SIXTH GRADE STUDENTS' CONCEPTUAL AND PROCEDURAL KNOWLEDGE AND WORD PROBLEM SOLVING SKILLS IN LENGTH, AREA, AND VOLUME MEASUREMENT

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ABSTRACT

SIXTH GRADE STUDENTS' CONCEPTUAL AND PROCEDURAL KNOWLEDGE AND WORD PROBLEM SOLVING SKILLS IN LENGTH, AREA, AND VOLUME MEASUREMENT

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The purpose of this study was to investigate sixth grade students' conceptual and procedural knowledge and word problem solving skills in the domain of length, area, and volume measurement with respect to gender, previous mathematics achievement, and use of materials. Through the Conceptual Knowledge test (CKT), the Procedural Knowledge Test (PKT), and the Word Problems test (WPT) and the Student Questionnaire, the data were collected from 445 sixth grade students attending public schools located in four different main districts of Ankara. Both descriptive and inferential statistics techniques (MANOVA) were used for the data analysis.

The results indicated that the students performed relatively poor in each test. The lowest mean scores were observed in the WPT, then CKT, and PKT respectively. The questions involving length measurement had higher mean scores than area and volume measurement questions in all tests. Additionally, the results highlighted a significant relationship not only between the tests but also between the domains of measurement with a strong and positive correlation.

According to the findings, whereas the overall performances of students on the tests significantly differed according to previous mathematics achievement level, gender did not affect the students' performance on the tests. Moreover, a wide range of mistakes were found from students' written responses to the length, area, and volume questions in the tests. Besides, the results indicated that use of materials in teaching and learning measurement was quite seldom and either low or non-significant relationship between the use of materials and the students' performance was observed.

Keywords: Conceptual and Procedural Knowledge, Word Problem Solving, Length, Area, and Volume Measurement

ÖZ

ALTINCI SINIF ÖĞRENCİLERİNİN UZUNLUK, ALAN VE HACİM ÖLÇÜLERİ KONUSUNDAKİ KAVRAMSAL VE İŞLEMSEL BİLGİLERİ VE SÖZEL PROBLEMLERİ ÇÖZME BECERİLERİ

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Çalışmanın amacı, 6. sınıf öğrencilerinin uzunluk, alan ve hacim ölçüleri konularındaki kavramsal ve işlemsel bilgilerini ve sözel problem çözme becerilerini araştırmaktır. Çalışmanın verileri, Ankara ilinin dört farklı merkez ilçesinde bulunan devlet ilköğretim okullarında öğrenim gören 445 altıncı sınıf öğrencisinden Kavram Testi, İşlem Testi, Sözel Problem Testi ve Öğrenci anketi yoluyla toplanmıştır. Elde edilen veriler betimsel ve yordamsal istatistik (Çoklu Varyans Analizi-MANOVA) yöntemleri kullanılarak analiz edilmiştir.

Bulgular, öğrencilerin testlerde oldukça düşük bir başarı gösterdiğini ortaya koymuştur. En düşük ortalama başarı, Sözel Problem Testinde bulunmuş olup, ardından Kavram Testi ve daha sonra da İşlem Testi gelmektedir. Tüm testlerde uzunluk ölçüleriyle ilgili soruların ortalaması, alan ve hacim ölçülerine göre daha yüksektir. Ayrıca, öğrencilerin hem testlerdeki başarısı arasında hem de ölçüler konusunun alt boyutları (uzunluk, alan ve hacim) arasında anlamlı, güçlü ve pozitif bir ilişki bulunmuştur. Çalışmanın bulgularına göre, öğrencilerin testlerde gösterdikleri genel başarı, önceki matematik dersi genel başarı notlarına göre anlamlı düzeyde farklılaşırken, cinsiyet açısından anlamlı bir fark bulunamamıştır. Bunun yanı sıra, öğrencilerin testlerdeki uzunluk, alan ve hacim sorularına verdikleri yazılı cevaplar incelendiğinde bir çok hata türü ile karşılaşılmıştır. Ayrıca, elde edilen bulgular, ölçüler konusunun öğretiminde materyal kullanımının oldukça nadir olduğunu ve öğrenci başarısıyla materyal kullanımı arasında düşük ya da anlamlı olmayan bir ilişki olduğunu ortaya koymuştur.

Anahtar Kelimeler: Kavramsal ve İşlemsel Bilgi, Sözel Problem Çözme, Uzunluk, Alan ve Hacim Ölçme

To my father and mother, Ali Uğur & Neriman Tan

To the loving memory of my grandfathers Hikmet Tan & Ali Kıyıcı

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INTRODUCTION

1.1 Background to the Study

Throughout the history of education, mathematical competence and literacy has always been considered as one of the most important subject areas for nations' mind power. The vital significance of mathematics for human life has been acknowledged by the National Council of Teachers of Mathematics' (NCTM) document entitled Principles and Standards for School Mathematics (2000) in the following statement

> …those who understand and can do mathematics will have significantly enhanced opportunities and options for shaping their futures. Mathematical competence opens doors to productive futures. A lack of mathematical competence keeps those doors closed (p.4).

In order to create mathematically literate societies for the 21st century, mathematics education should focus on solid understanding of mathematical concepts and skills that enable students not only to solve problems in their daily lives but also to transfer them into their future lives.

There is a great deal of agreement among mathematics educators that mathematics should be learned with understanding (Carpenter & Lehrer, 1999; Hiebert & Carpenter, 1992). According to Carpenter and Lehrer (1999), understanding is more than acquiring concepts or skills at a time. It is a complex and multifaceted mental activity that is emerged and deepened in a continuous and generative process. The vital bases of understanding are considered as one's available schema and the construction of new connections with previous knowledge (Backhouse, Haggarty, Pirie, & Stratton, 1992; Hiebert & Carpenter, 1992; Schroeder & Lester, 1989; Van De Walle, 2007). In this respect, a mathematical knowledge learned with understanding can be connected with and extended to learning new concepts/skills and applied in diverse problem settings including routine and non-routine problems. As Putnam (1987) pointed out the essential aspect of mathematical understanding is to be able to make links not only among bits of knowledge but also among other areas. Considering the place of richly connected links in the learner's mathematical understanding, the types of knowledge has continued to receive a great deal of attention and cause a lot of discussion under different conceptualizations over the last decades (Even & Tirosh, 2008).

Skemp (1978) introduced two forms of knowing in the context of mathematics and argued that these distinct types produced two different types of mathematics. The first form of knowing is instrumental understanding which means knowing "rules without reasons" (p.9) and the second was termed as relational understanding entails "knowing both what to do and why" (p.9). He claimed that instrumental mathematics is easily-grasped, context-dependent, provides immediate and concrete rewards, and enable learner to obtain the right answer quickly and reliably, whereas relational mathematics is easily-remembered, context-independent, considered as a goal in itself, and has organic schemas in quality.

Skemp's influential work stimulated the long-standing debate and discussion on how mathematics should be taught, which type of knowledge is more essential, and whether the balance between types of knowledge is needed. Especially after the publication of Hiebert's book (1986), the terms used for mathematical knowledge have been recognized mostly in the form of conceptual and procedural knowledge (Hiebert, 1986; as cited in Putnam, 1987; Star, 2000). As defined by Hiebert and

Lefevre (1986), conceptual knowledge is "connected web of knowledge" and "rich in relationships" (p.3). The development of this type of knowledge occurs when the learner is able to make connections or construct relationships between the bits of knowledge. Procedural knowledge, on the other hand, is composed of both the knowledge of mathematical symbols and the knowledge of algorithms or procedures that are "step-by-step instructions that prescribe how to complete tasks" (p.6). Hiebert and Lefevre (1986) also argued that a sound mathematical understanding includes richly interconnected structure of conceptual and procedural knowledge. Either one type of knowledge is inadequate or the relationship between them does not exist, then the learner is not considered to be fully competent in mathematics. Considering mathematics from the Skemp's view of relational understanding, Aksu (1997) asserted that both the development of learners' conceptual and procedural knowledge, and their link should be the main focus of mathematics education.

Although various definitions of knowledge of concepts and procedures have been characterized under different names such as declarative and procedural knowledge (Anderson, 1983); mechanical and meaningful knowledge (Baroody & Ginsburg, 1986); conceptual and procedural knowledge (Hiebert & Lefevre, 1986); conceptual understanding and successful action (Piaget, 1978); relational and instrumental understanding (Skemp, 1978); teleological and schematic knowledge (VanLehn, 1986), the distinctions between types of mathematical knowledge are generally overlapping and based on emphasis rather than kind (Hiebert & Lefevre, 1986).

In the mathematics education literature, several research studies conducted on conceptual and procedural knowledge have mainly tried to shed light on the following issues: (a) what is the relationship between them (b) which type of knowledge develops first (c) which is more important (d) what is the interaction between them (Hapaasalo & Kadijevich 2000; Rittle-Johnson & Siegler, 1998; Gelman & Williams, 1998; Siegler, 1991; Siegler & Crowley, 1994; Sophian, 1997; Star, 2005). Most of the researchers generally agree that conceptual and procedural knowledge, which are regarded as the critical elements of solid mathematics understanding, are positively correlated and acquired in tandem rather than separately (Hiebert & Lefevre, 1986; Rittle-Johnson & Siegler, 1998). With regards to the issues of developmental order of knowledge types and the interaction between them, Rittle-Johnson and Siegler (1998) reported that the acquisition of mathematical concepts and skills tend to differ according to context and topics. In other words, there is no such coherent theory that explains the relationship between two types of mathematical knowledge and produces consistent results (Star, 2000).

Considering mathematical strands, "measurement" has a unique place in almost all mathematics curricula because of its foundational nature and well-known importance in quantifying our world. Hart (1984) emphasized the vital importance of measurement in this way, "If teachers of mathematics were asked to choose the five or six most important topics in the school mathematics curriculum, then measurement would be likely to appear on every list" (p.16).

Measurement is an integral part of daily life and pervades mathematics programs as well as of other subject areas (Baroody, & Coslick, 1998; Hart, 1984; NCTM, 2000; Pope, 1994; Wilson & Rowland, 1992). According to Bishop (1988; as cited in Kordaki & Portani, 1998), measurement is one of the universal activities for the growth of mathematical ideas and it focuses on comparing, ordering, and quantifying qualities. Lehrer (2003) stated "Measurement is an enterprise that spans both mathematics and science but has its roots in everyday experiences" (p.179). The concepts and skills involved in measurement fill up our everyday life and are widely used in industry, engineering, architecture, physics, economy, etc. For instance, many people interact daily with measurement by finding their height, weight, the distance between two places, the space for new furniture, checking temperature, packing our briefcases, preparing our meals, or scheduling our activities (Lewis & Schad, 2006; Osborne, 1976). In the field of industry, for example, the knowledge of measurement plays a fundamental role in design, production, packaging, shipping, etc.

