there was a cue word leading the students to a particular operation. It was directly translated into Turkish. The expression "*6 times*" in the problem was expected to direct the students to do division by six. The correct solution should be dividing 168 by seven.

Problems 3 and 6 were taken from the study of Nesher and Teubal (1975) which is about examining interference effect of cue words in word problems such as more, and less. Problem 3 includes the word *"less"* that the students associate with subtraction operation while addition operation is required to get the correct answer. Problem 6 includes the word "*more"* that directs the students to do addition although subtraction is appropriate.

Problem 4 was taken from the study of Babai, Shalev and Stavy (2015) who examined the effect of a warning intervention on students' ability to overcome intuitive interference. In the question, it was asked to compare the perimeters of polygons. The second polygon had a smaller area while it had the same perimeter with the previous one. Area decreased from shape 1 to shape 2 while perimeter did not change. *Area* is regarded as a salient yet irrelevant variable interfering with relevant variable, *perimeter,* in this question*.* Since the variable *area,* does not change in the same direction with the other variable *perimeter,* this interference may cause the students to answer incorrectly by focusing on the irrelevant salient variable. It was a multiple-choice problem and the students were asked to mark one of three options: one is correct, one is incorrect and the other is intuitive incorrect option.

Problem 7 and 9 were taken from an article that is about intuitions in mathematical reasoning (Fischbein, 1999). In problem 7, the students compared two angles in opposite sides of two intersecting lines. The required logical answer was "angles are congruent". However, the students may claim the angle in the side of longer arms is bigger than the other. Because of the context (i.e., presenting opposite angles with longer arms in one side and shorter arms in the other side) the students were expected to answer incorrectly through intuitions. The problem presents two options to mark as an answer: one is the correct and the other is the incorrect intuitive answer. In problem 9, the students were asked to choose one of two options that represent the correct operation to obtain the correct answer of the problem. The correct operation for the solution should be multiplication of 5 by 0.75. However, the intuitive tendency "multiplication makes bigger and division makes smaller" may cause the students to select the division operation rather than multiplication (Fischebin, 1999).

Problems 5 and 8 were adapted from the Cognitive Reflection Test (CRT) which was used for measuring cognitive abilities in the studies of intuitive and analytic thinking about decision making and reasoning (Frederick, 2005). It is stated that people firstly have inclination to give a quick intuitive answer. People who respond incorrectly to these problems generally choose the quick intuitive answers (i.e., 10 in problem 5, 100 in problem 8) (Frederick, 2005). In the original one of problem 5, a bat and a ball cost $1.10 in total. It was stated in the problem that the bat costs $1 more than the ball. When the participants attempt to find the price of the ball, the erroneous answer, *10 cents,* "impulsively" emerges. For giving the correct answer, suppression of the intuitive answer is needed (Frederick, 2005). The amount of money, $1.10, in the problem was changed as 1.50 in the adapted form because as a money unit, 0.50 krs is more common in currency in Turkey. Besides, it is more meaningful according to the age of participants in the current study because other studies using the CRT applied the test to adults and university students. Similarly, in problem 8, the participants were expected to give the answer 100, as a quick intuitive answer impulsively emerged.

In the problems 1,2,3,5, 6, and 8 there were three possible solutions: the correct one, the incorrect one and the intuitive incorrect solution which was expected to emerge automatically by the leading words. The students were asked to show how they solved each problem. Each problem answered as correct was scored as one (1); the problems answered as incorrect or with no answer was scored as zero (0). In the problems 4, 7, and 9 the participants could choose one of the given choices in the problem. The students who chose the correct one obtained one (1) point; the students who chose the option/s other than the correct one got zero (0) point in scoring. Problem solving performance of the students was measured by calculating their cumulative scores from each problem.

After constructing the test, it was referred to expert teachers in both mathematics and English to evaluate the appropriateness of the test regarding its mathematical content and language in order to obtain evidence for the validity of the test. Expert opinion indicated that the test was appropriate to apply for seventh and eighth graders. A pilot study was conducted with 48 participants. Seventeen students (35%) gave intuitive answers to most of the problems in the problem test (more than 4 problems). Nineteen participants (40%) gave intuitive answers to almost half of the problems (4 problems were answered as intuitively). High intuitive answer rate was seen positive considering the criteria of selecting problems which is interfering effect directing the students to intuitive answers.

Reliability analysis of problem solving test was conducted through a pilot study with 48 participants. The alpha coefficient for the nine items is .70 indicating that the test items have internal consistency. According to item-total statistics results correlations of items with overall test scores ranged between .18 (problem 9) and .52 (problem 3). There was not an item that increases the alpha coefficient in the case of being deleted. So, it was decided not to remove any problem from the test.

4.2.2 Mathematics Achievement Scores

Mathematics achievement scores of students were obtained from mathematics grades reflected on the report card of previous school year. Mathematics grades are calculated according to two criteria. The first one is students' performances on three exams prepared and implemented by the mathematics teachers in the schools as matching with objectives in National mathematics curriculum. The other criterion is teachers' judgements about student' participation in mathematics classes. Considering the judgements of teacher included in grading and participants coming from different schools and grades, mathematics achievement scores in the present study may contain a validity threat as a limitation. However, Hardegree (2012), found that grades on report cards provide accurate information about the performance on a high-stakes standard-based testing.

As a mathematics performance measure in the current study, problem solving performance was expected to have high rate of significant correlation with current mathematics achievement levels of students. When calculating the correlational coefficient between problem solving performance and mathematics achievement scores (grades in report cards) of students participated in pilot study, a significant correlation was found $r(48) = .56$, $p < .001$. The significance in the relationship of mathematics achievement scores with problem solving performance as another mathematics performance measure is important for criterion-related validity. Low coefficient in relationship was interpreted as resulting from the interference effect in the problem solving test which has a tendency of decreasing student performance.

4.2.3 Metacognition

Metacognition as a construct involving multiple dimensions/skills such as awareness, monitoring, prediction, and evaluation was measured under two separate frameworks as metacognitive skills and calibration. Under metacognitive skills framework, a likert-type scale, *Metacognitive Skill Inventory* (MSI) developed by Çetinkaya and Erktin (2002) was used (see Appendix B). The scale has 32 items and involves four dimensions named as *self-checking, awareness, evaluation, and cognitive strategies*. Self-checking items (10 items) include statements about the student acts of control and regulation such as regulating the time and subject unit while studying or problem solving, checking of mistakes, understanding and misconceptions, and thinking over the proper learning methods (Items: 2, 8, 13, 22, 24, 28, 29, 30, 31, and 32). Awareness items (eight items) include statements about students' knowing their own learning characteristics in a particular situation or learning domain (Items: 6, 9, 10, 11, 12, 15, 16, and 19). Evaluation items (eight items) state students' actions and considerations after or during any learning process to get better result in following steps (Items: 4, 7, 14, 17, 18, 20, 26, and 27). Cognitive strategies dimension includes six items (1, 3, 5, 21, 23, and 25) implying students' awareness of which and how cognitive strategies are used in any learning process.

Each item in the scale ranged from one (never) to four (always). So, the score which could be obtained from the whole scale ranged from 32 to 128. Knowing that the scores were self-ratings of the students, the score obtained from any dimension showed how much the student considered his/her attainment in a given metacognitive skill. Adding all scores from each dimension generated the total metacognitive score of the student.

In inventory construction process, expert opinions were taken to evaluate the items and factor analysis was conducted through a pilot study (Çetinkaya & Erktin, 2002). After expert judgments and determining of sub-dimensions, the last version of inventory was constructed as a valid measure of metacognitive skills. According to two reliability analysis, the Cronbach's alpha reliability coefficient for internal consistency of the scale was obtained as 0.87 (Çetinkaya & Erktin, 2002).

4.2.4 Calibration

The Mathematical Calibration Instrument (MCI) developed by Özsoy (2012) was adapted and used in this study. MCI has two parts originally as prediction and evaluation including 14 mathematical problems in each. The mathematical problems in the original instruments were replaced with the problems in the current study. So, the students took the prediction scale first with mathematical problems as nine- item-scale before taking problem test and they took the evaluation scale as again nine-item-scale after they solved the problems.

In measuring prediction skills, the students were asked to decide how much they believed that they could solve the problem correctly by just reading the problem without solving. They were asked to mark the most appropriate option for each problem among six options like "I am sure that I can solve the problem correctly, I can solve the problem correctly, I can solve it yet I may make a mistake, I guess I cannot solve it correctly, I cannot solve it correctly, I am sure that I cannot solve it correctly” (see Appendix C). After they selected the appropriate option for each problem, they took the problem test to solve. Afterward, they did the same for the evaluation scale by choosing one of the six options for each problem in evaluation part which are stating how much they feel confident about the correctness of solution as ranging from being mostly confident about the correctness of the answer to being least confident about the correctness (see Appendix D).

The consistency between the students’ performance in problem solving test and their judgments before and after solving problems determined their calibration scores. The students who solved the problem correctly and stated that they are sure they can solve the problem correctly or they feel mostly confident about the correctness of the solution got the highest score three (3) in prediction or evaluation scale. Similarly, the students who could not solve the problem and stated that they are sure that they cannot solve it correctly or they are least confident about the correctness of the solution got the highest score (3). The scoring continued from highest to lowest as three, two and one according to the consistency between the performance and judgements in prediction and evaluation scales. When there was no consistency, the score was reflected as zero. Prediction and evaluation scores was scored separately by adding all points obtained from each item in the corresponding scale. So, the prediction and evaluation scores ranged from 0 to 27. Kappa values of prediction and evaluation items in determining internal consistency were reported as between .42 and .68 (Özsoy, 2012).

4.2.5 Inhibition

Inhibition scores were measured by a numerical Stroop task. Stroop tasks have different versions depending on the content of the items such as numeric, colourword and pictorial. In this study, numeric (counting) version of Stroop task was used as in two studies about mathematics achievement: the study of Bellon, Fias and Smedt (2016) examining the relationship between inhibition and arithmetic fact retrieval and the study of Bull and Scerif (2001) who examined the relationship mathematics ability and inhibition. The reason of choosing this type of task is that it was used in the studies about mathematics before and it is easy to prepare and implement.

In this numerical-quantity version, the students were asked to state the number of items presented. There were two conditions as baseline condition and incongruent condition. In baseline condition, the students stated the quantity of the items (i.e., three for XXX). In incongruent condition, the students stated quantity of digits in a written number (i.e., how many digits are there in 444?). For each condition, there were 48 stimuli. Students were asked to respond as quickly as possible and the time for completing each condition was recorded in addition to accuracy.

The Stroop task was prepared in computer environment. So, the students could take the test online via an assigned address. When the tests were completed the accuracy score and elapsed time were reflected on the screen for each condition. After the experiment, the total time needed to complete the test was divided by accuracy as an inverse efficiency score (Bellon et al., 2016). Inhibition score was measured by subtracting the score of baseline condition from the score of incongruent condition (i.e., Inhibition Score = [Time2 ÷ Accuracy2] – [Time1 ÷ Accuracy1]). Higher difference showed lower inhibitory control.

4.3 Procedure

As the study requires data collection through various scales and instruments from middle school students, consent forms for parents of students were prepared in which the details about the research were explained (see Appendix E). The consent forms and a short summary of the research were presented to the Ethics Committee of Boğaziçi University. An official report of the Ethics Committee indicating the approval of conducting the research was taken (see Appendix F). To be able to collect data from the selected schools a permission was taken from İstanbul Provincial Directorate for National Education (see Appendix G).

Data collection procedure of the study was followed in three parts. In the first part problem test together with calibration scales was implemented. Secondly, Metacognitive Skill Inventory was given to the students. Lastly, the Stroop task was performed by the students on computers. This process took two-lesson time (80 minutes) as total. The students took the tests in their own classrooms except the Stroop task. All testing instruments were implemented on 99 students in school A and 134 students in school B.

Firstly, problem solving test was implemented together with calibration scales. The students answered the prediction scale by reading each problem in the test without solving. They were asked firstly to take a look at each problem and select the appropriate option on prediction scale. Soon after they answered the prediction scale, they were asked to solve the problems by giving the problem solving test. Afterwards, they were given the evaluation scale to select the appropriate option for each problem again. They answered how much they are sure about the correctness of their answer in this scale. Secondly, they were given

Metacognitive Skill Inventory. So, all tests except the Stroop task were implemented in one lesson hour.

Lastly, the students performed the Stroop task on computers. In school A, there was a computer lab. In school B, the students took the Stroop task in their classrooms by using two personal computers in turn because there is no laboratory. During the implementation of Stroop task, classroom teachers assisted the experimenter. Stroop task was implemented into two stages: baseline condition (i.e., XXX) and incongruent condition (i.e., 222). The students firstly took a practice trial for baseline condition to understand how to answer the questions. When they completed the trial, they answered 48 items in the baseline condition by recording the scores. The same process was executed for incongruent condition. They initially answered 48 items in incongruent condition as a trial. Then, they performed the same task as main task. By this way, the data collection process with testing instruments was completed. Mathematics achievements scores in students' report cards belonging to previous year was obtained from school administrations. After scoring the problem solving test, the data collected was entered to SPSS program in version of 20.