In this respect, measurement is one of the subject areas that have real life applications of mathematics (Clements & Battista, 2001; Reys, Suydam, & Lindquist 1989). No matter whether it is concerned with volume, area, perimeter, or time, measurement is an essential part of life (Long, 2004). Emphasizing the importance of measurement, Inskeep (1976) claimed that "The importance of measurement in our personal lives and in society is often taken for granted. The scientist knows its importance, and the engineer can't avoid it; but the average citizen sometimes fails to appreciate the role of measurement." (p.63).

In addition to its substantial involvement in our daily and professional life, measurement provides learning opportunities for students in such domains as, operations, functions, statistics, fractions, etc. (NCTM, 2000). It is conceived as a foundational bridge across mathematical strands (Clements & Battista, 2001; Davydoy, et al., 1999, as cited in Owens & Outhred, 2006). Van De Walle (2007) points out the links between the study of measurement and the other disciplines of mathematics. Figure 1 summarizes Van De Walle's ideas about the relationships between measurement and other mathematical strands.

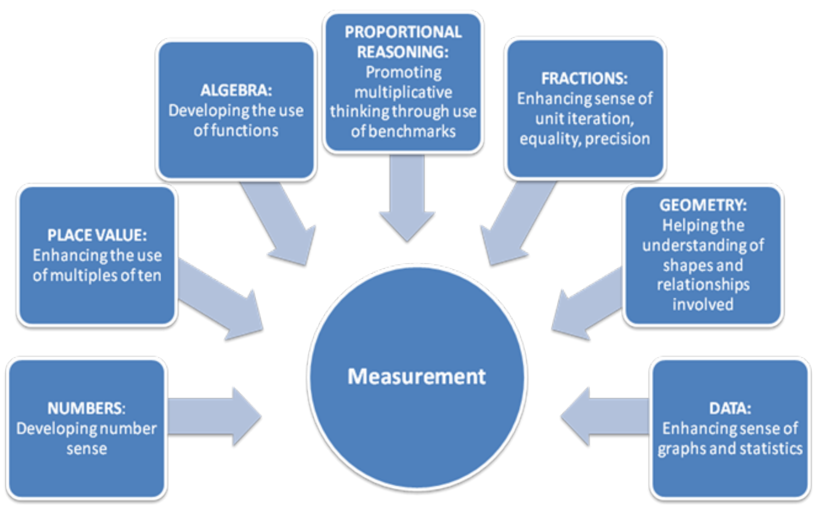


Figure 1.1 Relationships between Measurement and Other Mathematical Strands

In particular, it connects two main areas of mathematics: geometry and numbers (Clements, 1999; Clements, & Battista, 2001; Kilpatrick, et al., 2001). In other words, acquisitions of concepts and skills in measurement have potential to support developments in the domain of both real numbers and spatial relations and vice versa. Furthermore, the study of measurement is not only central in science lessons (Bladen, Wildish, & Cox, 2000; Lehrer, 2003; Lewis & Schad, 2006) but also builds links between mathematics studied in the classroom with other subject areas (NCTM, 2000). Besides, the study of measurement includes the affective area by indicating the usefulness of mathematics in everyday life so it helps students to appreciate the role of mathematics (Inskeep, 1976; NCTM, 2000).

Considering its vital role in mathematics, science, and our life, students should fully understand not only “how to measure” but also ‘what it means to measure”. However, several research studies on teaching and learning measurement has indicated that students have difficulty with the concepts of measurement (Chappell & Thompson, 1999; Kloosterman, et al., 2004; Martin & Strutchens, 2000; Robinson, Mahaffey, & Nelson, 1975). Most of the mathematics educators have agreed on that the reason behind students’ poor understanding of measurement is putting more emphasis on how to measure rather than what to measure means (Grant & Kline, 2003; Kamii & Clark, 1997). When asked for finding “volume” or “area” or “perimeter” of an object, many students automatically remember the formulas; volume is “length times width times height” or area is “length times width,” regardless of the shape involved. They plug in the numbers and perform the calculation without understanding of why or how the formula works. In the NCTM's 2003 Yearbook on Teaching and Learning Measurement, Stephan and Clements expressed the situation in this way “Something is clearly wrong with [measurement] instruction (Kamii & Clark, 1997) because it tends to focus on the procedures of measuring rather than the concepts underlying them.” (p.3).

In the current mathematics education literature, it has been reported that many students have poor and superficial understanding of length, area, and volume measurement especially. The sources of mostly-documented students' mistakes related to length measurement are due to insufficient understanding of the property being measured (Schwartz, 1995; Wilson & Rowland, 1992), of how to align a ruler (Nunes, et al., 1993; Carpenter et al., 1988; Hart, 1981; Bragg & Outhred, 2001) and of what is being counted when both informal units (Wilson & Rowland, 1992; Bragg & Outhred, 2001) and ruler are used (Bragg & Outhred, 2004).

Further, research studies have indicated that elementary and middle school students struggle to understand how length units produce area units (Kordaki & Portani, 1998; Nunes, et al., 1993). The results of the research study done by Woodward and Byrd (1983) with 8th grade students indicated that 60% of the students could not be able to distinguish the concept of area from the concept of perimeter and thought that rectangles with same perimeter cover the same area. In addition, the results of the study carried out by Chappell and Thompson (1999) revealed that middle school students had difficulty providing the explanation of why two figures could have the same area but have the different perimeter.

With regard to volume measurement, the results of Emekli's study (2001), among 744 seventh and eighth grade Turkish students, indicated that only 20% of them could be able to find the total number of unit cubes needed to fill up the rectangular box. Olkun (2003) conducted a research study to investigate 4-5-6 and 7th grade students' performance and the strategies used for finding the number of unit cubes in rectangular solids. According to the results, even 7th graders were not able to find the correct number of unit cubes in the rectangular solids. Therefore, he concluded that without understanding of unit cubes and their organizational structure in a rectangular prism, teaching the formula for volume does not make any sense to students.

As stated previously, unless procedural knowledge is supported with conceptual knowledge, the formulas and rules of mathematics are most often memorized rather than learned with understanding (Aksu, 1994; Baykul, 1999; Noss & Baki, 1996). From the perspective of conceptual knowledge, the study of measurement is full of various kinds of concepts (e.g. unit iteration, perimeter, surface area, volume, etc.). Besides, it is one of the strands that includes rich connections/relationships within its own content (e.g. understanding of area concept provides foundation for the concept of volume) and within the others (e.g. the underlying principle behind both the ruler and the number line). From the perspective of procedural knowledge, the study of measurement is also rich in terms of the skills (e.g. using tools to measure length, area, volume) and the formulas (e.g. for finding perimeter, area, volume, etc.).

Except for such nation-wide or international studies as TIMSS and NAEP, there is no research study investigating students' conceptual and procedural knowledge of length, area, and volume measurement together in Turkey. Apart from the Curry, Mitchelmore and Outhred's study (2006) which examines the concurrent development of student's understanding of length, area, and volume measurement in grades 1-4, there is also no study abroad looking into length, area, and volume measurement simultaneously. Hence, investigating students' conceptual and procedural knowledge about length, area and volume, which are the mostly-cited problematic areas in the literature, may provide insights to what accounts for the poor performance and understanding.

Moreover, the ability to solve problems in all areas of life is considered as one of the vital skills to competing in a rapidly changing world. Besides, problem solving in mathematics is "a hallmark of mathematical activity and a major means of developing mathematical knowledge" (NCTM 2000, p.116). Silver (1986) pointed out that mathematical problems are important vehicles for the development of both conceptual and procedural knowledge, as problem solving process entails the making use of both type of knowledge. Among the mathematical tasks, word problems have continued to be special part of almost all mathematics curricula and textbooks. Word problems were appeared even in ancient times (Verschaffel, Greer, & De Corte, 2000). While explaining the purposes of extensive inclusion of word problems in mathematics curricula, Verschaffel et al. (2000) stated that word problems create a context for the development of new concepts and skills if they are carefully selected and sequenced. Over the past decades, research in this area has been investigated mainly the effects of the mathematical structure, semantic structure, the context, and the format of word problems on students performance (Caldwell & Goldin, 1979; Cummins, et al., 1988; Galbraith & Haines, 2000; Gerofsky, 1996; Verschaffel et al., 2000). The topics studied in this area have been dominated with arithmetical problems especially focusing on addition and subtraction (Greer, 1992). In this respect, investigating students' performances on length, area, and volume measurement in three different contexts, namely word problems, conceptual knowledge, and procedural knowledge, might provide opportunity to diagnose their strengths and weaknesses in learning measurement specifically.

Furthermore, mathematics is a highly interrelated and cumulative subject and mathematical ideas are linked to and build on one another (NTCM, 2000). As mentioned previously, solid mathematical understanding requires for making connections or establishing relationships between existing knowledge and new information (Hiebert & Carpenter, 1992). At this point, it is obvious that students' previously learnt concepts and skills, and the relations/connections among them play a crucial role in making sense of mathematics. There have been research studies revealing that if a learner develops a well-structured mathematical knowledge schema, s/he has not only higher level of understanding in mathematics, but also can store this knowledge for a long time and retrieve when it is necessary (Cooper & Sweller,1987; as cited in Chinnappan, 2003). Besides, most of the mathematics researchers claimed that prior mathematics achievement has played an important role in students' subsequent attainment (Bandura, 1997; Pajares & Miller, 1994; Kabiri & Kiamanesh, 2004). Focusing on the study of measurement in particular, Bragg and

Outhred (2000) pointed out that having an understanding of length measurement may result in success in area and volume measurement. Since students' previous knowledge has a great impact on their future learning, it is considered as one of the variables of this study.

Moreover, tools, materials or manipulatives have also played a crucial role in students' understandings of the mathematical concepts. Numerous research studies conducted in mathematics education have supported the use of manipulatives in learning and teaching of mathematics (Bohan & Shawaker, 1994; Sowell, 1989). According to Clements (1999), students using manipulatives in their mathematics classes usually perform better than those who do not. Considering measurement strand, manipulatives are essential and not only the Principles and Standards for School Mathematics (2000) of National Council of Teachers of Mathematics but also many different mathematics curricula suggest the use of manipulatives such as rulers, paper clips, tiles, unit cubes while teaching measurement. Hence, the use of materials while teaching measurement is another variable of this study.