4.4 Analysis

Because the aim of the study is examining the relationship between metacognition, inhibition and mathematics performance of middle school students, descriptive and correlational analysis was conducted. To describe the sample characteristics in each variable, means, medians, standard deviations, possible and actual ranges were reported. The distribution of data for each variable was represented through histograms beside reporting the normality testing and skewness. Furthermore, considering the difference in school characteristics and in the districts the students came from, the students of two schools were compared in mathematics performance and metacognition measures. For this aim, Mann-Whitney U test was used since the data for each variable was not normally distributed.

In investigating the relationship between the variables, Spearman's correlations were calculated for the data having non-normal distribution. For answering the fourth research question, regression analysis was conducted. The analyses were done by using SPSS software in version 20.

CHAPTER 5

RESULTS

The aim of the study is to examine the relationship between metacognition and inhibition regarding the mathematics performance of middle school students. To investigate mathematics performance of students, mathematics achievement scores and the performance on a mathematical problem test were used. Metacognition was measured through a self-rating scale for students (Metacognitive Skill Inventory). Students' prediction and evaluation scores were also measured through a calibration scale in which they stated their judgments about their own performance on the mathematical problem test as a metacognitive measure. Lastly, inhibition was measured with a Stroop type test on computerized environment.

Considering the aim of the study, firstly demographic information of the sample is presented in this section. Secondly, descriptive characteristics of data obtained from the testing instruments is introduced by reporting the normality, means, ranges and standard deviations and group comparisons. Subsequently, correlation coefficients among the variables are reported to state the strength of the relationship between the two variables. Then, the results of regression analysis indicating the predictor role of independent variables on mathematics performance are presented.

5.1 Demographic characteristics of the sample

To describe the sample demographically, gender, and grade distribution of sample, type of school, students' mathematics achievement scores of the previous year are presented. Comparison of mathematics achievement scores in consideration of school-type are also presented to reveal how the schools differ from each other with respect to the mathematics achievement scores.

In this study, 234 students participated from two middle schools (School A and School B) in grades seven and eight. The number and percentages of students according to gender, grade and school are illustrated in Table 1. There were 103 seventh graders (44%) and 131 eighth graders (55.9%). A hundred and one students (43%) were thirteen years old, 126 of them (54%) were fourteen years old and seven of them (3%) were fifteen years old (see Table 2). There were 124 female students and 110 male students in total.

Mathematics achievement levels of students are reported to describe the sample's mathematics achievement. Mathematics achievement scores of students was obtained from the report cards of the 2016-2017 school year. The scores under 45 within the range 0 to 100, demonstrate failure of students in mathematics exams. The data obtained from the sample ranged from 35 to 100 and the mean of math achievement scores was 76.80 (*SD* = 20.27, *N* = 227, see Table 3). The median and mode were 83.92 and 100 respectively.

Table 3. Descriptive Statistics of Variables

	N	Possible Range	Range	Mean	Std. Deviation	Median
Math Achievement	227	0-100	35-100	76.80	20.27	83.92
Problem Solving	228	0-9	0-9	3.26	2.28	3
Metacognition	229	32-128	46-128	98.00	16.01	100
Prediction	229	0-27	0-27	8.78	6.30	7
Evaluation	223	0-27	0-27	10.65	6.17	10
Inhibition	215	0-	0-3339.98	200.62	296.18	149.10

The grades of seven students could not be obtained from the school administrators. Four students had highest grade (100) among 227 students. Both the curve of the mathematics grades (see Figure 1) and the result of Shapiro-Wilk test ($p < .001$)

concluded that mathematics grades of students were not normally distributed. The data were moderately skewed to the left (-.619).

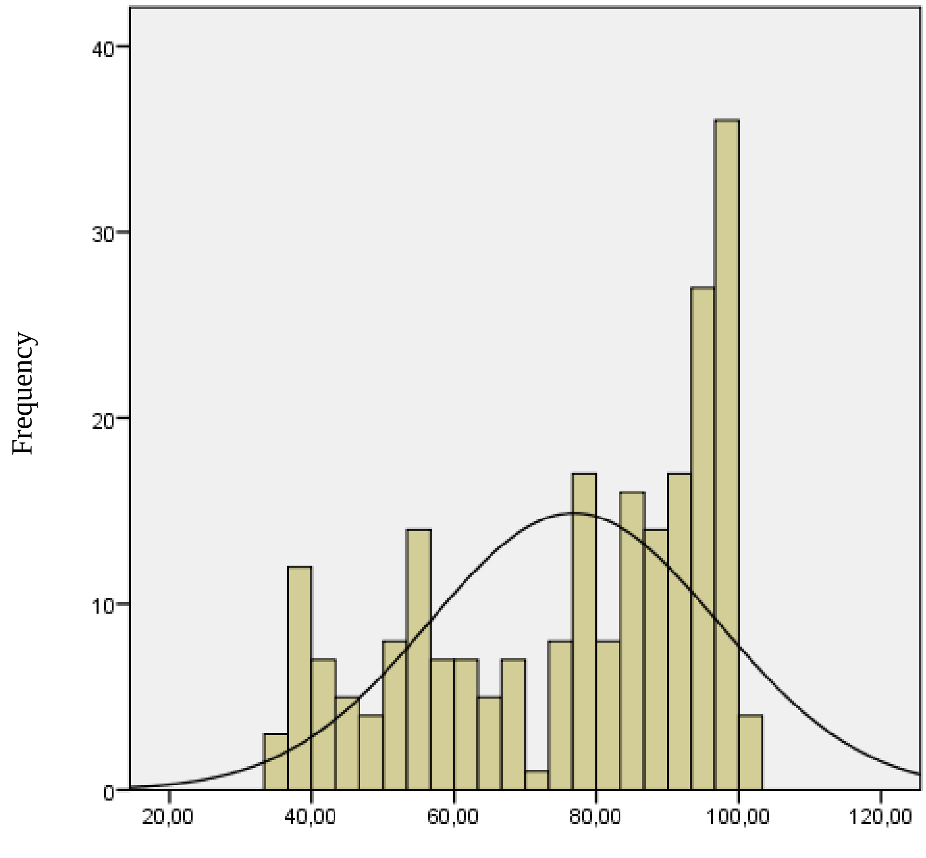


Figure 1 Distribution of mathematics achievement scores of participants

Mathematics achievement scores of students were compared for the two schools. A Mann-Whitney U test indicated that the mathematics achievement scores were higher for the students in school A (*Mdn* = 94.4, *SD* = 11.2) than the ones in school B (*Mdn* = 66.5, *SD* = 19.7), *U* = 1903.50, *p* < .001 (see Table 4). A large effect size was observed (*r* = .59). In school A, one student (1%) had a score under 45 (*n* = 93), whereas 25 students (19%) in school B (*n* = 134) had scores under 45. The findings reflected that the students in school A had higher grades in mathematics than the students in school B.

Table 4. Comparison of Math Achievement Scores of Students According to School

School	*N*	Mean Rank	Sum of Ranks	*U*	*Z*
A	93	160.53	14929.50	1903.50*	-8.893
B	134	81.71	10948.50		

* $p<.001$

5.2 Descriptive analysis of data

In this section, each variable was analyzed separately regarding the descriptive characteristics of data obtained from testing instruments. Data were analyzed on five measures: problem solving performance, metacognition, calibration (prediction and evaluation), and inhibition. Problem solving performance was measured by problem solving test, metacognition was measured by Metacognitive Skill Inventory (MSI), prediction and evaluation scores (calibration) were calculated through Mathematical Calibration Instrument (MCI), and inhibition was measured with a numerical Stroop task on computer. Descriptive characteristics of data obtained from these tests including the mean, range, variance, and standard deviations are shown in Table 3. They are reported in detail under each related variable heading. Group comparisons by school type for each variable were carried out since the sample consists of students from two different schools.

5.2.1 Problem solving performance

For measuring problem solving performance of the students, a problem solving test (see Appendix A) containing nine mathematical problems was used. Scoring for each problem was zero (0) or one (1). Incorrect answers were scored as zero (0) and correct answers were scored as one (1). Total score of the test ranged from zero (0) to nine (9). Reliability analysis carried out with the data from 228 students showed that Cronbach alpha coefficient was .73. The corrected item-total correlations ranged between .18 (Problem 9) and .57 (Problem 2) (see Table 5).

Table 5. Item-Total Statistics for Problem Solving Test

Problem	Corrected Item-Total Correlation
Prob1	.478
Prob2	.568
Prob3	.536
Prob4	.379
Prob5	.411
Prob6	.476
Prob7	.354
Prob8	.275
Prob9	.184

The data obtained from 228 students' problem test scores was analyzed for normality, central tendency, and dispersion. The frequencies and percentages of the total scores from the problem solving test are presented in Table 6. Seventeen students (7.5%) got lowest score (0) by answering all questions incorrectly whereas four students (1.8%) got the highest score (9) by answering all questions correctly (see Table 6). Mean score of problem solving performance of students was calculated as 3.26 (SD = 2.28, N=228, see Table 3). The median and mode were calculated as 3 and 1 respectively. A hundred and thirty-five students (59%) got scores under mean from the problem test. The data from the students' problem test scores were not normally distributed ($p < .001$). Data were skewed to the right with a value of .625 (see Figure 2).

Table 6. The Frequencies of Problem Solving Scores

Problem Solving Score	Frequency	Percent
0	17	7.5
1	44	19.3
2	39	17.1
3	35	15.4
4	30	13.1
5	24	10.5
6	15	6.6
7	9	3.9
8	11	4.8
9	4	1.8
Total	228	

For presenting the descriptive characteristics of each problem in the test, the mean for the scores obtained on each problem was calculated (see Table 7). Because the test consisted of problems directing the students to intuitive (automatic) incorrect answers, the proportion of students who gave intuitive answer to the problem was calculated for each question as well. As shown in Table 7, problem 7 had the highest correct answer rate (59%) whereas problem 8 had the lowest correct answer rate (9%). As the ratio of correct answers is considered as item difficulty index, problem 7 can be regarded as the easiest item while problem 8 is the most difficult among all the problems. The ratio of intuitive responses for each problem showed that problem 8 had the highest rate of intuitive response (68%) whereas problem 1 had the lowest rate (22%). Because problem test is comprised of the questions including interfering characteristics leading the students to intuitive answers, problem 8 can be regarded as the most distracting problem while problem 1 is the least distracting one considering the interference effect on participants.

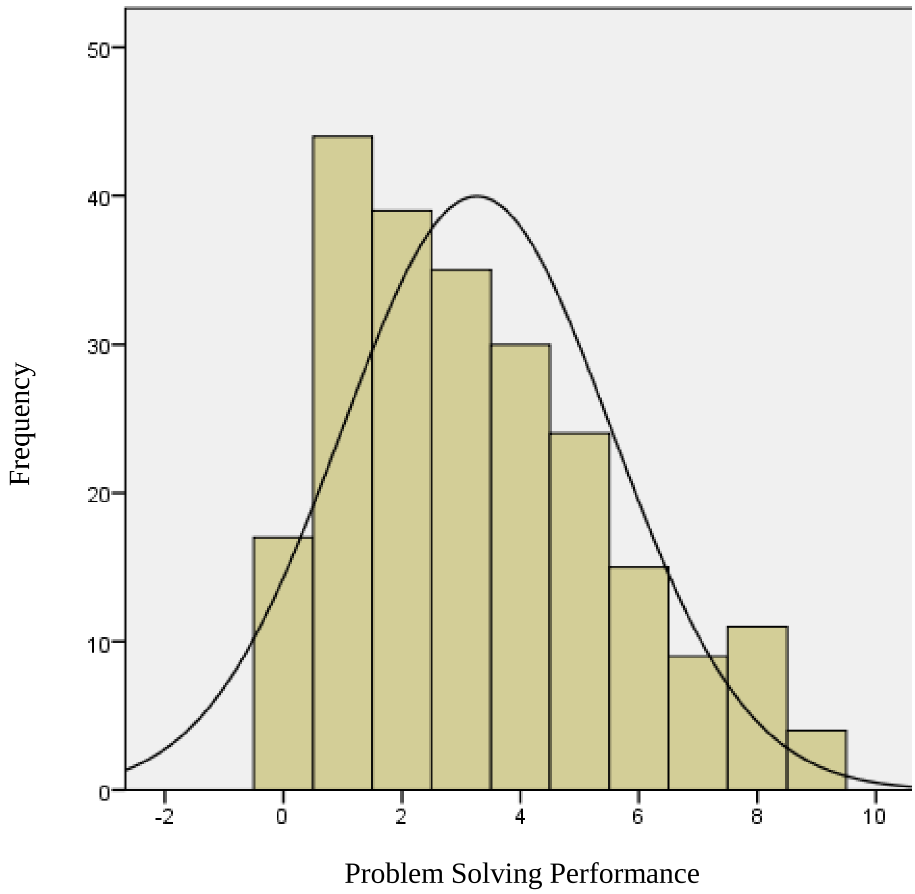


Figure 2 Distribution of performance of students in problem solving test

Problem 1 (see Appendix A) was about the interferences of clue words in word problems directing the students to incorrect responses through intuitions. It includes the word "*half*" that leads the problem solvers to divide the total by two, due to the interference effect of the clue word. When the incorrect solutions represented for Problem 1 include division of the total amount by two, the responses were accepted as intuitive. When there is no response or another incorrect answer, the response was accepted as incorrect. Item statistics revealed that the mean score for problem 1 was .16 (N = 228, see Table 7). Fifty students (22%) solved the problem intuitively whereas the responses of 141 students (62%) were incorrect. For this problem, the proportion of correct responses (16%) and intuitive ones (22%) were low compared to incorrect ones. Considering the high proportion of incorrect answers compared to correct and intuitive ones, it is seen that students had difficulty in answering problem 1.

Table 7. Item statistics in Problem Solving Test

	Correct		Incorrect		Intuitive	
	N	%	N	%	N	%
Prob1	37	16.2	141	61.8	50	21.9
Prob2	68	29.8	76	33.3	84	36.8
Prob3	114	50.0	25	10.9	89	39.0
Prob4	108	47.3	28	12.2	92	40.3
Prob5	52	22.8	55	24.1	121	53.0
Prob6	127	55.7	23	10.0	78	34.2
Prob7	135	59.2	14	6.1	79	34.6
Prob8	21	9.2	57	25.0	150	65.7
Prob9	82	35.9	9	3.9	137	60.0

In Problem 2, there was again the interference effect of a verbal expression. The students were expected to divide 168 by six due to the expression *"6 times*" in the problem whereas the correct solution should have been dividing 168 by seven. According to item statistics results, the mean score of problem 2 was .30 (N= 228, see Table 7). There were 84 (37%) intuitive and 76 (33%) incorrect answers for the second problem. The proportions of correct, incorrect, and intuitive answers for the problem were close to each other, but there were more individuals responding the problem intuitively.

Problem 3 includes the word "*less*" that leads the students to subtract by creating an association between "*less*" and "subtraction". Although the correct solution for the problem required addition, the students were expected to do subtraction as an intuitive decision. The mean score for the third problem was calculated as .50. It means half of the students gave the correct response to the problem. Eighty-nine students (39%) gave intuitive responses while 25 students (11%) gave either no answer or another incorrect answer to the problem. Although the number of students who answered the problem correctly and who answered incorrectly (including intuitive answers) were equal, intuitive answers were fewer than the correct ones.

Problem 4 was about comparing the perimeters of two polygons. It was a multiple-choice question and had three answer choices one being correct and two are incorrect. One of the incorrect choices represented the intuitive answer. The mean score of problem 4 was calculated as .47. It means almost half of the students selected the correct answer. Forty percent of the student selected the intuitive answer while 12 percent selected another incorrect answer. Although there are more students who gave the correct answer than the ones who gave intuitive response, the proportions are close to each other.

Problem 5 was one of the questions taken from the CRT (Cognitive Reflection Test). The total amount of cost for ball and bat was stated as 1.50 liras. It was stated that the bat costs 1 lira more than the ball. Participants who give a quick impulsive answer without spending enough time to find the correct answer think the price of the bat is 1 lira and the ball is 50 krş. Expected intuitive answer in this problem is “50 krş” though the correct answer should be “25 krş”. In this problem, majority of students gave intuitive answers (53%). It shows that the problem works as a good distractor regarding the interference effect. The number of students who answered the problem correctly was relatively low (23%). The number of students who gave intuitive answers (53%) was almost twice of the students giving incorrect answers (24%).

Problem 6 was similar with problem 3 which includes associative verbal cues for mathematical operations. In this problem, there was the word "*more*" as working in the same way with the word in the problem 3. Expected intuitive solution would be doing addition and finding "*fifteen"* (15) while the correct result is "*seven*" (7) which could be obtained by subtraction. As was the case for problem 3, over half of the students answered the problem correctly (56%). The amount of intuitive responses was counted as 79 (35%) while the number of incorrect answers was 23 (10%). This problem was the second problem having the highest ratio of correct responses among the nine problems. Since the rate of intuitive answer is relatively low, the students were seen as being less distracted from interference effect exposed in the problem.

Problem 7 is another multiple-choice question which is about comparing vertical angles. It had two answer choices: one is correct and the other is intuitive (incorrect) one. This problem had the highest rate of correct responses (59%). A hundred and thirty-five students selected the correct choice while 79 students (35%) answered intuitively. The rest of the students (14) did not give any answer to the problem. The highest rate of correct answer together with the relatively low rate of intuitive answer in the problem shows that fewer students were affected by the interference effect in the problem compared to other problems.

Problem 8 was another problem taken from CRT which creates a tendency to answer the question automatically. The automatic answer (100) is the incorrect one which is expected from the students to think as soon as they read the question. When the students think analytically, they are expected to give the answer "5" as correct. Findings revealed that problem 8 had the highest rate of intuitive answers (66%) among the other problems while the proportion of correct answers, namely the mean, was calculated as .09 as the lowest (see Table 7). Fifty-seven (25%) students gave different incorrect answers to the problem. Considering the mean of the problem scores, problem 8 could be regarded as the most difficult problem in the test. It is also seen that the students were affected by the interference effect most in this problem considering the high rate of intuitive answer.

Problem 9 was a two-option multiple-choice problem. When the students answer the problem with intuitive tendency they are expected to choose intuitive (incorrect) answer choice. For this problem the mean was calculated as .36. Namely, 82 students chose the correct answer while 137 students (60%) gave the intuitive answer. Nine students (3%) did not give any response to the problem. More than half of the students gave the intuitive answer to this problem. It shows that the students were highly affected by the interference effect in the problem.

The mathematics performance as assessed by the mathematics achievement scores were previously found to be significantly different for each school. The participants from the two schools were compared according to their scores on the problem solving test. The findings revealed that the students coming from school A (Mdn = 4.00, SD = 2.27) showed higher performance on problem solving test than the students coming from school B (Mdn = 2.00, SD = 2.12), U = 4123.50, $p < .001$. The median difference in problem solving test was found to be statistically significant for the two schools. The effect size is medium (r = .30).

Table 8. Comparison of Problem Solving Performance According to School

School	*N*	Mean Rank	Sum of Ranks	*U*	*Z*
A	95	137.59	13071.50	4123.50*	-4.514
B	133	98.00	13035.50		

* p < .001

5.2.2 Metacognition and Calibration

Metacognition was measured under two headings: one is metacognitive skills and the other is calibration. Metacognitive skills of students were measured with a likert-type scale (MSI) including 32 items ranging from 1 (strongly disagree) to 4 (strongly agree). So, the score which can be obtained from the scale ranges between 32 and 128. The scale had four dimensions named as *self-checking, awareness, evaluation, and cognitive strategies* (Çetinkaya & Erktin, 2002). According to reliability analysis of the scale with 229 seventh and eighth grade students, the Cronbach alpha coefficient was calculated as .93 through the data obtained from the sample of this study.

To describe the data obtained from MSI, descriptive statistics was conducted. Findings revealed that metacognition scores ranged between 46 and 128 with the mean of 98.0 and the standard deviation of 16.01 (N= 229, see Table 3). The median of the scores obtained from the MSI was calculated as 100 while modes were 92, 101 and 111. Ninety-nine students (43.2%) took a score under the mean. Metacognitive scores significantly deviated from normal distribution according to Shapiro-Wilk test ($p < .001$). The scores were skewed to the left with the value of -.561 (see Figure 3).

Considering the significant mean difference of two schools in the mathematics achievement scores, group comparison in consideration of school type for metacognition scores was calculated. The mean of metacognition scores of students in school A was calculated as 103.20 while the mean in School B was 94.26. A Mann-Whitney test indicated that the metacognition scores were higher for the students in school A (Mdn = 105.00, SD = 14.60) than the ones in school B (Mdn = 96.00, SD = 15.99), U = 4193.00, $p < .001$ (see Table 9). The effect size is medium (r

= .29). In short, the students in school A got higher scores in metacognition scale compared to the students in school B like in mathematics achievement scores.

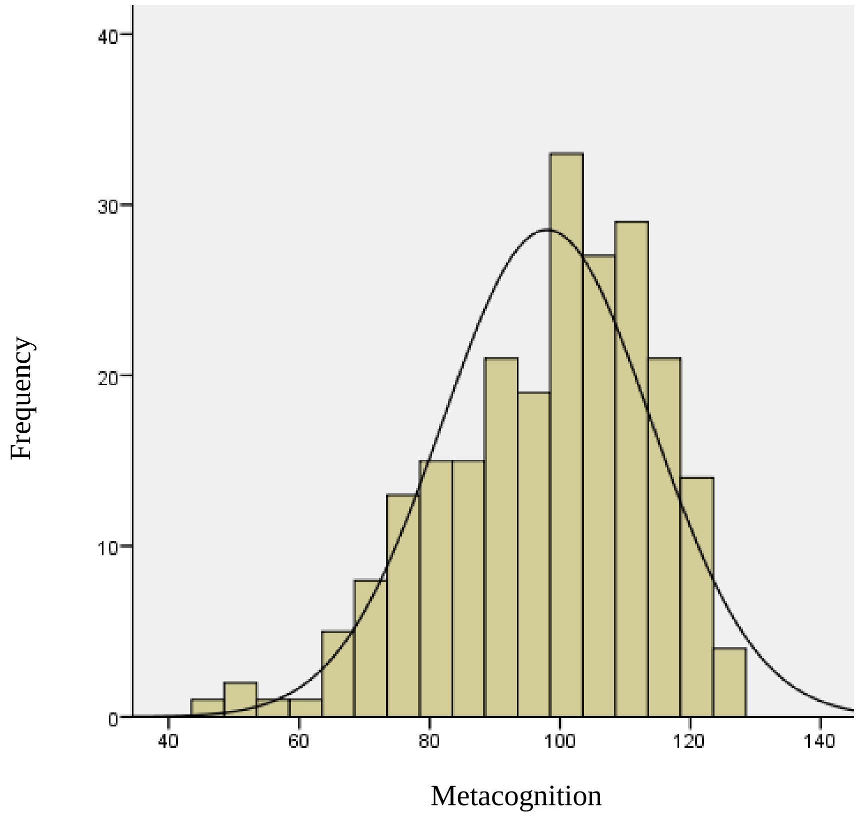


Figure 3 Distribution of metacognition scores of participants

Table 9. Comparison of Metacognition Scores According to School

School	*N*	Mean Rank	Sum of Ranks	*U*	*Z*
A	96	137.82	13231.00	4193.00*	-4. 43
B	133	98.53	13104.00		

* p < .001

As stated before, metacognition of students was investigated also through calibration scores obtained from mathematical calibration scale. The scores which can be obtained from prediction and evaluation scales separately range from 0 to 27 for nine mathematical problems. Descriptive analysis was carried out for prediction and evaluation scores of students to observe what is the general tendency of data and dispersion. There were 229 valid data obtained from the prediction scale and 223 data from evaluation scale. According to descriptive analysis (see Table 3), prediction scores of students ranged from 0 to 27 with the mean of 8.78 and the standard deviation of 6.30 (N = 228). There were three (3) students who had the highest score (27) from prediction scale. The median and mode of prediction scores were found as 7 and 3-6 respectively. Prediction scores of students were not normally distributed (p < .001) and were skewed to the right with the value of .904. (see Figure 4).