Furthermore, the gender gap in mathematics, historically favors boys, has been long-debated issue over the years. Research indicates that differences in mathematical achievement between boys and girls are not clear during the elementary school years, yet girls begin to fall behind boys as they move into higher grades (Fennema, 1980; Leder, 1985; Peterson & Fennema, 1985; as cited in Alkhateeb, 2001). Based on the results of the 2003 Programme for International Student Assessment (PISA), Guiso et al, (2008) argued that even though girls' mathematics scores are lower than boys' mathematics scores in general, there is a positive correlation between gender gap in mathematics and the gender equality. Whereas it is recently reported that the gender gap has declined slightly (Barker, 1997; Isiksal, & Cakiroglu, 2008; Knodel 1997) and there might be other causes accounted for the gender gap (Guiso et al, 2008), it is still a factor to be taken into consideration in this study.

With regard to the educational system, Turkey has a centralized educational system and the main body that has control over the primary and secondary education is the Ministry of National Education (MONE). Under the control of MONE, developing the school curricula, determining national education policies, and developing course books and materials are the responsibilities of the Board of Education (BOE). In such a centralized structure, all primary and secondary schools in Turkey have to follow the same national curricula developed by the BOE.

Together with the low performance of Turkish students, especially in the subject areas of mathematics and science, in such international benchmarking studies as the Trends in International Mathematics and Science Study (TIMSS-R), Progress in International Reading Literacy Study (PIRLS); and Programme for International Student Assessment (PISA) (Aksit, 2007; Babadogan & Olkun, 2006; Berberoglu,et al, 2003; Bulut, 2007; Erbas & Ulubay, 2008; OECD, 2004; PIRLS, 2001) and the start of negotiations on European Union membership, Turkish Ministry of National Education (MONE) has accelerated the reform movements and made substantial changes in the educational system. Compulsory primary education was extended from five to eight years in 1997. Secondary education, which is non-compulsory, was increased from three to four years during the academic year of 2005-2006. Furthermore, the curricular reform movements have been started with the redevelopment of the primary school curriculum for the 1st - 5th grades. The five subject areas, Turkish language, mathematics, life studies, social studies, science and technology, were renewed in line with the national needs and values, contemporary scientific-technical data and also the different interests, wishes, and capabilities of the students (MONE, 2004). After the pilot testing, the new elementary school curricula were put into practice in September 2005. Similarly, nation-wide dissemination of the newly developed curriculum for 6th, 7th, and 8th grade levels has already started with a step-wise approach in the 2006-2007 academic year.

Regarding the new mathematics curriculum, the most important differences between new and previous curriculum are considered as the shift from the subject-centered curriculum to the student-centered one and from the behaviorist way of learning to the constructivist one (Olkun & Babadogan, 2006). The ultimate goal of new mathematics curriculum is to raise mathematically competent individuals who think critically and independently, solve real life problems, reason analytically, communicate with mathematical ideas, make mathematical connections, apply mathematical knowledge and skills both in mathematical and non-mathematical contexts (MONE, 2009). With this vision of mathematics education, more emphasis is put on the development of students' conceptual knowledge and problem solving skills along with procedural (computational) fluency in the new curriculum.

Besides, in Turkey, although measurement as a subject matter is started to be taught from first grade to eighth grade, the attention given to this subject seems to be low. Considering the number of studies on measurement in the world, a few research studies have been done so far in Turkey. Most of the studies have been focused on such subjects as algebra, fractions, and geometry. So we believe that there is a need for finding out students' knowledge of measurement.

Although research has shed significant light on the how children learn measurement and how they internalize measuring process, students still have tough times while learning measurement. In this sense, investigating students' conceptual and procedural knowledge and word-problem solving performances together on length, area and volume, which are oft-cited problematic areas in measurement, may provide insights to what accounts for the poor performance and understanding. Knowing to what extent students make sense of length, area, and volume measurement and to what extent they are capable of applying the knowledge of measurement in these three domains would enable teachers and curriculum developers to design effective measurement instruction.

1.2 Purpose of the Study

The main purpose of this study was to investigate sixth grade students' conceptual and procedural knowledge and word problem solving skills in the domain of length, area, and volume measurement with respect to the selected variables (gender, previous mathematics achievement, and the use of materials). More specifically, the study focused on the determination of differences in students' performances when three domains of measurement [length, area, and volume] were assessed by different tests [concept, procedure, and word problems] and the examination of the differences and relationships among the selected variables [gender, previous mathematics achievement, and the use of materials].

This study addressed the following research problems:

1. What is the overall performance of 6^{th} grade students on the Conceptual Knowledge, Procedural Knowledge, and the Word Problems Test?

    1.1. What is the 6^{th} grade students' performance on the Conceptual Knowledge, Procedural Knowledge and Word Problems Test with regard to length measurement?

    1.2. What is the 6^{th} grade students' performance on the Conceptual Knowledge, Procedural Knowledge and Word Problems Test with regard to area measurement?

    1.3. What is the 6^{th} grade students' performance on the Conceptual Knowledge, Procedural Knowledge and Word Problems Test with regard to volume measurement?

2. Is there a significant relationship between the 6^{th} grade students' overall performance on the Conceptual Knowledge, Procedural Knowledge and Word Problems Test?
    2.1. Is there any significant relationship between the 6^{th} grade students' performance on the Conceptual Knowledge, Procedural Knowledge and Word Problems Test with regard to length measurement?
    2.2. Is there any significant relationship between the 6^{th} grade students' performance on the Conceptual Knowledge, Procedural Knowledge and Word Problems Test with regard to area measurement?
    2.3. Is there any significant relationship between the 6^{th} grade students' performance on the Conceptual Knowledge, Procedural Knowledge and Word Problems Test with regard to volume measurement?
    2.4. Is there any significant relationship between the 6^{th} grade students' performance on the Conceptual Knowledge, Procedural Knowledge and Word Problems Test with regard to length, area, and volume measurement?
3. Does 6^{th} grade students' overall performance on the Conceptual Knowledge, Procedural Knowledge and Word Problems differ according to gender?
4. Does 6^{th} grade students' overall performance on the Conceptual Knowledge, Procedural Knowledge and Word Problems differ with respect to previous mathematics achievement?
5. What are the 6^{th} grade students' common mistakes/errors in three tests with regard to length, area, and volume measurement?
6. What are the mostly-used materials while teaching/learning measurement?
    6.1. Who are mostly using the materials in measurement instruction?
    6.2. Is there any significant relationship between the 6^{th} grade students' performance on the Conceptual Knowledge, Procedural Knowledge and Word Problems Test according to whether the materials used in teaching/learning measurement?

1.3 Significance of the Study

Doing a research study on investigation of students' conceptual knowledge, procedural knowledge and word-problem solving skills in length, area, and volume measurement is valuable from several perspectives.

First of all, in field of mathematics education, most of the studies have been focused on students' competence in counting, addition, subtraction, multiplication, division, and fractions. In 2001, Glenda Lappan, the past president of the NCTM, pointed out the importance of the study of measurement in her presentation entitled with "Measurement, The Forgotten Strand" (Lewis & Schad, 2006). Although several studies have been conducted on students' understanding of measurement in different domains (e.g. length, area, volume, angle, time) so far, none of them has been conducted to examine specifically students' conceptual knowledge, procedural knowledge and word problem solving skills in the domains of length, area, and volume measurement together with respect to the selected variables (gender, the use of manipulative materials, and previous mathematics achievement). In this respect, the present study is very important in contributing to the related field.

Further, research studies in this area are rarely observed in Turkey, yet there is no research study investigating students' conceptual knowledge, procedural knowledge and word-problem solving skills in length, area, and volume measurement together in Turkey. Thus, carrying out the present study might be beneficial to the Turkish elementary school mathematics curriculum. It will be valuable to find out the deficiencies that our students have and to provide more effective ways for teaching and learning measurement. Besides, this study might initiate new research area on the study of measurement among Turkish mathematics educators and scholars.

As stated previously, unless we know well what students understand and think about measurement, we fail to design effective measurement instruction (Stephan & Mendiola, 2003; Curry, & Outhred, 2005). Providing teachers with research-based explicit knowledge about student's thinking in a specific content domain positively affects teachers' instruction and students' achievement (Carpenter, et al., 1989). Therefore, it is believed that the results of the study will offer significant suggestions and guidelines both for mathematics teachers and curriculum developers who would like to develop students' conceptual and procedural knowledge as well as their word-problem solving abilities.

1.4 Definitions of the Terms

Although the terms of this study have variously been defined in the mathematics education literature, the following definitions were chosen for this study.

Measurement

Measurement is "the assignment of a numerical value to an attribute of an object" (NTCM, 2000, p.44).

Length

Length is "a characteristic of an object and can be found by quantifying how far it is between the endpoints of the object." (Stephan & Clements, 2003, p. 3).

Length/ Linear Measurement

It is "measurement in a straight line between two points" (Schrage, 2000; p.5).

Area

Area is "the two-dimensional space inside a region" (Van De Walle, 2007, p.382).

Area measurement

It is “based on partitioning a region into equally sized units which completely cover it without gaps or overlaps” (Cavanagh, 2007, p.136).

Volume

Volume is “the amount of space occupied by, or the capacity of, a three-dimensional shape” (Lappan, et al., 2006, p. 136). Piaget and Inhelder (1967, as cited in Zembat, 2007, p.208) defined three kinds of volume as “amount of space occupied by an object (occupied volume), the capacity of a container (interior volume), and the volume of displaced water when a figure is immersed into a cup with full of water (displacement volume).”

Volume Measurement

It is “measure of the size of three-dimensional regions”, “…the capacity of container” and “… the size of solid objects.” (Van De Walle, 2007, p.387).

The Content of Measurement Strand

In the Sixth Grade National Mathematics Curriculum, the measurement unit covers the following topics: measurement of angles, length measurement, area measurement, volume measurement, and liquid measurement. There are totally 18 learning objectives and the time allocated for the attainment of these objectives is 30 hours.

Conceptual knowledge

In the literature, conceptual knowledge is defined as

- “knowledge rich in relationships, a connected web of knowledge” (Hiebert & Lefevre,1986, p. 3)
- “knowledge of and a ‘skilful’ drive along particular networks, the elements of which can be concepts, rules and even problems given in various representation forms” (Haapasalo & Kadijevich, 2000, p. 141)

- "an integrated and functional grasp of mathematical ideas." (Kilpatrick, et al., 2001, p.118)
- "the ability to show understanding of mathematical concepts by being able to interpret and apply them correctly to a variety of situations as well as the ability to translate these concepts between verbal statements and their equivalent mathematical expressions. It is a connected network in which linking relationships is as prominent as the separate bits of information." (Engelbrecht, Harding, & Potgieter, 2005, p.704).