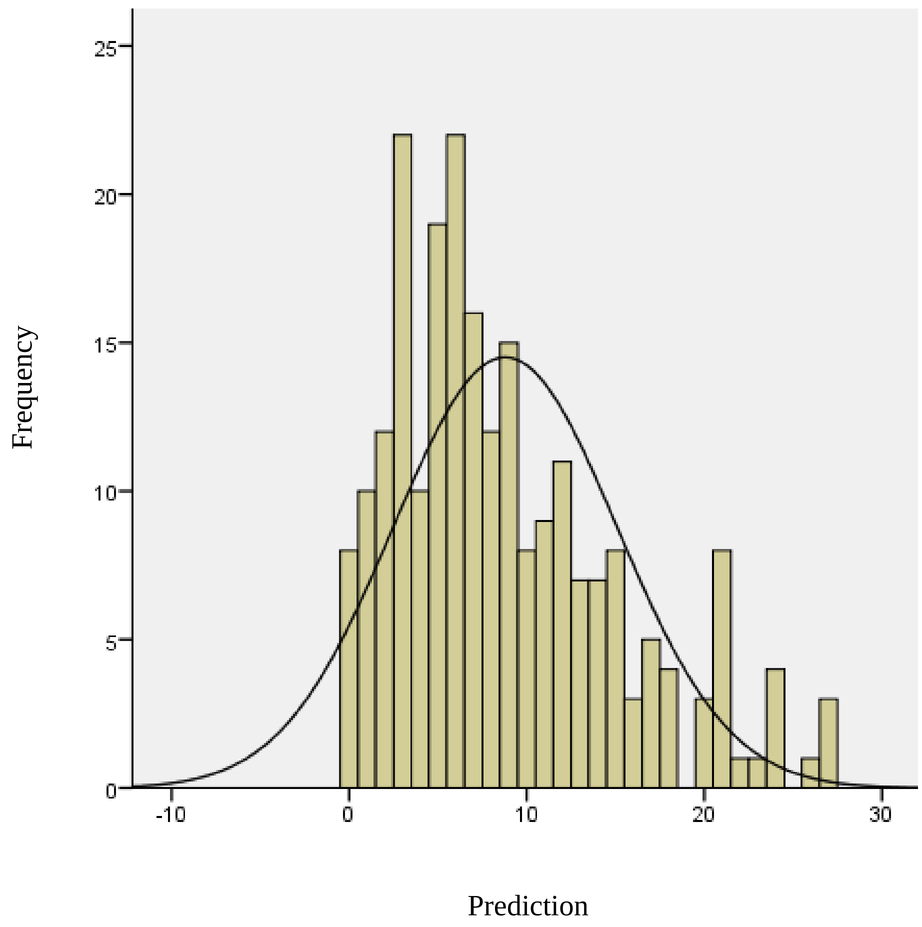


Figure 4 Distribution of prediction scores of participants

Further, evaluation scores of students ranged between 0 and 27 with the mean of 10.65 and the standard deviation of 6.17 (N = 223). There were three (3) students who took the highest score (27) from evaluation scale too. There were two (2) students with the lowest score (0) from evaluation scale. Median was 10 and mode was 6 for evaluation scores. Evaluation scores of students were not normally distributed (p < .001) and were skewed to the right with the value of .654. (see Figure 5).

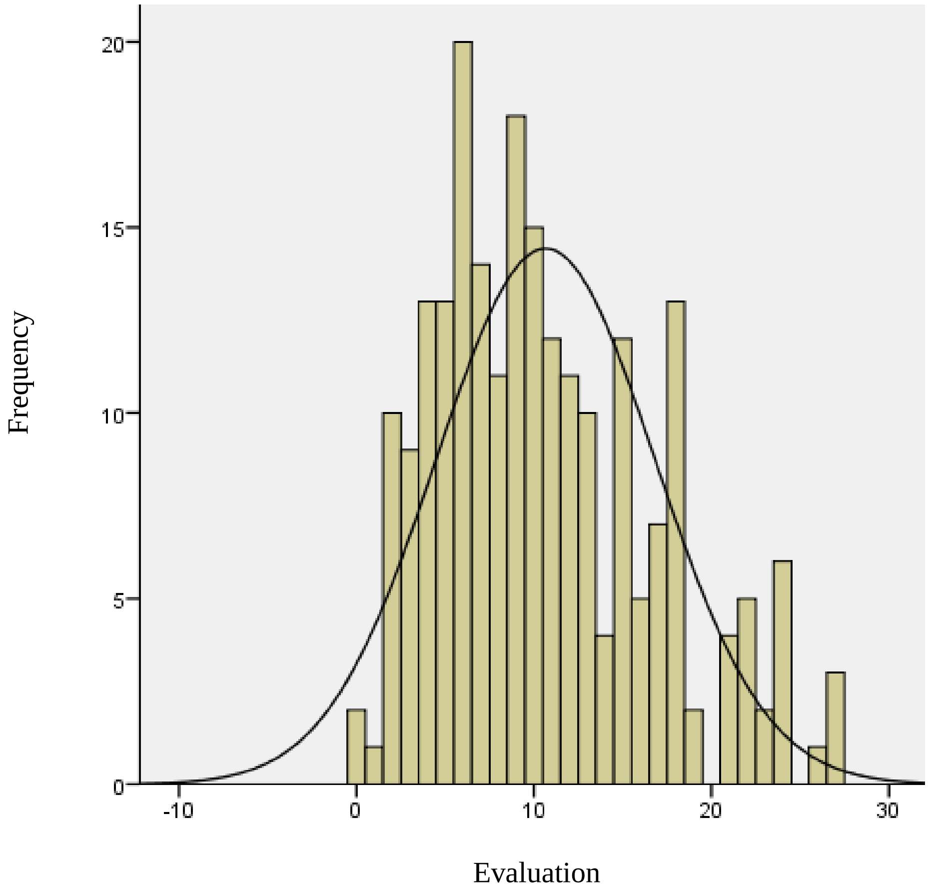


Figure 5 Distribution of evaluation scores

As in the metacognition scores, prediction and evaluation scores with respect to school were compared to observe whether there is a difference between schools in calibration as well. Prediction scores of the students in school A (Mdn = 9, SD = 6.92) were significantly higher than the ones in school B (Mdn = 6, SD = 5.52 see

Table 10) with a small effect size *r* = .19. Similarly, evaluation scores in school A (*Mdn* = 11, *SD = 6.56*) were higher than the ones in school B (*Mdn* = 9, *SD* = 5.63). The effect size laid small to medium (*r* = .20). The students in school A got higher scores than the ones in school B in all calibration scores like in mathematics achievement scores and metacognition scores.

Table 10. Comparison of Prediction and Evaluation Scores According to School

School		*N*	Mean Rank	Sum of Ranks	*U*	*Z*
Prediction	A	96	129.68	12449.50	4974.50*	-2.855
	B	133	104.40	13885.50		
Evaluation	A	91	127.67	11618.00	4580.00*	-3.016
	B	132	101.20	13358.00		

* $p < .05$

5.2.3 Inhibition

Inhibition scores were calculated via computer-based testing including two separate conditions as baseline and incongruent. In baseline condition items were generated by the letter x and in incongruent condition items were generated by digits to create an interfering effect. There were 48 items to be responded in each condition. The accuracy scores (in baseline and incongruent conditions) and the time elapsed in milliseconds (in both conditions separately) were recorded for each participant. The time elapsed was divided by the accuracy score in each condition (baseline score and incongruent score) as an inefficiency score. By this way, each participant had inefficiency scores in milliseconds for both baseline condition and incongruent condition. Inhibition scores were calculated by subtracting the baseline score from incongruent score (Inhibition Score = [Time2 ÷ Accuracy2] – [Time1 ÷ Accuracy1]). The larger difference means lower inhibitory skill of participants. Namely, the scores that are close to zero indicate higher inhibitory skills while higher scores show a lack of inhibitory skills.

According to Stroop interference effect (Redick, Heitz, & Engle, 2007) time spent for answering under the incongruent condition is longer than baseline or congruent condition and accuracy is higher in baseline condition than incongruent one. Data obtained from the sample formed by 215 students revealed that the time in incongruent condition was longer (M = 48837.23, SD = 9096.62) than baseline condition (M = 42188.17, SD = 8483.86) as expected (see Table 11). Similarly, accuracy score was higher in baseline condition (M = 46.51, SD = 1.77) than incongruent condition (M = 45.12, SD = 3.83). The difference score (inhibition score) which was calculated through subtracting the baseline score from the incongruent one was found as significantly different than zero (t (214) = 9.995, $p < .001$). This showed that the design of the Stroop task in the current study worked successfully.

Table 11. Descriptive Statistics for Accuracy and Time in Stroop Task

	N	Min	Max	Mean	SD
Time-Baseline (ms)	215	26003	86088	42188.17	8483.86
Accuracy-Baseline	215	38	48	46.51	1.77
Time-Incongruent (ms)	215	30750	82780	48837.23	9096.62
Accuracy-Incongruent	215	17	48	45.12	3.83

There were 215 valid inhibition scores that ranged from -547.10 ms to 3339.98 ms with the mean of 193.29 and the standard deviation of 304.62. Inhibition scores were not normally distributed and were skewed to the right with the value of 7.02. There were 12 unexpected negative inhibition scores. They were altered from negative to zero (0) as being lowest inhibition scores implying the highest inhibitory skill. After editing the data, scores ranged from .00 to 3339.98 ms with the mean of

200.62 and standard deviation of 296.18 (see Table 3). Median was calculated as 149.08. The distribution was not normal and was skewed to the right with the new score of 7.56 (see Figure 6).

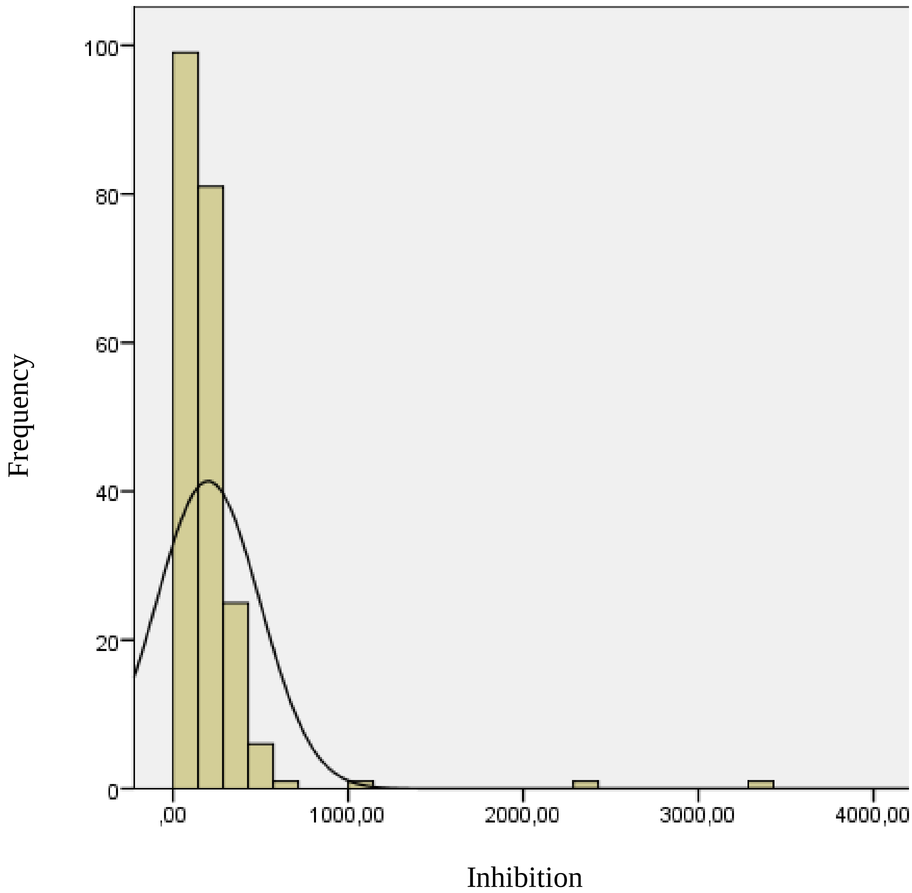


Figure 6 Distribution of inhibition scores of participants

5.3 Correlation analysis

Descriptive analysis revealed the general characteristics of each variable. In this section, correlation coefficients that were calculated to investigate the relationship between variables according to research questions are reported. Spearman correlation was calculated to investigate the relationship between the variables because the variables do not provide normality assumption.

5.3.1 The relationship between inhibition and metacognition of middle school students

In this study, two procedures were followed to measure metacognition: online and offline measure. Offline measure of metacognition was accomplished by a self-evaluation inventory (MSI) in which the student answered likert-type items stating students' actions and awareness about general performance in a mathematical task or learning. For online measure of metacognition, calibration procedure was followed in which the students predicted and evaluated their performance in the current mathematical task (Problem solving test). So, the correlational analysis of inhibition with metacognition was conducted with two separate measures of metacognition. Because the data for each variable was not normally distributed, Spearman's rho was calculated to examine whether there is a significant relationship between inhibition and metacognition scores.

Correlation coefficients calculated between inhibition, scores from MSI, prediction and evaluation scores showed that there is no significant relationship between inhibition and three metacognitive scores of participants (see Table 12). Coefficients were found as $r_s = -.02$ ($N = 212$) between inhibition and the scores obtained from MSI, $r_s = -.09$ ($N = 211$) between inhibition and prediction (calibration) scores and $r_s = -.10$ ($N = 208$) between inhibition and evaluation (postdiction-calibration) scores ($p > .01$). However, the negative coefficients showed that inhibition and metacognition scores moved in the same direction because lower inhibition score showed higher inhibitory skill as stated previously.

Table 12. Relationship between Inhibition and Metacognition: Spearman's rho Correlation

		Inhibition	Metacognition	Prediction (Calibration)
Metacognition	Correlation Coefficient	-.02		
	N	212		
Prediction (Calibration)	Correlation Coefficient	-.09	.25*	
	N	211	228	
Evaluation (Calibration)	Correlation Coefficient	-.10	.21*	.81*
	N	208	222	223

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

The correlation coefficients were computed again after the participants were grouped into three categories as high, average and low achievers depending on their problem solving performance. The students who scored higher than 5.54 (one standard deviation above the mean) were regarded as high achievers (n = 38) while the students who scored 1 or below 1 (almost one standard deviation below the mean) were regarded as low achievers (n = 55). Other students placed in the middle were named as average achievers (n = 117). In this condition, a significant relationship was found between inhibition scores and evaluation scores (post-diction calibration) of high achieving students (r_s = -.39; p = .015, n = 38). Namely, the successful students in problem solving performance test with higher inhibitory skills were found to be good at evaluating their own mathematical performance in the problem test. A significant relationship was not found between inhibition and other metacognition measures (prediction and MSI score) for high achievers. However, a significant relationship between inhibition scores and any metacognition measure was not found for both average achievers (n = 117) and low achievers (n = 55).

5.3.2 The relationship between inhibitory skills and mathematics performance of middle school students

Correlation coefficients were calculated for examining the relationship between inhibition scores and mathematics performance of students. Mathematics performance was defined through two different variables: one is the performance on problem solving test and the other is mathematics achievement score reflected on students' report cards of the previous school year. Inhibition was found negatively and significantly related with mathematics achievement scores (r_s = -.15, p =.028; N = 209, see Table 13) with a very low correlation coefficient while not significantly related with performance on problem solving test (r_s = -.10; p = .137; N = 210). In other words, the students with higher achievement scores in mathematics in the school showed higher inhibitory skills in Stroop task to some extent. No relationship was seen for the performance on problem solving test.

Table 13. Relationship between Inhibition and Mathematics Performance: Spearman's rho Correlation

		Problem Performance	Math Achievement
Inhibition	Correlation Coefficient	-.10	$-.15^{*}$
	N	210	209
Problem Performance	Correlation Coefficient		$.62^{**}$
	N		223

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).

When the students were grouped into three groups as high, average and low achievers according to problem solving performance test, a significant relationship between inhibition and problem solving performance was found for only high achievers (r_s = -.40, p = .013; n = 38). In other words, high achievers in problem solving who had higher inhibitory skills got higher scores from problem solving test.

However, mathematics achievement scores of high achievers particularly were not significantly related with inhibition (r_s = .06, p = .736, n = 38). A significant relationship between inhibition and both mathematics performance was not found for the groups of average and low achievers.

5.3.3 The relationship between metacognition and mathematics performance of middle school students

Lastly, whether there is a significant relationship between metacognition and mathematics performance of participants was examined. There were five operational definitions: three of them were measures of metacognition (score of metacognitive skill inventory, prediction score from calibration scale, and evaluation score from calibration scale) while two of them were showing mathematics performance (mathematics achievement scores, and performance on problem solving test). Because the data for each variable were not normally distributed, Spearman correlation coefficient was calculated to examine the relationship between variables (see Table 14).

Table 14. Relationship between Metacognition and Mathematics Performance

		Problem Performance	Math Achievement
Metacognition	Correlation Coefficient	.30*	.44*
	N	227	224
Prediction (Calibration)	Correlation Coefficient	.83*	.51*
	N	228	224
Evaluation (calibration)	Pearson Correlation	.74*	.42*
	N	223	219

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

Metacognition scores of students from MSI were found to be significantly related with both performance in problem solving test (r_s = .30; p <.001; N = 227) and mathematics achievement scores (r_s = .44; p <.001; N = 224). When calibration scores were used in correlational analysis, performance in problem solving test was found significantly associated with prediction scores (r_s = .83; p < .001; N = 228) and evaluation scores (r_s =.74; p <.001; N = 223). In other words, it was seen that the students who got higher scores in problem solving test judged their performance well both before and after taking problem solving test. Similarly, mathematics achievement scores of students were found significantly related with prediction scores (r_s = .51; p < .001; N = 223) and with evaluation scores (r_s = .42; p <.001, N = 219).

5.4 Regression analysis

To examine the predictor role of inhibition and metacognition in mathematics performance, a regression analysis was run on mathematics achievements and performance in problem solving test as dependent variables; metacognition, calibration and inhibition scores as independent variables. Regression model revealed that prediction and the scores from MSI predicted increases on mathematics achievement, $F(2,202)$ = 45.636, p < .001, with an R^2 of .311. According to this model, mathematics achievement scores of participants equal to 30.860 + 1.376 (Prediction) + .344 (Metacognitive skills). It was found that prediction scores (β = .41, p < .001), and metacognition scores (β = .26, p < .001) significantly predicted mathematics achievement. Furthermore, prediction by itself was found as a significant predictor of mathematics achievement with R^2 = .249 as another model (β = .499, p < .001, see Table 15).

Table 15. Predictors of Mathematics Achievement

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	R^2
		B	Std. Error	Beta			
1	(Constant)	62.041	2.206		28.118	.000	.249
	Prediction	1.670	.203	.499	8.212	.000	
2	(Constant)	30.860	7.621		4.049	.000	.311
	Prediction	1.376	.207	.412	6.646	.000	
	Metacognition	.344	.081	.264	4.259	.000	

Dependent Variable: Math Achievement

When the performance in problem solving test was taken as the dependent variable, and metacognitive skills and inhibition scores were taken as independent variables it was seen that only metacognitive skills contributed to problem solving performance with R^2 = .095, F(1,208) = 21.928, p < .001). Although metacognition was a significant predictor (β = .499, p < .001) of problem solving performance the percent of variance was low (see Table 16).

Table 16. Predictors of Problem Solving Performance

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	R^2
		B	Std. Error	Beta			
1	(Constant)	-1.030	.952		-1.082	.281	.095
	Metacognition	.045	.010	.309	4.683	.000	

Regression analysis was conducted again by including prediction and evaluation scores from calibration instrument. In this situation, there were two models found as significant predictors of problem solving performance. One was prediction scores which contribute to problem solving performance with R^2 of .813 and β = .902, F(1,206) = 896.210, p < .001. The second model showed that prediction and evaluation together contribute to problem solving performance with R^2 = .817, $F(2, 205) = 459.139$, $p < .001$. Beta values for prediction and evaluation were .790 and .130 respectively (see Table 17).

Table 17. The Contribution of Prediction and Evaluation Scores to Problem Solving Performance

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	R^2
		B	Std. Error	Beta			
1	(Constant)	.389	.121		3.207	.002	.813
	Prediction	.332	.011	.902	29.937	.000	
2	(Constant)	.234	.139		1.683	.094	.817
	Prediction	.291	.021	.790	13.545	.000	
	Evaluation	.049	.022	.130	2.222	.027	

CHAPTER 6

DISCUSSION

The role of inhibitory skills and metacognition in mathematics performance and the relationship between inhibition and metacognition were investigated in this study. Inhibition enables the person to interrupt the interference of irrelevant element in a cognitive task as an executive control function. Metacognition provides the person to plan appropriate strategies by monitoring and controlling cognitive processes. So, both has a control function implemented in cognitive tasks. Considering the roles of inhibitory skill and metacognition on math performance, the relationship between the two and their indicative roles on mathematics performance were investigated. In this study, 234 middle school students who were seventh and eighth graders participated. They were administered Metacognitive Skill Inventory (MSI) which is a self-rating metacognitive scale for measuring metacognition. Calibration skill, a metacognitive indicator, was measured through prediction and evaluation of the performance on a problem solving test. To assess mathematics performance, the scores in problem solving test including nine mathematical problems were used beside mathematics achievement scores on the report card of previous school year. Inhibitory skill was measured by a Stroop-like task asking the quantity of items reflected on the computer screen.

The first question of current research was whether there is a significant relationship between inhibitory skills and metacognition of students. The scores from the Stroop task (inhibition), Metacognitive Skill Inventory, and calibration scales (prediction and evaluation) were used to explore the association between the variables. The results showed that inhibition was significantly related with neither metacognition scores from the self-report instrument and nor calibration scores although the sign of the coefficients showed that constructs move in the same direction. Studies in the literature investigated the relationship between metacognition and executive functions mostly as a whole construct, not by separating it into subcomponents such as inhibition and shifting etc. (e.g., Bekci and Karakas 2006; Perrotin et al., 2007; Perrotin et al., 2008). They showed divergent results in examining whether there is a significant relationship between the two. Some of them found a significant relationship between inhibition and metacognition (e.g., Bryce et al., 2015; Roebers et al., 2012) while some did not.

Inhibition, as an executive function, has been studied considering the similar role with metacognition on higher order tasks in variety of studies. The results in this study showed similarities with some of the research investigating the relationship between executive functions and different metacognitive constructs (e.g., Spies, Meier, & Roebers, 2015; Tsalas, Sodian, & Paulus, 2017). It has been observed that executive functions were associated with metacognition while a significant relationship between metacognition and inhibition particularly was not observed (Spies et al., 2015; Tsalas et al., 2017). Follmer and Sperling (2016), in their study investigating the relationship between metacognition, self-regulated learning and executive functions in college students, indicated that inhibition by itself was not associated with metacognition but inhibition and shifting, another executive function, together significantly predicted metacognition. On the other hand, there are studies that found a significant relationship between different metacognitive constructs and inhibition (e.g., Bryce et al., 2015; Roebers et al., 2012). Bryce and colleagues (2015) found that inhibitory skills were significantly related with monitoring and general metacognitive skills in five-year-old students while for seven-year-old students, they found that inhibition was significantly related with only monitoring. In another study, a significant relationship was found between inhibition and metacognitive control in a spelling task for eight-year-olds, yet not with monitoring (Roebers et al., 2012).

In the current study, a significant relationship was not observed between metacognition and inhibition for the whole group. However, when the students were grouped according to their achievement on the problem test, a significant relationship was detected between inhibition and evaluation scores (calibration skill) as a metacognitive construct for high achieving students. This means that high achieving students with high inhibitory skills showed higher performance on evaluating their own mathematics performance in the problem test.

Inhibition task requires detecting and overriding the interference effect in the items. Similarly, a high evaluation score requires accurately detecting the deficiencies and attainment level in a performance. However, these processes proceed on the performance on two different tasks: problem test and Stroop task. Showing higher performance on problem solving test inspite of the interference effect in each problem is a common characteristic of students in high achieving group. This showed their success on detecting and overriding the interference effect while solving problems. They could solve most of the problems (more than five problems) correctly. Research stated that participants have higher evaluation accuracy for “simpler and well-defined” (p. 11) tasks rather than complex ones (Pieschl, 2009). Complexity of tasks as an external objective characteristic, may bias the calibration measures through the students’ own perceptions (Pieschl, 2009). Interference factor in the problem test may represent a high complexity although some problems required only one arithmetic operation. Considering the higher accuracy rate on problem solving test for high achieving group despite of the interference factor in the task, problem solving test may be regarded simpler as a reference task for high achieving students than for the other students. Similarly, inhibition task is a simpler task regarding its requirements to be completed (stating the quantity of items). Hence, the students' detection and prevention of interference on inhibition task may indicate the accuracy on judging their performance on problem test as similar simpler tasks for high achieving students.

Second research question was about the relationship between inhibition and mathematics performance. There were two measures of mathematics performance in the current study. They were mathematics achievement scores reflected on report card and the performance on the problem test. A low significant relationship was found between inhibitory skills and mathematics achievement scores (r_s = -.15), whereas performance on the problem test was not significantly related with inhibitory skills. The relationship between inhibition and attainment in variety of mathematical tasks was investigated (e.g., Bull & Scerif, 2001; Gilmore et. al, 2015; Lubin, Vidal, Lanoe, Houde, & Borst, 2013; St. Clair-Thompson & Gathercole, 2006). Many researchers found a significant relationship between mathematics measures and inhibitory skills for preschoolers (Blair & Razza, 2007; Espy, McDiarmid, Cwik, Stalets, Hamby & Senn, 2004), primary school children (Bull & Scerif, 2001; Friso-van den Bos, Van der Ven, Kroesbergen, & Von Luit, 2013; Lubin et al., 2013; St. Clair-Thompson et al., 2006) and both secondary school students and adults (Gilmore et al., 2015).

The results of the current study showed similarities with those findings considering the significant relationship revealed between inhibition and mathematics achievement scores. However, it is unclear why the performance on problem test as another mathematics performance measure was not significantly related with inhibition. The reason can be distinctive characteristics of two mathematics performance measures despite the significant correlation between the two (r_s = .62). Mathematics achievement score was a more general measure of performance of students on mathematics during the entire previous semester in comparison with problem solving performance. Problems in the problem solving test included interfering components. Problem solving process itself can require higher order thinking processes such as sorting the relevant elements in the problem, planning, and selection of the correct strategy or the operation. As Van Dooren and Inglis (2015) reported in comparison of numerical Stroop task with “Bat and Ball” problem (problem 5), these kinds of problems require more effort to solve in comparison with inhibition task because problems require some analytical work to get the correct answer beyond inhibition of intuitive answer as in Stroop Task.