In line with these definitions, conceptual knowledge is defined here as knowledge of mathematical concepts, ideas, and principles that are connected to knowledge networks and justifies mathematical procedures, symbols, and/or algorithms. Specifically in this study, conceptual knowledge refers to the concepts, ideas, and principles of length, area, volume measurement (e.g. perimeter, surface area, zero-concept, etc.), and their relationships.

Procedural knowledge

In the literature, procedural knowledge is characterized as

- "… composed both of the symbol representation system of mathematics and of the algorithms or rules for completing mathematical tasks" (Hiebert, & Lefevre, 1986, p. 6).
- "denotes dynamic and successful utilization of particular rules, algorithms or procedures within relevant representation form(s), which usually require(s) not only knowledge of the objects being utilized, but also knowledge of the format and syntax for the representational system(s) expressing them." (Haapasalo & Kadijevich, 2000, p. 141).
- "the ability to physically solve a problem through the manipulation of mathematical skills, such as procedures, rules, formulae, algorithms and symbols used in mathematics." (Engelbrecht, Harding, & Potgieter, 2005, p.704).

In line with these definitions, procedural knowledge refers to here as "knowledge of mathematical procedures, symbols, formulas, rules, and algorithms that are used to complete mathematical tasks in sequence of actions/steps. In the domain of measurement, procedural knowledge refers to the procedures, techniques, tools, and formulas used for measuring length, area, and volume.

Word problem

Word problem is defined "as verbal descriptions of problem situations wherein one or more questions are raised the answer to which can be obtained by the application of mathematical operations to numerical data available in the problem statement" (Verschaffel et al., 2000, p.xi).

Materials

The term "materials" used in the present study is defined as concrete objects that are used as a means of tools or manipulatives to introduce, practice, or remediate mathematical concepts and/or skills (Boggan, Harper, & Whitmire, 2010). More specifically, the concrete objects listed under the name of materials in this study are ruler, isometric paper, unit cubes, dot paper, pattern blocks, square blocks, tangram, cubes blocks, volume blocks and geometry stripes.

Previous Mathematics Achievement

In the present study, the variable named as previous mathematics achievement refers to the sixth grade students' mathematics report card grade in 5^{th} grade ranging from 5 (excellent) to 1 (needs improvement).

CHAPTER II

LITERATURE REVIEW

This part includes the presentation of previous works on conceptual and procedural knowledge; word problem solving; length, area, and volume measurement by addressing both theoretical and empirical perspectives in mathematics education. In addition, current research studies on gender gap, previous mathematics achievement, and the use of materials in mathematics education are also presented in this chapter.

2.1 Theoretical and Empirical Studies on Conceptual and Procedural Knowledge

Several theories of learning and instruction assigned the fundamental role for “knowledge” in one's cognitive development and learning process (De Jong & Ferguson-Hessler, 1996). Schneider and Stern (2006) concluded that at least two types of knowledge are shaping one’s understanding and actions: the first one is knowledge of concepts and the second is knowledge of procedures in a certain domain. A bulk of research and theory in cognitive science supports the notion that deep understanding depends on how well a learner represents and connects bits of knowledge (Kilpatrick, et al, 2001).

In the context of mathematics education, conceptual and procedural knowledge are considered as gatekeepers for a learner to understand mathematics meaningfully and become mathematically competent (Hiebert & Carpenter, 1992; Rittle-Johnson & Alibali, 1999). Putting emphasis on the connections and relationships between types of knowledge, Hiebert and Carpenter (1992) defined mathematical understanding

> A mathematical idea or procedure or fact is understood if it is part of an internal network. … the mathematics is understood if its mental representation is part of a network of representations. The degree of understanding is determined by the number and the strength of the connections. A mathematical idea, procedure, or fact is understood thoroughly if it is linked to existing networks with stronger or more numerous connections. (p.67).

Within this vision, success in mathematics relies mostly on how learners internalize the meaning related a procedure they are learning or a concept is being taught and make connections between them. Kilpatrick, et al., (2001) maintained that learning mathematics with understanding is more powerful when compared to learning by rote, since it contributes to retention, fluency and assists learning related material.

As stated in the previous chapter, conceptual and procedural knowledge have been one of the long-debated issues over the years and so, different mathematics educators have taken different positions while defining two types of knowledge under different labels/names (Even & Tirosh, 2008; Haapsaalo & Kadijevich, 2000; Hiebert &Lefevre, 1986). The following Table 2.1 presents the different labels for conceptual and procedural knowledge.

Table 2.1

Types of Knowledge under Different Labels

Author(s)	Labels
Piaget, (1978)	Conceptual understanding vs. Successful action
Skemp, (1978)	Relational understanding (knowing “what to do and why”) vs. Instrumental understanding (rules without reasons)

Table 2.1

Types of Knowledge under Different Labels (cont'd)

Author(s)	Labels
Anderson (1983)	Declarative knowledge (knowing "that") vs. Procedural knowledge (knowing "how")
Baroody & Ginsburg (1986)	Mechanical knowledge (knowledge of facts, rules and algorithms) vs. Meaningful knowledge (knowledge of concepts and principles)
Gelman & Meck (1986)	Conceptual competence (knowledge of principles) vs. Procedural competence (procedure performance)
Hiebert & Lefevre (1986)	Conceptual knowledge (connected web of knowledge) vs. Procedural knowledge (rules or procedures for solving mathematical problems)
VanLehn (1986)	Teleological knowledge (conceptual) vs. Schematic knowledge (procedural)
Gray & Tall (1993)	Proceptual thinking (use of procedure where appropriate and symbols as manipulable objects where appropriate) vs. Procedural thinking (use of procedure) (as cited in Haapsaalo & Kadijevich, 2000, p.141)

Although different forms of knowledge and skills have been described in mathematics education literature, the Hiebert's edited book (1986) titled as "*Conceptual and Procedural Knowledge: The Case of Mathematics*" provided a widely-used framework for mathematics education community while thinking and analyzing mathematical knowledge (Star, 2000).

Hiebert and Lefevre (1986) characterized conceptual knowledge as "knowledge that is rich in relationships … [and] a connected web of knowledge, a network in which the linking relationships are as prominent as the discrete pieces of information" (p. 3-4). They continued to assert that only if it is stored as a bit of knowledge connected within a network, this is conceptual knowledge. Through establishing relations, isolated bits of knowledge become a part of a network. Lawler (1981; as cited in Hiebert & Lefevre, 1986) claimed that when previously unrelated networks are integrated, a remarkable reorganization between cognitive schemas will be occurred. Assimilation of new information into the existing one will also contribute to the growth of conceptual knowledge (Baroody, et al., 2007).

In addition to providing framework for conceptual knowledge, Hiebert and Lefevre (1986) also mentioned about the two levels of relationships between pieces of conceptual knowledge in terms of abstractness. The first level is called as primary level. At this level, the link tied to the information is built at the same level of abstractness or at a less abstract level than the information itself. At the second level, named as reflective level, relationships are constructed at a higher level of abstractness than the information itself. Building relationship at reflective level requires going into a deeper process of looking back and reflecting on the pieces of knowledge being integrated.

In a broader view, Kilpatrick, et al. (2001) characterized conceptual knowledge as "an integrated and functional grasp of mathematical ideas." (p.118). They pointed out that those who understands mathematics conceptually (a) knows why a mathematical idea is important (b) applies this idea into different contexts, and (c) makes coherent organization among pieces of knowledge which results in learning new ideas. In this respect, Kilpatrick and his colleagues (2001) argued that whether a learner has deep or superficial conceptual knowledge depends on both the richness and the extent of connections that a learner has made.

On the other hand, Hiebert and Lefevre (1986) defined procedural knowledge under two distinct parts. The first part, also known as the form of mathematics, includes the knowledge of the formal language or the symbol representation systems of mathematics. Awareness of the mathematical symbols and of the syntactically acceptable rules for symbols is the main aspects of the first part. They continued to claim that knowing the characteristics of mathematical representations does not involve the knowing the meaning of them. For instance, a learner possessing knowledge of form of mathematics, might recognize that the expression $\sqrt{4}$ x Δ = 8 is an acceptable syntactic equation, even though s/he is not able to execute the equation correctly, and that $\sqrt{\quad}$ ÷ Δ 8 x = 5 is not acceptable equation.

According to Hiebert and Lefevre (1986), the second part of procedural knowledge is the knowledge of algorithms, rules, procedures “step-by-step instructions that prescribe how to complete tasks” (p.6). Hierarchical structure is considered as the main characteristic of procedural knowledge. In order to execute a procedure a learner goes through hierarchically arranged sub-procedures embedded in others. The end point is super-procedure which is defined as “an entire sequence of step-by-step prescriptions or sub-procedures” by Hiebert and Lefevre (1986, p.7). The authors also noted that not all procedures are performed at the same level.

Hiebert and Lefevre’s initial definition of knowledge types has still been fueling the debate on the characterization of “knowing how to do” and “knowing what and why”. Whereas some mathematics educators accept that conceptual knowledge refers to richly connected knowledge and procedural knowledge is sparsely connected knowledge, some of them disagree on these definitions (Baroody, et al., 2007).

Haapasalo & Kadijevich (2000) asserted that procedural knowledge is often regarded as automated and unconscious steps; in contrast, thinking consciously is generally attributed to conceptual knowledge. They criticized both the describing conceptual knowledge as static and procedural knowledge as superficial and straightforward. Based on the level of consciousness of the applied actions, Haapasalo & Kadijevich (2000) distinguished two forms of mathematics knowledge as follows:

> Conceptual knowledge denotes knowledge of and a skillful drive along particular networks, the elements of which can be concepts, rules (algorithms, procedures, etc.) and even problems (a solved problem may introduce a new concept or rule) given in various representation forms (p.141).
>
> Procedural knowledge denotes dynamic and successful utilization of particular rules, algorithms, or procedures within relevant representation form(s).This usually requires not only the knowledge of the objects being utilized, but also the knowledge of format and syntax for the representational system(s) expressing them (p.141).