When the students were grouped into three according to their performance on problem solving test, the correlation was significant between inhibition and problem-solving performance for high achievers (n = 38) which is a divergent result than the previous one with whole group. In the findings with whole group of students, inhibition was significantly related with mathematics achievement scores, not with problem solving performance. However, for the high performing group, inhibition was not significantly correlated with mathematics achievement scores. The problems in the test were regarded as complex requiring higher order thinking processes for the whole group such as detecting the interference effect, handling with that interference, and selecting the correct strategy. However, it was deduced that the students in high achieving group who showed higher performance on problem solving test (answering more than five problems correctly) were not affected from the interference of irrelevant variables in the problems as much as other students. This demonstrates that the students who are already successful on problem solving test, succeed more if they have higher inhibitory skills.

As the relationship between mathematics performance and metacognitive measures was investigated, the relationship was significant as consistent with previous findings in literature. Both metacognitive measures, the scores from MSI and calibration scores (prediction and evaluation), were significantly related with both mathematics achievement scores and problem-solving performance. The studies investigating the role of metacognition on mathematics performance have already indicated the significant relationship between the two (Desoete, 2008; Pennequin et al., 2010; Schoenfeld, 1987). Students' ability to predict their performance as a calibration score was also related with mathematics performance as consisted with the current study (Zhao, Valcke, Desoete, Zhu, & Sang, 2014). The correlation between problem solving performance and calibration scores were significantly high (prediction: $r_s = .83$; evaluation: $r_s = .74$). Mathematics achievements scores as a general mathematics performance were also significantly related with both calibration scores (prediction: $r_s = .51$; evaluation: $r_s = .42$). This is important to illustrate the relationship between mathematics performance and metacognition considering that different procedures in measuring metacognition were used as both online and offline.

Correlation coefficients showed that mathematics performance was significantly related with metacognition whereas inhibition was only related with mathematics achievement scores. When mathematics achievement scores were considered as dependent variable in regression analysis, the scores of MSI and prediction scale together explained 31% of the variance in mathematics achievement.

Another model showed that prediction scores by itself explained 25% of the variance in mathematics achievement as well. According to the results, beside general metacognitive skills of the students reported by themselves, how the students can accurately predict their performance explains their mathematics achievement. Previous research has also indicated the predictor role of metacognition on mathematics performance (Desoete, Roeyers, & Buysse, 2001; Özsoy, 2011; Veenman, Van Hout-Wolters, & Afflerbach, 2006; Zhao et al., 2014). Although there is a significant relationship between inhibition and mathematics achievement scores, inhibition was not included in any of the models in predicting mathematics achievement. This supports the findings of other studies indicating that inhibition itself did not predict mathematics performance (Miller, Müller, Giesbrecht, Carpendale & Kerns, 2013; Monette, Bigras, & Guay, 2011).

When problem solving performance was considered as dependent variable as another mathematical performance measure, the findings of the regression analysis showed a similarity. Only metacognitive skills as a variable was a significant predictor of problem-solving performance (R^2 = .095). In both analyses including mathematics achievement and problem-solving performance, metacognition was a significant predictor rather than inhibition. In the beginning of the study, the similar role of inhibition and metacognition considering their activity during cognitive processes and the findings of related literature prompted to investigate the relationship between the two. However, the findings revealed that they were not significantly related with each other and metacognition is stronger in association and prediction of mathematics performance. This illustrates the significant role of metacognition as an analytic and meta-level process in mathematics performance. Inhibition, despite the association with mathematics achievement, did not predict the mathematics performance. It would indicate that inhibition as an executive function is required to accomplish an ordinary cognitive task while metacognition as a personal disposition can put in action in variety of cognitive task to get better results (Bryce et al., 2015).

According to dual process theories, giving an intuitive response by missing the relevant item in a cognitive task is a fast and automatic process while detecting the conflict, suppressing the intuitive answer, and giving the correct answer require a slow and analytic process. Inhibition of intuitive response and finding the correct answer indicates a slower process in which analytical reasoning is active (Lem, 2015). Monitoring the output of automatic processes, being aware of the conflict and deciding whether inhibition is required or not are other processes requiring analytical reasoning called reflective mind as well (Stanovich, 2009). Considering general function of metacognition in cognitive tasks such as planning, monitoring, and evaluating, the role of metacognition on mathematics performance is observed. However, another cognitive process, inhibition, was not observed to be associated with mathematics performance in the current study. Failing to observe the predicting role of inhibition on mathematics performance may result from the existence of metacognition construct which has a wider scope of functioning in cognitive tasks than inhibition. During a mathematical task variety of metacognitive processes should be active to get a better result such as checking the knowledge about the self or strategy, selecting a strategy, monitoring, and controlling. Inhibition can be active when there is a detected conflict in a cognitive task. When there is not a conflict during a cognitive task it should be hard to observe the role of inhibition. In case of conflict, metacognition can be necessary to detect and monitor it, while to get the correct response by suppressing the incorrect one it may not enough by itself. There should be more complex cognitive processes functioning together to successfully accomplish a task.

The results revealed that inhibition and metacognition was not significantly correlated. Regarding two different mathematics performance of students, metacognitive constructs assessed in the study were significantly correlated with both mathematics performance measures while inhibition has a significant relationship only with mathematics achievement scores. Furthermore, the regression analysis showed that mathematics performance was predicted by metacognition constructs rather than inhibition. Metacognition appeared as a more important predictor of mathematics performance in general contrary to inhibition. However, a significant relationship between problem solving performance and inhibition was observed when analyzing the scores of high achieving students in problem solving test. Furthermore, inhibition was significantly correlated with evaluation (calibration) scores of high achieving students. This group of students showed divergent results in some aspect than the results of whole group in the study. This causes thinking over inhibition more when the participants are high achievers in mathematical tasks.

CHAPTER 7

CONCLUSION

The aim of the present study was to investigate the role of inhibition and metacognition on mathematics performance of middle school students and to examine the relationship between inhibition and metacognition. The idea in dual process theories was the starting point of the study. The framework asserting two different thinking processes, as automatic and analytic, is significant to investigate in mathematics education which includes various cognitive activities like reasoning, decision making, problem solving etc. Intuitions and automatic processes, which may direct the students to erroneous answers in mathematical problem solving points out inhibition concept. The control mechanism of inhibition which provides to notice the conflict among automatic and analytic processes and to suppress the erroneous automatic decisions brought out the question of whether inhibition process is related with metacognitive processes which enable people to control their cognitive processes at meta level. Moreover, the role of inhibition and metacognition on mathematics performance regarding their predictive role was investigated.

The results of the main study revealed that there is not a significant relationship between metacognition and inhibition contrary to what was hypothesized. Considering there is not a significant correlation, inhibition may be viewed as a separate construct than metacognition. However, a significant relationship between inhibition and evaluation scores (calibration) was found for only high achieving students in problem test. In this group of students, students with high inhibitory skills showed high performance in evaluating themselves about how they performed in problem solving test. This puts another question mark about whether there is a divergent case for higher achievers in mathematics performance. Grouping students according to their achievement levels in mathematical tasks may demonstrate differing cognitive processes in performing mathematics. This may cause the dissimilar results regarding the correlation between separate cognitive skills. Furthermore, the significant association was observed between inhibition and only evaluation score as a calibration score rather than other metacognitive measures in this group of students. Investigating the constructs by dividing them into sub-dimensions may reveal new associations. Focusing on the whole construct may cause to overlook some associations between other sub-dimensions of separate constructs. Hence, the relationship of inhibition can be investigated with various metacognitive constructs in future beyond focusing on high achieving students.

For examining the role of inhibition and metacognition on mathematics performance, correlation coefficients were calculated between each variable. As expected, there was a significant relationship between metacognitive constructs (metacognitive skills, prediction, and evaluation) and mathematics performance of students. This corresponds to the findings of various research reporting there is a significant relationship between mathematics achievement and metacognition. The significance in relationship between metacognition and mathematics performance was not observed in association between inhibition and mathematics performance. Inhibition was only associated with mathematics achievement scores of students with a low coefficient, not with problem solving performance. The students who have higher mathematics scores on report card of previous school year showed higher inhibitory skills. When students were grouped according to their achievement levels in problem solving test, the findings regarding the relationship between inhibition and mathematics performance differed from the ones for the whole group. For high achieving students, inhibitory skills were associated with problem solving performance, not with mathematics achievement scores. So, a discrepancy was observed in the analyses between the group of high achieving students and the whole group. It indicates that the role of inhibition may have different meanings for the students showing a distinctive achievement levels in mathematics contrary to other students showing an average performance. It may reflect different levels of processing during cognitive tasks.

The role of metacognition and inhibition on mathematics performance was also examined through regression analysis. It was observed that metacognition had a predictive role on mathematics performance in both general mathematics achievement and problem solving performance. Mathematics achievement was predicted by prediction and metacognition skills of students. Problem solving performance was predicted by metacognition in one model and prediction and evaluation together in another model. Inhibition did not contribute to any of the models. This indicates that metacognition has a comparatively major role in mathematics performance. As a slow, analytic process it contributes to the performance in various mathematical tasks. Despite of the comparative significance of metacognition revealed in the present study, the role of inhibition should not be ignored.

Limitations and Suggestions

The present study corresponds to the various research studies investigating the metacognitive processes in mathematics performance, considering the findings showing the significant relationship between metacognition and mathematics performance. Although the prediction and evaluation skills of students as calibration constructs were measured as online, metacognitive skills were assessed through an offline method with the likert-type self-rated inventory. This is one limitation of the study considering the criticisms about offline methods used for measuring metacognitive skills. Another related limitation was failing to measure different metacognitive skills by separating it into dimensions such as metacognitive control and monitoring. This would figure different associations either with mathematics performance and inhibition. Especially for investigating the relationship between inhibition and metacognition, assessment of sub-dimensions such as metacognitive control and monitoring, would reveal diversified results because inhibition itself is a process of monitoring the conflict and suppressing the automatic erroneous answers. This investigation would uncover some overlapped cognitive processes among inhibition and metacognition if there is.

Measurement of inhibition was another limitation of the study. There are various kinds of Stroop task to measure inhibition in the literature. The task in the present study was prepared as similar with two studies in mathematics literature (Bellon et al., 2016; Bull & Scerif, 2001). The task was applied to the participants on computers. So, it is a testing environment affecting from various compounding variables such as attitudes to technology (computer) and typing skills on keyword. The performance of students who feel nervous while working on computer could be affected badly. This could be reflected on their inhibition scores. Similarly, the students who are not good at typing could perform poorly on either accuracy and typing speed. In further research, controlling this compounding variable, for example by measuring it through a self-report item, may provide to have more reliable results for inhibition.

Beyond the measurement issues of metacognition and inhibition, using the current achievement levels of students in mathematics would be better regarding the time of measurement of each variable. Mathematics scores of students were taken from the report cards of previous year. So, there is a six-month interval between the mathematics achievement scores and the remaining measurements in this study. Even though these scores represent the mathematics achievement levels of students based on a whole year of studying, there may be a threat for consistency in measurement of students' achievement levels. Using the current achievement levels in mathematics would be better from a measurement perspective. Moreover, these scores were obtained two different schools. It means different teachers and assessment processes. Although the students share a common curriculum, the assessment process of mathematics achievement levels could differ than each other for each classroom. So, this could cause a small amount of error or lack of reliability in measuring mathematics achievement levels.

In exploring the association of inhibition with either metacognition and mathematics performance, the results for the whole group differed from the analyses in high achieving students. While a significant relationship was not observed between inhibition and other measures (metacognition, calibration, problem solving performance) for the group of all participants, some associations were observed between inhibition and some variables (evaluation, problem solving performance) in high achieving students. Investigating the role of these cognitive processes particularly for high achieving students in mathematics may reveal new associations in future. From this point of view, the issues of automaticity, analytic thinking processes, thinking fast and slow may be investigated especially for gifted participants. The results may clarify the links between metacognition and inhibition and the role of each cognitive function in different levels of processing. The relationship among these cognitive processes can be investigated after grouping students according to their answers to problems as well in future studies. Giving intuitive answer to problems or answering them correctly in problem solving test may reveal differing cognitive processes the students have in solving these kinds of problems. These investigations can guide the teachers and curriculum developers to get decisions on differentiated instruction and objectives for diversified groups of students.