Star (2000) claimed that conceptual knowledge is received much more attention and importance in the field of mathematics education, because it is considered to be generated meaningfully and required more sophisticated thinking process. Regarding the significance of procedural knowledge in the field, in his 2005 research commentary, Star argued that knowledge of procedures is generally described by such adjectives as superficial, uncomplicated and also considered to be rote learning. After examining the Hiebert and Lefevre's characterization of two knowledge types, he concluded that

> …these terms suffer from an entanglement of knowledge type and knowledge quality that makes their use somewhat problematic, especially for procedural knowledge. The term conceptual knowledge has come to encompass not only what is known (knowledge of concepts) but also one way that concepts can be known (e.g. deeply and with rich connections). Similarly, the term procedural knowledge indicates not only what is known (knowledge of procedures) but also one way that procedures (algorithms) can be known (e.g. superficially and without rich connections)… if knowledge type and knowledge quality have become conflated, then what would it mean to disentangle them?. (p.408).

Star continued to argue that the current definition of procedural knowledge does not reflect completely how procedures are known and this limited view is considered as one possible reason for ignorance of procedural knowledge in the mathematics education research. He proposed a model in which knowledge types (conceptual vs. procedural) and quality (deep vs. superficial) are separated from each other. Different from the current assumptions related to types of knowledge, he claimed that conceptual knowledge might be superficial and procedural knowledge might be deep that is knowledge of procedures "associated with comprehension, flexibility, and critical judgment is distinct from (but possibly related to) knowledge of concepts." (p.408).

Baroody and his colleagues were inspired by the Star's call for re-conceptualization of procedural knowledge and expressed their arguments and critiques in their 2007 research commentary. Although Baroody and Star meet a common ground that there is neither precise nor clear-cut characterization for both knowledge types (Star, 2007), the main disagreement between them is related to definition of deep procedural knowledge. Whereas Baroody, et al. emphasized that deep procedural knowledge cannot be achieved without conceptual knowledge, Star asserted that conceptual knowledge is not a necessary condition for deep procedural knowledge. The discussion between Star and Baroody, et al. represents the current conceptualizations of knowledge types and also clearly indicates that there will be continuous attempts to provide a well-defined framework for students' knowledge of mathematics.

2.1.1 Studies on the Relationship Between Conceptual and Procedural Knowledge

Certainly, developments and changing perspectives in the field of mathematics education, (e.g. constructivist way of learning, emphasis on mathematical learning with understanding) have great impact on how curriculum developers and policy makers shape the nature of mathematics education and curriculum (English, 2007).

Considering the fact that the relative importance of knowledge of concepts versus knowledge of procedures has generally been realized in the context of instructional programs, emphasizing one type of knowledge over the other depends on how these types of knowledge are related and valued (Hiebert &Carpenter, 1992). For instance, in the NCTM's *Principles and Standards for School Mathematics* book, it is stated that students should actively build new knowledge from existing knowledge and experience and mathematics curriculum is "more than a collection of activities: it must be coherent, focused on important mathematics, and well articulated across the grades" (p. 14). Within this vision of mathematics education, it is believed that more emphasis put on the development of conceptual underpinnings of mathematical ideas along with procedural knowledge will result in making sense of mathematics. Although the majority of mathematics educators have acknowledged the notion that both conceptual and procedural knowledge of mathematics has a very important role in learning and doing mathematics (Hiebert & Lefevre, 1986; Hiebert & Carpenter, 1992; Ohlsson & Rees, 1991; Star, 2000, Van de Walle, 2007), 'whether knowledge of concepts or procedures is the most beneficial for mathematical competency' and 'which type of knowledge develops first' have been remained as one of the long-standing discussion among mathematics educators over the years (Baroody, 2003; Byrnes & Wasik, 1991; Hiebert & Carpenter, 1992; Rittle-Johnson, & Siegler, 1998; Rittle-Johnson, Siegler, & Alibali, 2001; Star, 2000). The bulk of theoretical and research-based arguments concluded that linking conceptual knowledge with procedural knowledge and vice versa has many advantages for development of students' mathematical understanding. Hiebert and Carpenter (1992) stated that procedures enable a learner to execute mathematical tasks efficiently and previously practiced and memorized procedures are completed quickly and easily.

Even though the ability to execute procedures successfully does not require the conceptual bases behind them, building connections between procedures and their associated conceptual bases is assumed to maximize understanding (Baroody, 2003; Hiebert & Lefevre, 1986; Silver, 1986; Star, 2005). By using 'cooking' metaphor, Silver (1986) explained the linking procedural knowledge with conceptual knowledge as follows:

> …a person who knows how to prepare a meal only by following explicit cookbook directions is left almost helpless when a needed ingredient is unavailable or when the cookbook fails to be explicit about all the details; the person is unlikely to modify a recipe according to taste or to create other recipes based on one found in the cookbook. But when the person's procedural knowledge of cooking is enriched with conceptual information about the nature of spices, the role of various ingredients in the cooking process, and so on, then the person is likely to be able to apply the knowledge to novel situations (p.185).

Hiebert and Lefevre (1986) claimed that links between types of knowledge play critical role in the development of students' mathematical competence. If procedures are linked with the underlying rationale, a learner is able to give meaning for symbols, to understand how and why procedures/formulas work, and to use procedures effectively in problem solving process in which conceptual knowledge might assist learner in the selection and execution of procedures (Gelman & Meck, 1986; Hiebert &Lefevre, 1986). Similarly, Rittle-Johnson, et al. (2001) argued that with the help of conceptual bases, a learner can focus on the key features of a problem and build well-organized problem situation that might facilitate the generation and execution of the appropriate procedures in order to reach the correct answer. In other words, successful problem solving performance can be achieved through the conceptually-built problem representation (Silver, 1986).

Moreover, procedural knowledge connected with its underlying principles enables a learner to make smooth transfers in similarly structured problems, so the number of procedure transfers increases, the number of procedures needed to learn decreases (Hiebert & Lefevre (1986). Put differently, the increase in integration of types of knowledge will result in more efficient use of procedures across different problems and will expand the holder's strategy selection choices (Carpenter, 1986). As far as problem solving is concerned, conceptual support for a procedural advance is required for flexibility which is considered as "… the major cognitive requirement for solving non-routine problems" (Kilpatrick et al., 2001, p.127). When a learner gains flexibility in the selection of procedures, not only s/he becomes more flexible in the selection of strategies for various kinds of problems, but also the procedures themselves become more flexible (Carpenter, 1986). In brief, procedural knowledge without the conceptual bases is likely to generate more error-prone, inflexible, context-bounded, or fragmented outcomes (Baroody, 2003; Carpenter, 1986).

Even though benefits of conceptual knowledge on procedural knowledge have attracted more attention than benefits of procedural knowledge on conceptual knowledge, without doubt, building connections between types of knowledge promotes the development of conceptual knowledge as well. Byrnes and Wasik (1991) noted that concepts entail the organization of experiences by creating/forming networks or by making causal, temporal, or spatial connections.

Hiebert and Lefevre (1986) described the ways in which procedural knowledge can trigger the development of conceptual knowledge. Firstly, mathematical symbols based on meaningful referents might enable a learner to think about the concepts they symbolize. Since the formal symbol system of mathematics may shelter or may pack sophisticated concepts, the cognitive demand to manage the concepts might be decreased by concentrating on the symbols.

Another way that procedural knowledge enhances conceptual knowledge as described by Hiebert and Lefevre is that procedures allow the applications of concepts in problem solving situations. Anderson (1983) argued that non-routine problems initially require the conceptual knowledge. However, practicing similarly structured problems are no longer considered as non-routine and thus the knowledge that is previously conceptual might become procedural knowledge. In this respect, being competent in using procedures automatically and effectively also makes it possible to apply concepts.

In the light of abovementioned theoretical claims, it is clear that building connections between conceptual and procedural knowledge has many advantages for the development of both types of knowledge, as a result, for becoming fully competent in mathematics. The formal symbols of mathematics connected with conceptual principles are considered as a process in which the holder constructs meaning to symbols, namely, s/he makes sense of mathematical symbols. Further, mathematical procedures linked with the conceptual knowledge enhance the use of procedures effectively and help a learner to store and retrieve them easily and successfully. Linking concepts with procedures also contributes to the development of conceptual knowledge. With the help of procedural knowledge, it is also assumed that level and applicability of conceptual knowledge might be increased and thus, a learner finds opportunity to apply concepts in problem solving situations. Underlining interwoven pattern of knowledge types, Kilpatrick and his colleagues (2001) summarized the vital importance of conceptual and procedural knowledge as follows:

> …Understanding makes learning skills easier, less susceptible to common errors, and less prone to forgetting. By the same token, a certain level of skill is required to learn many mathematical concepts with understanding and using procedures can help strengthen and develop that understanding… once students have learned procedures without understanding, it can be difficult to get them to engage in activities to help them understand the reasons underlying the procedure. …Without sufficient procedural fluency, students have trouble deepening their understanding of mathematical ideas or solving mathematical problems (p.122).

Another hotly-debated issue on the relations between conceptual and procedural knowledge is related to 'which type of knowledge develops first' (Baroody, 2003; Rittle-Johnson, Siegler, & Alibali, 2001; Star 2000). There have been two opposite camps prevailing on this debate; on one side the advocates of "concepts-first" (concepts-before-skills) view; and on the other side the proponents of "skills-first" (skills-before-concepts) view (Baroody, 2003; Baroody, Lai, & Mix, 2006; Rittle-Johnson, Siegler, & Alibali, 2001).

The advocates of "conceptual knowledge before procedural knowledge" claim that conceptual knowledge in a domain is either initially developed or comes with birth. Through applying this conceptual knowledge, procedures are generated and used to solve problems (Rittle-Johnson, Siegler, & Alibali, 2001). In other words, knowledge of concepts takes the lead in the development of knowledge of procedures. Several lines of research on mathematics education have supported the developmental precedence of conceptual knowledge in different mathematical domains (Rittle-

Johnson & Alibali, 1999; Baroody, 2003). As opposed to concepts-first view, the proponents of "skills-first" (skills-before-concepts) view claimed that mathematical procedures/skills predate and highlight the mathematical concepts (Baroody, 2003). By imitating, practicing, using trial and error method, children initially learn procedures in a domain and gradually grasp domain-specific concepts through repeated practice and reflections (Baroody, 2003; Rittle-Johnson, Siegler, & Alibali, 2001; Schneider, & Stern, 2006). As the review by Rittle-Johnson and Alibali (1999) indicated that there have been research studies evidencing the precedence of procedural knowledge over conceptual knowledge in different mathematical domains.