APPENDIX A

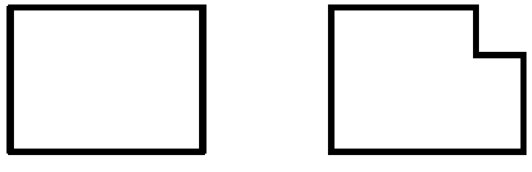
PROBLEM SOLVING TEST

1. Ali ve Berke 480 liranın tamamını kendi aralarında paylaşacaktır. Berke, Ali'ye düşen paranın yarısı kadarını alacağına göre Berke kaç lira alır? [*Alan and Bob were given $381 to share. If Bob's share was half as much as Alan's share, how much did each of them get?* (Khng &Lee, 2009)]

2. Bir okuldaki öğrenci ve öğretmenlerin toplam sayısı 168'dir. Okuldaki öğrenci sayısı öğretmen sayısının 6 katı olduğuna göre, okulda kaç öğretmen vardır? [*There are 6 times as many students as there are teachers in a school. If there are altogether 168 students and teachers, how many teachers are there?* (Khng & Lee, 2009)]

3. Bir sütçü pazartesi günleri 7 litre süt satmaktadır. Pazartesi günleri sattığı süt miktarı Pazar günü sattığı sütten 4 litre daha az olduğuna göre sütçü Pazar günleri kaç litre süt satmaktadır? [*The milkman brought on Monday 7 bottles of milk. That was 4 bottles less than he brought on Sunday. How many bottles did he bring on Sunday?* (Nesher & Teubal, 1975, p.51)]

4. Aşağıda verilen dikdörtgen şeklindeki bir kartonun sağ üst köşesinden kare şeklinde bir kısmı kesilip çıkartılıyor. Buna göre yeni durumda kartonun çevre uzunluğu ilk duruma göre nasıl değişmiştir? [*There are a rectangle and a derived polygon obtained by removal of a small square from one of the corners of the rectangle. You are requested to compare the perimeters. Is the perimeter of the obtained polygon bigger than/smaller than/ equal to the perimeter of the original rectangle?* (Babai et al., 2015)]

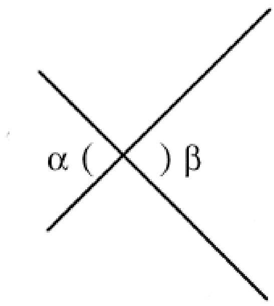


A)Artmıştır B)Azalmıştır C) Değişmemiştir

5. Bir tenis topu ve raketinin fiyatı toplamı 1.50 liradır. Tenis raketinin fiyatı, topun fiyatından 1 lira daha fazla olduğuna göre tenis raketi kaç liradır? [*A bat and a ball cost $1.10 in total. The bat costs $1.00 more than the ball. How much does the ball cost?* _____ *cents* (Frederick, 2005)]

6. Bir sütçü pazar günü 11 litre süt getiriyor. Pazar günü getirdiği süt miktarı pazartesi günü getirdiği sütten 4 litre daha fazla olduğuna göre, bu sütçü pazartesi günleri kaç litre süt getiriyordur? [*The milkman brought 11 bottles of milk on Sunday. That was 4 more than he brought on Monday. How many bottles did he bring on Monday?* (Nesher & Teubal, 1975 p.51)]

7. Aşağıda verilen iki açıyı büyüklüklerine göre karşılaştırdığınızda nasıl bir sonuç çıkar? işaretleyiniz. [*There are two intersecting lines and they form two opposite angles. You are requested to compare the angles, α and β* (Fischbein, 1999, p.17)]



A) α > β B) α < β C) α = β

8. Bir fabrikada 5 makine 5 dakikada 5 parça üretiyorsa, aynı fabrikadaki makinelerden 100 tanesi 100 parçayı kaç dakikada üretir? [*If it takes 5 machines 5 minutes to make 5 widgets, how long would it take 100 machines to make 100 widgets?* _____ *minutes* (Frederick, 2005)]

9. 1 litre meyve suyu 5 lira olduğuna göre 0,75 litre meyve suyu kaç liradır? Bu soruyu çözmek için aşağıdaki işlemlerden hangisini yaparsınız? [*One litre of juice costs 5 shekels. How much will 0.75 litre of juice cost?* (Fischbein, 1999, p.16)]

A) 5 x 0,75 B) 5 : 0,75

APPENDIX B

METACOGNITIVE SKILL INVENTORY

	Hiç (***Never***)	**Bazen** (***Sometimes***)	**Sık sık** (***Often***)	**Her zaman** (***Always***)
1. Sınavda soruları cevaplarken, nasıl düşündüğümün farkındayım. (*I am aware of my thinking while answering to the questions in the test.)*	(1)	(2)	(3)	(4)
2. Bir soruyu cevaplarken, nasıl yaptığımı kontrol ederim. (*I check my work while I am answering a question*)	(1)	(2)	(3)	(4)
3. Hangi düşünme biçimini, ne zaman kullanacağımı bilirim. (*I know which and when to use the thinking strategies*)	(1)	(2)	(3)	(4)
4. Sınavlarda hatalarımı fark eder, dönüp düzeltirim. (*I realize and correct my errors in the tests*)	(1)	(2)	(3)	(4)
5. Sınav sorularının bildiğim konularla ilgisi olup olmadığını anlamaya çalışırım. (*I ask myself if the problems in the test are related to what I already know*)	(1)	(2)	(3)	(4)
6. Sınavlarda, soruları cevaplamadan önce, ne sorulduğunu anlamaya çalışırım. (*I try to understand the test questions before I attempt to solve them*)	(1)	(2)	(3)	(4)
7. Sınavlarda gerek görürsem, düşünüş ve çözüm yollarımı değiştiririm. (*If necessary, I change my thinking and solving techniques in tests*)	(1)	(2)	(3)	(4)
8. Soruları cevaplarken doğru yapıp yapmadığımı kontrol ederim. (*I check my accuracy as I progress through the test*)	(1)	(2)	(3)	(4)

	Hiç (*Never*)	Bazen (*Sometimes*)	Sık sık (*Often*)	Her zaman (*Always*)
9. Hangi konuyu ne kadar anladığımı değerlendirebilirim. (*I am a good judge of how well I understand something*)	(1)	(2)	(3)	(4)
10. Bir sınavdaki başarımı doğru olarak tahmin edebilirim. (*I know how well I did once I finish a test*)	(1)	(2)	(3)	(4)
11. Bir bilginin benim için önemli olup olmadığını anlar,dikkatimi ona yoğunlaştırırım. (*I consciously focus my attention on important information*)	(1)	(2)	(3)	(4)
12. Hangi bilgiyi öğrenmemin daha önemli olduğunu bilirim. (*I know what kind of information is most important to learn*)	(1)	(2)	(3)	(4)
13. Kafamdaki bilgileri kolay hatırlayabileceğim bir şekilde düzenlerim. (*I organize the information in my mind so that I can easily remember them*)	(1)	(2)	(3)	(4)
14. Bir sınavda soruları çözebilmek için belirli yöntemler kullandığımın farkındayım. (*I am aware that I am using specific strategies for solving the problems in the test*)	(1)	(2)	(3)	(4)
15. Fikir sahibi olduğum bir konuyu daha iyi öğrenirim. (*I learn best when when I know something about the topic*)	(1)	(2)	(3)	(4)
16. Öğretmenin benden ne öğrenmemi beklediğini bilirim. (*I know what the teacher expects me to learn*)	(1)	(2)	(3)	(4)
17. Duruma bağlı olarak farklı öğrenme yolları kullanırım. (*I use different learning strategies depending on the situation*)	(1)	(2)	(3)	(4)
18. Bir soruyu çözdükten sonra kendime, daha kolay bir çözüm yolu olup olmadığını sorarım. (*I ask myself if there was an easier way to solve a problem after finishing the task*)	(1)	(2)	(3)	(4)
19. Daha iyi öğrenip, öğrenememem bana bağlıdır. (*I have control over how well I learn*)	(1)	(2)	(3)	(4)
20. Bir problemle karşılaştığımda bir sürü çözüm yolu düşünür, en iyisini seçerim. (*I use multiple thinking techniques/strategies to solve the test questions and choose the best one*)	(1)	(2)	(3)	(4)

	Hiç (***Never***)	**Bazen** (***Sometimes***)	**Sık sık** (***Often***)	**Her zaman** (***Always***)
21. Çalışırken hangi yöntemleri kullandığımın farkındayım. (*I am aware of what strategies I use when I study*)	(1)	(2)	(3)	(4)
22. Çalışırken kullandığım yöntemlerin işe yarayıp yaramadığını düşünürüm. (*I think about the usefulness of the strategies when I study*)	(1)	(2)	(3)	(4)
23. Bir konuyu anlayıp anlamadığımı bilirim. (*I know whether or not I understand a topic*)	(1)	(2)	(3)	(4)
24. Bir şeyi anlayıp anlamadığımı kontrol ederim. (*I check whether or not I understand something*)	(1)	(2)	(3)	(4)
25. Hangi yöntemi, nerede kullanırsam daha etkili olacağını bilirim. (*I know when each strategy I use will be most effective*)	(1)	(2)	(3)	(4)
26. Yeni öğrendiğim bir konuyu daha kolay anlayabileceğim bir hale getirmeye çalışırım. (*I try to make new information into something I can understand easier*)	(1)	(2)	(3)	(4)
27. Bir konuyu anlayamadığım zaman kullandığım yöntemi değiştiririm. (*I change strategies when I fail to understand*)	(1)	(2)	(3)	(4)
28. Sınavlarda soruları cevaplamak için gerekli olan süreyi bilir ve kendimi ona göre ayarlarım. (*I know the given time for the tests and I organize myself accordingly*)	(1)	(2)	(3)	(4)
29. Sınavlara hazırlanırken, çalıştığım konuları bölümlere ayırırım. (*When I study for a test, I break down the subjects into smaller chapters*)	(1)	(2)	(3)	(4)
30. Çalışmayı bitirdiğimde, öğrenebileceğim kadar öğrenip, öğrenmediğimi anlamaya çalışırım. (*I ask myself if I learned as much as I could have once I finish a task*)	(1)	(2)	(3)	(4)
31. Tam olarak anlamadığım konuyu tekrar ederim. (*I go back over new information that is not clear*)	(1)	(2)	(3)	(4)
32. Kafam karıştığı zaman durur ve tekrar okurum. (*I stop and reread when I get confused*)	(1)	(2)	(3)	(4)

APPENDIX C

PREDICTION SCALE

SAMPLE ITEM

Problem 6: “Bir sütçü pazar günü 11 litre süt getiriyor. Pazar günü getirdiği süt miktarı pazartesi günü getirdiği sütten 4 litre daha fazla olduğuna göre, bu sütçü pazartesi günleri kaç litre süt getiriyordur?”

Bu soru ile ilgili ne düşünüyorsunuz?

- □ Kesinlikle doğru çözeceğime eminim
- □ Bu problemi doğru çözerim
- □ Doğru çözebilirim ama hata olabilir
- □ Sanırım doğru çözemem
- □ Doğru çözemem
- □ Kesinlikle çözemeyeceğimi düşünüyorum

Problem 6: “The milkman brought 11 bottles of milk on Sunday. That was 4 more than he brought on Monday. How many bottles did he bring on Monday?”

What do you think about the problem?

- □ *I am sure that I can solve it correctly*
- □ *I can solve it correctly*
- □ *I can solve it, yet I may make a mistake*
- □ *I guess I cannot solve it correctly*
- □ *I cannot solve it correctly*
- □ *I am sure that I cannot solve it correctly*

APPENDIX D

EVALUATION SCALE

SAMPLE ITEM

Problem 6: "Bir sütçü pazar günü 11 litre süt getiriyor. Pazar günü getirdiği süt miktarı pazartesi günü getirdiği sütten 4 litre daha fazla olduğuna göre, bu sütçü pazartesi günleri kaç litre süt getiriyordur?"

Sizce cevabınız doğru mu?

- [ ] Evet, tabii ki
- [ ] Yaklaşık olarak doğru
- [ ] Sanırım doğru
- [ ] Doğru olduğunu sanmıyorum
- [ ] Doğru değil
- [ ] Kesinlikle hayır

Problem 6: "The milkman brought 11 bottles of milk on Sunday. That was 4 more than he brought on Monday. How many bottles did he bring on Monday?"

Do you think that your answer is correct?

- [ ] *Yes, I am sure*
- [ ] *It is probably correct*
- [ ] *It may be correct*
- [ ] *It may be incorrect*
- [ ] *It is not correct*
- [ ] *It is certainly incorrect*

APPENDIX E

INFORMED CONSENT FORM

Araştırmayı destekleyen kurum: Boğaziçi Üniversitesi
Araştırmanın adı: Ortaokul Öğrencilerinde Problem Çözme Performansı, Üstbilişsel Beceri ve İnhibisyon Becerileri Arasındaki İlişkinin İncelenmesi
Proje Yürütücüsü: Prof. Dr. Emine Erktin
E-mail adresi: erktin@boun.edu.tr
Telefonu: 0 212 359 45 58
Araştırmacının adı: Fatma Acar
E-mail adresi: fatma.acar@boun.edu.tr / ftmacr@gmail.com
Telefonu: 05415126004
Proje konusu: Matematik eğitimi alanındaki çeşitli çalışmalar öğrencilerin sezgisel ve çağrışımlara dayanarak cevapladıkları matematiksel problemler üzerine araştırma yapmışlardır. Öğrencilerin daha hızlı ve kolay olduğu için tercih ettiği bu düşünme biçiminin onları zaman zaman doğru cevaba ulaştırsa da bazı durumlarda hata yapmalarına da neden olmaktadır. Yalnız, öğrencilerin sahip oldukları bazı becerilerin çeşitli matematiksel görevlerdeki performansıyla ve matematik başarısıyla ilişkisi de bilimsel çalışmalarca ortaya konmuştur. Bunlardan biri üstbilişsel beceriler diğeri de inhibisyon becerisidir. Güncel matematik müfredatında da belirtilen geliştirilmesi hedeflenen üstbilşsel beceriler öğrencinin kendi düşünme süreçlerinin farkında olması ve bunları kontrol edebilmesi anlamına gelmektedir. İnhibisyon becerisi ise düşünme süreçleri sırasında çatışma yaratan, doğru çözüm yoluna müdahale eden alakasız bilgilere ya da yanıtlara karşı koyabilme, onları kontrol edebilme anlamına gelmektedir.