It is obvious that the two opposite camps have the empirical evidence that proves their claims related to the developmental order of knowledge types. However, the issue has been still unsolved. Putting emphasis on complex relationships and mutual benefits, Hiebert and Lefevre (1986) stated that it is hard to draw a clear picture demonstrating the developmental order of conceptual and procedural knowledge, as defined by skills-first or concepts-first proponents. They continue to assert that the main obstacle behind the contradictory claims may lie in the difficulties in making clear distinction between types of knowledge and state "Not all knowledge can usefully described as either conceptual or procedural. Some knowledge seems to be a little of both, and some knowledge seems to be neither." (p.3). In this respect, the intractable nature of procedural and conceptual knowledge also raises the concern about assessment process in terms of validity (Schneider & Stern, 2006).

Besides, Rittle-Johnson, and her colleagues (2001) summarized the common results of the past research on the conceptual and procedural knowledge development as follows: (a) students often have both types of knowledge partially, (b) having greater knowledge of one type is correlated with greater knowledge of the other, (c) advances in one type of knowledge can lead to the improvements in the other type of knowledge. For these reasons, instead of arguing that one type of knowledge straightforwardly develops first, they concluded that knowledge of concepts and procedures might develop in a hand-over-hand process. In this respect, the third approach explaining another possible way of relationship between mathematical concepts and skills is “Iterative Model” proposed by Rittle-Johnson, et al. (2001).In this model, the relationship between knowledge types is assumed to be bi-directional, and causal, and thus, “Increases in one type of knowledge lead to gains in the other type of knowledge, which in turn lead to further increases in the first.” (p. 347). Different from other approaches, either conceptual or procedural knowledge might develop first in this iterative process. The indicator of which type of knowledge is the beginning point is student’s prior experiences (i.e. time spent on and frequency of exposure) with the domain. Rittle-Johnson, et al. (2001) exemplified this situation in the following way,

> Initial knowledge in a domain tends to be conceptual if the target procedure is not demonstrated in the everyday environment or taught in school or if children have frequent experience with relevant concepts before the target procedure is taught. In contrast, initial knowledge generally is procedural if the target procedure is demonstrated frequently before children understand key concepts or if the target procedure is closely analogues to a known procedure in a related domain (p.347).

Another important point addressed in the Iterative Model is explicit recognition of children’s partial knowledge gained previously. This recognition eliminates the assumption that a child has one kind of knowledge in a domain does not mean the other kind of knowledge is totally absent.

Furthermore, Haapasalo and Kadijevich (2000) used another strategy to explain the possible interplay between types of knowledge. Based on the review of research studies in terms of students’ performance on procedural and conceptual knowledge test items, they documented four different views that are empirically proved. Table 2.2 summarizes four relations between procedural and conceptual knowledge as outlined by Haapasalo and Kadijevich (2000, p.145):

Table 2.2

Haapasalo and Kadijevich's Classification of the Possible Relation between Types of Knowledge

Four different views	*The possible relation between types of knowledge*	*Examples from research studies*
1. Inactivation view	There is no relationship between procedural and conceptual knowledge.	Nesher (1986); Resnick & Omanson (1987)
2. Simultaneous activation view	Conceptual knowledge is both necessary and sufficient for correct use of procedures. (Byrnes & Wasik, 1991, p.778).	Byrnes & Wasik, (1991); Hiebert (1986); Haapasalo, (1993)
3. Dynamic interaction view	Conceptual knowledge is a necessary but not sufficient condition for acquiring procedural skill. (Byrnes & Wasik, 1991, p.778).	Byrnes & Wasik, (1991)
4. Genetic view	Procedural knowledge is a necessary but not sufficient for conceptual knowledge	Kline (1980); Kitcher (1983); Vergnaud (1990); Gray & Tall (1993); Sfard, (1994).

Moreover, the last twenty years or so have provided a wealth of important data about the impacts of conceptual and procedural knowledge on children's mathematics learning. Although there have been conflicting results regarding the precedence of knowledge types, most of mathematics education scholars and researchers have acknowledged the fundamental role of the conceptual and procedural knowledge in mathematical understanding.

According to Star's (2000) review of literature, researchers generally have focused on elementary school mathematics, particularly on the topics of counting, single-digit addition, multi-digit addition, and fractions. Considering the assessment of conceptual and procedural knowledge, there have been various methods used in the studies ranging from open-ended tasks to individual interviews.

Further, researchers have investigated the relationship between conceptual/procedural knowledge of students and different variables such as their cognitive styles, and confidence level, the benefits of written mathematical thought, the effects of instruction etc. (e.g. Engelbrecht et al., 2005; Kadijevich & Krnjaic, 2003; Jitendra, et al., 2002).

In the case of counting, Gelman and his associates found that preschool kids understand the conceptual bases of counting before they practice and they suggested concept-based procedural knowledge for mathematical competency (Gelman & Meck, 1983, 1986; Gelman, Meck, & Merkin, 1986).

Contrary to Gelman and his colleagues findings in the case of counting Briars and Siegler (1984) reported that preschoolers' skills of standard counting preceded their knowledge of underlying principles. Similarly, Frye and his colleagues' (1989) investigation on 4-year-old's knowledge of counting and cardinality principle yielded the supportive results with skills-first approach.

Moreover, Hiebert and Wearne (1996) reported that conceptual knowledge, in multi-digit arithmetic, enables children to use procedures correctly as well as makes it possible to predict children's future competency in procedures. In an experimental study, Byrnes and Wasik (1991) investigated effectiveness of dynamic interaction view and simultaneous activation view with a sample of 4^{th}, 5^{th}, and 6^{th} grade students in the case of fractions. The results generally favored the dynamic interaction view and indicated that conceptual principles were acquired before procedures of fractions which also support the concepts-first approach.

In order to examine the iterative development process of conceptual and procedural knowledge, Rittle-Johnson, et al. (2001) conducted an experimental study with fifth and sixth graders. Two experiments were used to examine students' learning about decimal fractions. The results indicated that not only initial knowledge of concepts predicted gains in knowledge of procedures, but also gains in knowledge of procedures predicted advancements in knowledge of concepts. Most importantly, they found that the relationship between conceptual and procedural knowledge is bidirectional and procedural knowledge has power to develop conceptual knowledge and vice versa.

In a similar point of view, Star's work (2002) on procedural flexibility in the case of equation solving indicated that the strategies and procedures used by students were clearly the signs of different levels of conceptual knowledge as reflected in their procedures. He (2000) also concluded that "…understanding in mathematics is the synthesis of knowing and doing, not the accomplishment of one in the absence of the other." (p. 89).

In summary, Resnick and Ford (1981) underlined that the attempt to explaining the relationship between skills and concepts is one of the oldest concerns among mathematics educators. The evidence from research on mathematics education favors especially the concepts-first view as well as the skills-first view. With regards to the iterative model, it is reported that gains in one type of knowledge strengthens developments of other type which consequently support gains in the first.

Consequently, it is obvious that drawing a clear picture still remains an unsolved problem in the field of mathematics education, probably due to different educational contexts, student abilities, various teaching approaches and topics chosen for studies. Considering the current theoretical and empirical claims, Table 2.3 (p.36), summarizes the views for the links between procedural and conceptual knowledge.

Table 2.3

The Views for the Links between Conceptual and Procedural Knowledge

Links between Procedural and Conceptual Knowledge	*Possible Relation between Types of Knowledge*
1. Concepts-first view	Conceptual knowledge develops before procedural knowledge
2. Procedures-first view	Procedural knowledge develops before conceptual knowledge
3. Iterative model	There are bi-directional causal and gradually developing links between conceptual and procedural knowledge.
4. Inactivation view	There is no relationship between procedural and conceptual knowledge.
5. Simultaneous activation view	Conceptual knowledge is both necessary and sufficient for correct use of procedures.
6. Dynamic interaction view	Conceptual knowledge is a necessary but not sufficient condition for acquiring procedural skill.
7. Genetic view	Procedural knowledge is a necessary but not sufficient for conceptual knowledge.

2.2 Theoretical and Empirical Studies on Length, Area, and Volume Measurement

Measurement is the fundamental and broad strand of mathematics curriculum. It is arisen from the need to quantify different attributes of objects or phenomenon (Kilpatrick, et al., 2001). Measuring is a process in which students need to make a number of decisions at the same time in order to reach a measurement. First of all, they have to decide the attribute of an object being measured. Secondly, a unit of measure being used should be determined. Then, they need to decide the strategy for measuring such as filling, covering, or iterating, and finally compare the unit with the attribute of the object or phenomenon (Van de Walle, 2007; Wilson & Rowland, 1992). In order to complete measurement process successfully, students should fully understand not only “how to measure” but also ‘what it means to measure”.

In the literature, a variety of concepts and skills has been underlined as crucial for full understanding of measurement in general. Lehrer (2003; p.181) summarized these major conceptual foundations of measurement as follow:

a) Unit-attribute relations: It is the understanding that the attribute of object being measured and the unit corresponds to each other. For example, while determining the amount of carpeting to cover a floor, the units of area are suitable but in order to find out the amount of molding for the edges of a floor, the units of length are appropriate.

b) Iteration: It is the understanding that units can be iteratively used. Subdivision and translation are the main aspects of iteration. A learner should realize that iterating a unit of length, for instance, requires for placing a unit (e.g. paper clip) successively along the object being measured.

c) Tiling (Space-filling): It is the understanding that units fill lines, planes, and volumes. For area measurement, square units are needed to be arranged successively without overlaps and gaps in order to cover the area of a plane.

d) Identical Units: It is the awareness that only if the units are identical, a count is considered as the measure. In other words, a child should know the need for identical units while measuring.

e) Standardization: It is the understanding about conventions of units. Knowing conventions about units contributes to such communication as subdivision, fractions, ratio, etc.

f) Proportionality: It is the understanding of inverse relationship between size of unit and quantity of measurement. The main idea is that different quantities measured with different-sized units will represent the same measure. For instance, a meter-long rope has a measure of 100 centimeters.

g) Additivity: It is the understanding that segments/parts of measurement can be added in order to determine the measurement of the whole. For instance, if D is any point on the segment KM, then KD + DM = KM.

h) Origin (Zero-point): It is the understanding that any location on a scale and/or ruler can serve as an origin, namely, a zero-point. For example, while measuring with a ruler, a child should know that the distance between 0 and 5 is the same as that between 15 and 20.

In addition to them, conservation, transitivity, comparing measurements, and choosing appropriate measuring tools have also been identified in the literature as other measurement principles and skills needed for students to effectively learn measurement (Barrett, et al., 2003; Grant & Kline, 2003; Stephan & Clements, 2003). Acquisition and coordination of these fundamental components outlined above establish the basis for a full understanding of measurement as well as for future mathematic learning (Lehrer, 2003; Outhred, et. al., 2003). The literature review of theoretical and empirical bases of length, area, and volume measurement is presented in the following sub-sections.

2.2.1 Studies on Length/Linear Measurement

Length measurement has a unique place in grasping the main ideas of measurement. The concepts and skills involved in length measurement are particularly essential for students' understanding of area and volume measurement as well as understanding of more advance topics taught in secondary school (Nührenbörger; 2001; Outhred, et. al., 2003; Outhred & Mitchelmore, 2000). Barret, et al., (2006) defines measuring length as "… the process of moving along an object, segmenting it, and counting the segments" (p.188). In order to successfully achieve this process, children need to acquire the key concepts identified by Stephan and Clements (2003) as presented in Figure 2 (p.39).

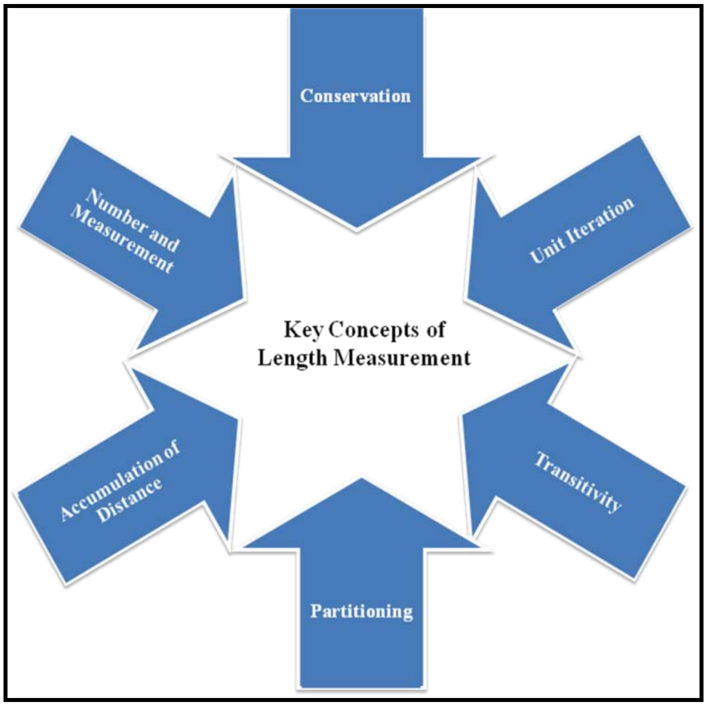


Figure 2.1 Key Concepts of Length Measurement

The first concept is “*conservation*”. It is the understanding that when an object is moved or its parts are reorganized to result in a different shape, the length of an object stays constant. Second key concept is ‘*unit iteration*” defined as “the ability to think of the length of a small block as part of a whole and to use it repeatedly” by

Kamii and Clark (1997; p.118). “*Transitivity*” is another necessary concept that is required to compare two objects where direct comparison is impossible. In order to reason transitively, a child should realize the following relationships:

a) If the length of object 1 is equal to the length of object 2 and object 2 is the same length as object 3, then object 1 is the same length as object 3;
b) If the length of object 1 is greater than the length of object 2 and object 2 is longer than object 3, then object 1 is longer than object 3;

c) If the length of object 1 is less than the length of object 2 and object 2 is shorter than object 3, then object 1 is shorter than object 3. (Stephan & Clements, 2003, p.5)

The fourth key concept is “*partitioning*” which is “the mental activity of slicing up the length of an object into the same-sized units” (Clements & Stephan, 2004; p.301). When students realize that units are partitionable, the notion that length is continuous will be grasped.

“*Accumulation of Distance*” is another key concept in length measurement. It involves the understanding that “the result of iterating a unit signifies, for students, the distance from the beginning of the first iteration to the end of the last.” (Stephan & Clements, 2003; p.5).

The last necessary concept for linear measurement is “*Relation between Number and Measurement*”. Measuring length is not just a matter of counting, it is the number obtained by counting the number of iterations and it requires not only realizing that different sized units can be used to represent the same length but also awareness of objects that are being counted to measure continuous units, not discrete units (Clements & Stephan, 2004). Overall, all of the key concepts are crucial for students to understand measurement meaningfully and thus, should be explicitly taught.

Focusing on different aspects of teaching and learning of length measurement, there has been an extensive body of research studies conducted on length measurement so far. However, the works of Piaget and his colleagues have been considered as the pioneering studies to understand the developmental progress of measurement concepts and skills (Nührenbörger; 2001; Stephan, 2003). Piaget et al., (1960; as cited in Stephan 2003) asserted that children develop the understanding of measurement by passing through a series of stages.

For instance, the development of conservation of length has three stages named as early stage, transitional stage, and operational measurement stage which generally occurs at the ages of 8-10 years. Piaget et al., (1960; as cited in Szilágyi, 2007) placed the concept of unit iteration at the heart of length measurement and they concluded that the concept of transitivity and conservation must be developed prior to measuring length. They conducted several different length measurement tasks with young children.

Considering the concept of conservation, young children were shown two sticks with the equal length as shown in Figure 2.2.a and were asked whether the length of the sticks were equal. Then, one of the sticks was moved in front the children as shown in Figure 2.2.b and the same question was asked to children again.

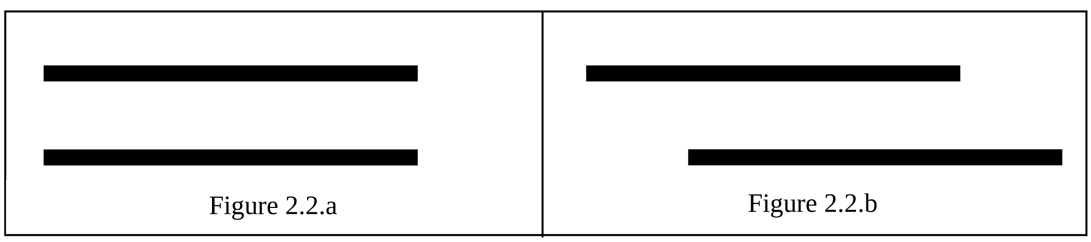


Figure 2.2 Piaget's Length Conservation Task (Stephan, 2003, p.19).

The answer for the correctness of second questioning is the indicator of whether a child is able to conserve length or not. Piaget argued that the conservation of length developed around the ages of 6 or 7 years (Piaget & Inhelder, 1972; as cited in Stephan 2003). Moreover, in the Piaget's task for the concept of transitivity as illustrated by Kamii and Clark (1997; p.118), young children were shown sticks A and B and asked to find out the longer one (Figure 2.3.a, p.42). Then, the longer stick (A) were removed and hidden; the new stick C was included in comparison (Figure 2.3.b, p.42).

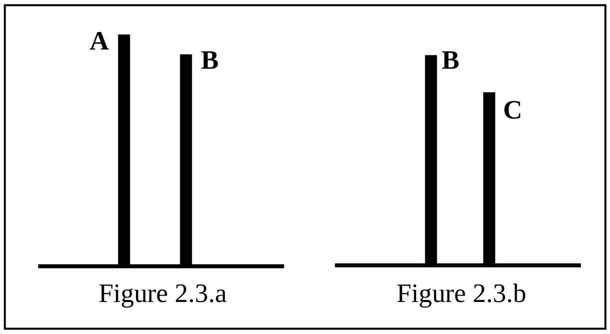


Figure 2.3 A Piagetian Task for Transitivity (Kamii & Clark, 1997; p.118)

At this time, the same question "which one is longer?" was asked to children again. Afterward, the vital question "Is the stick C longer than the stick A or vice versa" was asked to young children. Since direct comparison was not allowed, younger children were required to use third object as a referent. According to Piaget et al., (1960; as cited in Eysenck, 2004), most of children develop the concept of transitivity after the age 7 or 8 years.

The works of Piaget and his associates have been enormously influential and have sparked off numerous studies in the field. Some of the studies have been focused on two issues highlighted by Piaget, namely, the order in which children develop measurement concepts and skills, especially conservation and transitivity and the ages at which children acquire concepts and skills involved in measurement (Stephan, 2003).

Some researchers have explored children's conceptions and stages of length measurement as well as the problems and/or misconceptions that children face with during measuring process (Barrett et al., 2003; Boulton-Lewis, Wills & Mutch, 1996).

Considering the follow-up studies of Piaget, there have been both contradictory and supportive results yielded by different researchers. For instance, the work of Shantz and Smock (1966; as cited in Stephan, 2003) supported the Piaget's claims. However, Brainerd (1974) reported that 7-and 8-year-old children could reason transitively before they were able to conserve and also teaching the concept of transitivity to children 4-5 years of age was easier than teaching conservation, although Piaget et al. (1960; as cited in Eysenck, 2004) argued that conservation and transitivity were essential concepts that must be gained before measurement instruction and conservation must be acquired in order to reason transitively. Another study questioning the Piaget's claims was conducted by Hiebert (1981). Focusing on the basic abilities of length measurement (e.g. unit iteration), the lessons were taught to 32 first-grade children. The findings indicated that Hiebert's children could learn some measurement ideas before they were able to conserve or reason transitively. More recently, Kamii and Clark's research study (1997) revealed that most of children developed transitive reasoning by the age of 7-8 years that is the age reported by Piaget. They also argued that children should reason transitively before iterating a unit.

According to Clements (1999), conservation and transitivity are necessary concepts only for the understanding of inverse relationship between the unit-size and the number of the units and for grasping idea of the need for equal length units. Most researchers have acknowledged the importance of conservation and transitivity in measurement process, especially in length measurement; they have also claimed that students do not have to gain these two notions before they start to learn measurement (Stephan & Clements, 2003).

Another study done by Kamii (1991) focused on the concept of unit iteration which is considered as at the heart of any understanding of measurement (Piaget, et al., 1960; as cited in Eysenck, 2004, Stephan & Clements, 2003; Lehrer, 2003). She used the Piaget's lines experiment in which there were lines with the same length and perpendicular to one another, students were given a block to use as a measurement tool and asked to prove that one line was longer than the other. The results revealed that 10% of first grade, 33% of second grade, 55% of third grade, 76% of fourth grade and, 78% of fifth grade students could understand the concept of unit iteration.