Bu bilgilerden yola çıkarak bu araştırmada, yedinci ve sekizinci sınıf öğrencilerinin, sezgisel düşünmeye yönlendiren problemleri çözmedeki performansı, üstbilişsel becerileri, inhibisyon becerileri ve matematik notları arasındaki ilişkinin incelenmesi amaçlanmaktadır.

Sayın veli,

Boğaziçi Üniversitesi İlköğretim bölümü yüksek lisans öğrencisi ve Matematik Öğretmeni Fatma Acar "Ortaokul Öğrencilerinde Problem Çözme Performansı, Üstbilişsel Beceri ve İnhibisyon Becerileri Arasındaki İlişkinin İncelenmesi" adı altında yüksek lisans tezi çerçevesinde bir araştırma yürütmektedir. Bu bilimsel çalışmanın amacı ortaokul öğrencilerinin üstbilişsel becerileri ve inhibisyon becerileri arasındaki ilişkiyi incelemek ve üstbilişsel becerilerin ve inhibisyon becerisinin matematiksel problem çözme performansı ve matematik başarısı ile de ilişkisini araştırmaktır. Müdürünüz okulunuzun bu çalışmaya katılmasına izin verdi. Bu araştırmada çocuğunuzun bize yardımcı olması için velisi olarak izniniz gerekmektedir. Kararınızdan önce araştırma hakkında sizi bilgilendirmek istiyoruz. Bu bilgileri okuduktan sonra çocuğunuzun araştırmaya katılmasını isterseniz lütfen bu formu imzalayıp bize ulaştırınız.

Çocuğunuzun araştırmaya katılmasını kabul ettiğiniz takdirde çocuğunuza üç farklı test uygulanacaktır. Bunlardan biri problem çözme performansını ölçen 9 soruluk bir testtir. İkinci test öğrencinin üstbilişsel becerilerini, üçüncü test de inhibisyon becerisi ölçmek için uygulanacaktır. İnhibisyon becerilerini ölçmek için uygulanan test bilgisayar ortamında olacaktır. Bu testler çocuğunuzun kendi okulunda ve kendi sınıfında ya da okulunun bilgisayar laboratuvarında uygulanacaktır.

Problemlerin olduğu test ve üstbilişsel becerileri ölçen envanter toplamda bir ders saati (40 dk) içinde cevaplandırılabilecek testlerdir. İnhibisyon becerilerini ölçmek için uygulanacak test diğer testlerle farklı bir günde yapılacaktır. Bu testin her bir öğrenci için 5-10 dakika arasında sürmesi tahmin edilmektedir.

Çocuğunuzun çalışmaya katılımı tamamen isteğe bağlıdır. Sizden ücret talep etmiyoruz ve size herhangi bir ödeme yapmayacağız. Çocuğunuz da çalışmaya katıldığı için herhangi bir şekilde ödüllendirilmeyecektir (ders notu gibi). Bununla beraber, uygulanan problem testi öğrencilerin sık yaptığı hataları fark etmeleri açısından dolaylı bir katkı sağlayabilir. Çocuğunuzun çalışmaya katılmasını kabul ettiğiniz takdirde, dilerseniz çalışmanın sonuçları ve analizi sizinle paylaşılacaktır. Öğrencinin ölçeklerde gösterdiği performans ders notlarını herhangi bir şekilde etkilemeyecektir.

Bu araştırma bilimsel bir amaçla yapılmaktadır ve katılımcı bilgilerinin gizliliği esas tutulmaktadır. Çocuğunuzun yanıtlarını ve kişisel bilgilerini içeren belgeler araştırmacı tarafından muhafaza edilip, araştırma sona erdiğinde yok edilecektir. Araştırmada çocuğunuzun kişisel bilgileri kullanılmayacaktır. Bazı öğrenci yanıtları çocukların kimliği belirtilmeden çalışmada öne sürülen bir fikri desteklemek amacıyla kullanılabilir.

Bu araştırmaya katılmak tamamen isteğe bağlıdır. Çalışmaya katılan öğrenciler çalışmanın herhangi bir aşamasında herhangi bir sebep göstermeden çalışmadan çekilme hakkına sahiptir. Çalışmadan çekilmeleri durumunda herhangi bir olumsuzlukla karşılaşmayacaklardır ve çekilen katılımcıların toplanan verileri yakılarak yok edilecektir. Bu araştırmada farklı okulları, farklı sınıfları veya farklı öğrencileri karşılaştırmadığımızı vurgulamak istiyoruz.

Eğer çocuğunuzun bu araştırma projesine katılmasını kabul ediyorsanız, lütfen bu formu imzalayıp kapalı bir zarf içerisinde bize geri yollayın.

Bu formu imzalamadan önce, çalışmayla ilgili sorularınız varsa lütfen sorun. Daha sonra Araştırma projesi hakkında ek bilgi almak istediğiniz takdirde lütfen Boğaziçi Üniversitesi Matematik ve Fen Bilimleri Eğitimi Bölümü Öğretim Üyesi Emine Erktin (Telefon: 0 212 359 45 58, Adres: Boğaziçi Üniversitesi Eğitim Fakültesi, 34342 Bebek, İstanbul) veya Boğaziçi Üniversitesi İlköğretim Bölümü Yüksek Lisans Öğrencisi Fatma Acar (Telefon: 05415126004, E-mail adresi: fatma.acar@boun.edu.tr) ile temasa geçiniz. Araştırmayla ilgili haklarınız konusunda Boğaziçi Üniversitesi İnsan Araştırmaları Kurumsal Değerlendirme Kurulu'na (İNAREK) danışabilirsiniz.

Adres ve telefon numaranız değişirse, bize haber vermenizi rica ederiz.

Bana anlatılanları ve yukarıda yazılanları anladım. Bu formun bir örneğini aldım / almak istemiyorum (bu durumda araştırmacı bu kopyayı saklar).

Çocuğumun çalışmaya katılmasını kabul ediyorum.

Katılımcı Adı-Soyadı:…………………………………..
İmzası:……………………………………………
Tarih (gün/ay/yıl):........./.........../.............

Varsa Katılımcının Vasisinin Adı-
Soyadı:..
İmzası:..
Tarih (gün/ay/yıl):........./.........../.............

18 YAŞ ALTI KATILIMCI VARSA:
Varsa Katılımcının VELİSİNİN Adı-
Soyadı:..
İmzası:..
Tarih (gün/ay/yıl):........./.........../.............

Araştırmacının Adı-Soyadı:………………………
İmzası:
Tarih (gün/ay/yıl):........./.........../...........

APPENDIX F

LETTER OF APPROVAL FROM THE ETHICS COMMITTEE

T.C.
BOĞAZİÇİ ÜNİVERSİTESİ
İnsan Araştırmaları Kurumsal Değerlendirme Alt Kurulu

26 Ekim 2017

Fatma Acar

İlköğretim

Sayın Araştırmacı,

"Ortaokul Öğrencilerinde Problem Çözme Performansı, Üstbilişsel Beceri ve İnhibisyon Becerileri Arasındaki İlişkinin İncelenmesi" başlıklı projeniz ile ilgili olarak yaptığınız SBB-EAK 2017/68 sayılı başvuru İNAREK/SBB Etik Alt Kurulu tarafından 26 Ekim 2017 tarihli toplantıda incelenmiş ve uygun bulunmuştur.

Doç. Dr. Ebru Kaya
(İZİNLİ)

Doç. Dr. Mehmet Yiğit Gürdal

Doç. Dr. Gül Sosay

Yrd. Doç. Dr. Mehmet Artemel

Dr. Nur Yeniçeri

APPENDIX G

PERMISSION FROM

ISTANBUL PROVINCIAL DIRECTORATE FOR NATIONAL EDUCATION

T.C.
İSTANBUL VALİLİĞİ
İl Millî Eğitim Müdürlüğü

Sayı : 59090411-44-E.18894465 09.11.2017
Konu: Anket ve Araştırma İzin Talebi

Sayın: Fatma ACAR

İlgi: a) 02.11.2017 tarihli dilekçeniz.
b) Valilik Makamının 08.11.2017 tarih ve 18806588 sayılı oluru.

"Ortaokul Öğrencilerinde Problem Çözme Performansı, Üstbilişsel Beceri ve İnhibisyon Becerileri Arasındaki İlişkinin İncelenmesi" konulu teziniz hakkındaki ilgi (a) dilekçe ve ekleri ilgi (b) valilik onayı ile uygun görülmüştür.

Bilgilerinizi ve söz konusu talebiniz; bilimsel amaç dışında kullanmaması, **uygulama sırasında bir örneği müdürlüğümüzde muhafaza edilen mühürlü ve imzalı veri toplama araçlarının kurumlarımıza araştırmacı tarafından ulaştırılarak uygulanılması,** katılımcıların gönüllülük esasına göre seçilmesi, araştırma sonuç raporunun müdürlüğümüzden izin alınmadan kamuoyuyla paylaşılmaması koşuluyla, gerekli duyurunun araştırmacı tarafından yapılması, okul idarecilerinin denetim, gözetim ve sorumluluğunda, eğitim-öğretimi aksatmayacak şekilde ilgi (b) Valilik Onayı doğrultusunda uygulanması ve işlem bittikten sonra 2 (iki) hafta içinde sonuçtan Müdürlüğümüz Strateji Geliştirme Bölümüne rapor halinde bilgi verilmesini rica ederim.

M. Nurettin ARAS
Müdür a.
Müdür Yardımcısı

EK:1- Valilik Onayı
2- Ölçekler

İl Milli Eğitim Müdürlüğü Binbirdirek M. İmran Öktem Cad.
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T.C.
İSTANBUL VALİLİĞİ
İl Millî Eğitim Müdürlüğü

Sayı : 59090411-20-E.18806588 08/11/2017
Konu : Anket ve Araştırma İzin Talebi

VALİLİK MAKAMINA

İlgi: a) 02.11.2017 tarihli ve 18376227 Gelen Evrak No'lu dilekçe.
b) MEB. Yen. ve Eğ. Tk. Gn. Md. 22.08.2017 tarih ve 12607291/ 2017/25 No'lu Gen.
c) Milli Eğitim Müdürlüğü Araştırma ve Anket Komisyonunun 07.11.2017 tarihli tutanağı.

Boğaziçi Üniversitesi Sosyal Bilimler Enstitüsü yüksek lisans öğrencisi Fatma ACAR'ın **"Ortaokul Öğrencilerinde Problem Çözme Performansı, Üstbilişsel Beceri ve İnhibisyon Becerileri Arasındaki İlişkinin İncelenmesi"** konulu tezi kapsamında, ilimiz Ataşehir, Beşiktaş ve Kağıthane ilçelerinde bulunan tüm özel/resmi ortaokul ve imam hatip ortaokullarında öğrenim gören öğrencilere; problem çözme performansı ölçme testi, üstbiliş anketi ve inhibisyon becerisi ölçeme testini uygulama istemi hakkındaki ilgi (a) dilekçe ve ekleri Müdürlüğümüzce incelenmiştir.

Araştırmacının söz konusu talebi; bilimsel amaç dışında kullanılmaması, **uygulama sırasında bir örneği müdürlüğümüzde muhafaza edilen mühürlü ve imzalı veri toplama araçlarının kurumlarımıza araştırmacı tarafından ulaştırılarak uygulanılması, katılımcıların gönüllülük esasına göre seçilmesi, araştırma sonuç raporunun müdürlüğümüzden izin alınmadan kamuoyuyla paylaşılmaması koşuluyla, okul idarelerinin denetim, gözetim ve sorumluluğunda, eğitim-öğretimi aksatmayacak şekilde ilgi (b) Bakanlık emri esasları dâhilinde uygulanması, sonuçtan Müdürlüğümüze rapor halinde (CD formatında) bilgi verilmesi kaydıyla** Müdürlüğümüzce uygun görülmektedir.

Makamlarınızca da uygun görülmesi halinde olurlarınıza arz ederim.

Ömer Faruk YELKENCİ
Milli Eğitim Müdürü

OLUR
08/11/2017

Dr. Osman GÜNAYDIN
Vali a.
Vali Yardımcısı

Ek:1- Genelge
2- Komisyon Tutanağı

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