As stated previously, the stages or levels that children go through to gain expertise in measurement is another focus of mathematics educators. Copeland (1979) stated that children's understanding of measurement moves progressively from being unable to measure correctly to developing conservation in a set of age-depended levels. A child learns the concept of a measurement unit without conservation at 6½ years of age. One year later, a child starts to understand the conservation and then, at 8 or 8 ½ year of age, s/he is able to measure successfully and efficiently. Another study aimed to find out the grade level at which length measurement should be taught to students done by Kamii (1991). Through individual interviews, the data were collected from 383 students in grades 1-5. The author concluded that since transitive reasoning was demonstrated by most of the students in second grade and unit iteration was developed in third grade, instruction for length measurement should be started in third grade.

In more recent studies, children's understanding of length measurement has been outlined in a detailed manner. Barrett and his associations conducted several research studies to investigate children's thinking about length measurement (Barrett & Clements, 2003; Barrett, Clements, Klanderman, Pennisi, & Polaki, 2006; Barrett, Jones, Thornton, & Dickson, 2003). They designed teaching experiments and individual teaching sessions involving path and perimeter tasks with the students in second grade through tenth grade. Elaboration of the results emerged from these studies; they categorized children's length understanding under hierarchical levels which starts from visual guessing for measures of length, to the inconsistent and uncoordinated use of markers as units of length, to consistent identification and iteration of units, and ends with the use of coordinated units (Barrett et al., 2006).

Further, Battista (2006) described students' reasoning about length under two different types of reasoning which are *Nonmeasurement reasoning* and *Measurement reasoning*. The first type, nonmeasurement reasoning, includes only focusing strictly on appearance, visual examination, and direct comparison about length. Therefore, this type of reasoning does not involve use of numbers. Measurement reasoning, on the other hand, "involves determining the number of unit lengths that fit end to end along and object, with no gaps or overlaps" (Battista, 2006, p. 141). He also characterized these types of reasoning about length in terms of levels of sophistication as presented in Table 2.4.

Table 2.4

Levels of Sophistication in Students' Reasoning about Length

Non-Measurement Levels	Measurement Levels
N0. Holistic visual comparison	M0: Use of numbers unconnected to unit iteration
N1. Comparison by decomposing or recomposing	M1: Incorrect unit iteration
1.1 Rearranging parts for direct comparison	M2: Correct unit iteration
1.2 One-to-one matching of pieces	M3: Operating on Iterations
N2. Comparison by property-based transformations	M4: Operating on Numerical Measurements

In addition, Boulton-Lewis et al., (1996) conducted a research study to investigate the strategies and measurement tools used by young children in the first 3 years of school. Through individual interviews, they determined children's length measurement strategies and categorized under eight groups as Visual perception; Arbitrary device; Standard device; Standard device language error; Standard device nonconventional use; Standard device arbitrary use; Mixed units; and No strategy.

The authors concluded that measuring directly and indirectly with both standard and non-standard units should be started in first grade and the construction of, and need for a standard tools should be introduced to children aged 8 or 9 year. The findings of this study also confirmed that children prefer to use a standard measurement tool even if they do not understand it fully or use it accurately.

Regarding the instructional sequence of measurement, many mathematics curriculum and mathematics educators advise to start with comparisons of length, move gradually to measurement with nonstandard units (e.g. paper clips), with manipulative standard units, and finally with standard devices (e.g. rulers) (Clements, 1999). This specific instructional sequence for length measurement follows the Piagetian tradition. He and his colleagues (1960; as cited in Eysenck, 2004) claimed that before the age of 9, instruction on length measurement was not effective, since children are not mature enough to develop certain logical reasoning abilities necessary for measuring length. Nonetheless, the lines of research proved that students' difficulties related to length measurement are probably due to ineffective instruction, rather than lack of readiness for it (e.g. Hiebert, 1981; Sophian, 2002).

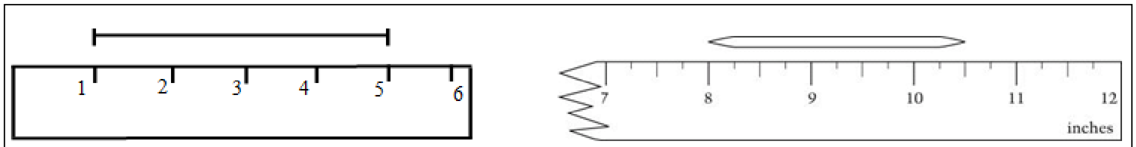
Additionally, there is a substantial body of research focused on the problems encountered by students in the learning of length measurement. Although Bryant and Nunes's study (1994; as cited in Nunes & Bryant, 1996) indicated that while comparing the length of different stripes in centimeters and inches a few numbers of 5-and 6-year-olds and most 7-year-olds knew the relationship between the unit and the number of units in the measurement, Hiebert (1984) found that first-year students were unable to recognize the inverse relation between the size of the units and the resulting measurement number.

Similarly, Lindquist's work (1989; as cited in Schrage, 2000) revealed that even 3rd and 7th graders could not recognize the inverse relationship between the unit-size and the number of the units. When Lindquist's students were asked "Sam reported the length of an object to be 8 of his units, and Sue reported that its length was 6 of her units, who did use the largest unit?", more than 50% percent of them reported that Sam was the person who used the largest unit. Furthermore, a significant number of students in the age group of 9-13 years could not conceptualize that while making iterations with a unit, the quantity being measured must be covered without overlaps or gaps (Hiebert, 1981). Students' conception of a ruler is another research topic that continues to receive great attention from mathematics educators. In 1985, Thompson and Van de Walle asserted that a majority of students could not comprehend the notion that "a ruler is an indirect method of laying down units of length end to end" (as cited in Schrage, 2000, p.17). Nührenbörger (2001) stated that in order to measure with a ruler, students only need to know aligning the ruler and reading the scale and thus, as highlighted by Stephan & Clements (2003), the hash marks on a ruler and procedures for measuring might hide the conceptual bases underlying the ruler and the physical activity. Several research reports revealed that the correct use of ruler is not the indicator of students' understanding of linear measurement (e.g. Hiebert, 1984; Bragg & Outhred, 2000).

Heraud (1989) reported that third grade students (9 years old) had difficulties related to associating the marks with the units on a ruler, especially placing the "0" mark correctly, and focusing on the number appearing on the ruler. Moreover, Kamii conducted a series of studies with elementary school students in order to shed light on students' difficulties in using rulers. In 1991, she reported that only 11% of fifth grades used the "0" on a ruler correctly. Kamii's study in 1995 indicated that half of fourth graders counted the points, instead of intervals, on the ruler. Based on the results of these studies, Kamii concluded that students' difficulties mostly arose from lack of understanding of zero-point, incorrect alignment, and counting numerals/hash marks/points, rather than intervals, on the ruler. Ellis, Siegler, and Van Voorhis, (2001; as cited in Lehrer, 2003) also reported that a majority of students from first to upper grades started to measure from one instead of zero.

In addition, Bragg and Outhred' research study (2000) investigating students' knowledge of length measurement with 120 students from grades 1-5 highlighted the same difficulties as reported by Kamii. The findings indicated that the students' strategies for measuring length with a ruler were mostly procedurally-dominated (e.g. counting units and/or marks). Although many of the students measured and drew lines correctly by grade 5, they failed the tasks which required the understanding of scale (e.g. the concept of zero-point). The results also pointed out that a few students could use informal units to construct a ruler and understand the meaning of numerals on a ruler. According to the results of the Lehrer, Jenkins, and Osana's study (1998) and the Petitto's study (1990), whereas most first to third grade students could recognize the difference between equal-interval and unequal subdivisions on rulers, they were not aware of the need for an equal subdivision when measuring. Schrage (2000) did a study that addressed to middle school students' ruler reading deficiencies. The findings indicated that sixth grade students' deficiencies were counting the lines on a ruler rather than the intervals and the lack of estimation skills, inability of dealing with fractional parts on a ruler.

Besides, students' superficial knowledge regarding length measurement has also been documented by reports announcing and discussing the results of such large-scale tests as the National Assessment of Educational Progress (NAEP) and the Trends in International Mathematics and Science Study (TIMSS). To cite examples from the NAEP, the two questions are presented below (Figure 2.4).



How long is this line segment?
(Carpenter, et al., 1981)

What is the length of the toothpick in the figure above?
(Blume, Galindo, & Walcott, 2007)

Figure 2.4 NAEP Items

Carpenter and his colleagues (1981) reported that 19 % of the nine-year-olds and 59 % of the thirteen-year-olds found the length of the line segment correctly. Besides, nearly 80% percent of students aged 9 and 40% of students aged 13 ignored the alignment of endpoints of the line and reported that the length of the line segment was 5 inches. With regard to the second question, the broken ruler, nearly 75% of fourth graders and about about 40% of eight graders answered incorrectly (Blume, Galindo, & Walcott, 2007). Similarly, only forty-one percent of 8th grade students responded correctly for the TIMSS 1999 item asking to find the length of a curved string placed on a ruler (TIMSS Report, 2001).

2.2.2 Studies on Area Measurement

The study of area measurement is one of the crucial topics of mathematics curriculum. As being one of the mostly-used domains of measurement in real life, measuring of area not only expands students' understanding of spatial measurement but also provides foundations for the development of students' understanding of multiplication, fractions, algebraic multiplication and enlargement (Sarama & Clements, 2009; Douady & Perrin, 1986; Freudenthal, 1983; as cited in Nunes & Bryant, 1996; Hirstein, Lamb & Osborne, 1978; Schultz, 1991; Outhred & Mitchelmore, 2000). Since area measurement is directly linked with the concept of number (Skemp, 1986; Steffe & Glasersfeld, 1985; as cited in Kordaki &Potari, 1998), like other domains of measurement, it allows students to see the real connections between the abstract world of numbers and the concrete world of physical objects (Hiebert, 1981).

Area is "an amount of two-dimensional surface that is contained within a boundary" (Sarama & Clements, 2009, p.293). Accordingly, area measurement is based on tiling a region with congruent two-dimensional units of measure until a region is covered completely without gaps and overlaps (Cavanagh, 2007; Reynolds and Wheatley, 1996; Stephan & Clements, 2003). According to Reynolds and Wheatley (1996), finding the area of a region is to compare this region with another region such as a square unit and during this process the following assumptions are made: (a) an appropriate two-dimensional region is chosen as a unit; (b) equally-sized regions have equal areas; (c) regions are disjoint; (d) the area of the union of these disjoint regions is the sum of their areas.

Understanding of area requires coordinating two linear dimensions to build the idea of a two-dimensional space (Clements & Battista, 2001). In this respect, it is obvious that meaningful understanding of area measurement involves the organization and coordination of various concepts and skills. Stephan and Clements (2003) stated that partitioning, unit iteration, conservation, and structuring an array are the foundational ideas of area measurement which are presented in Figure 2.5.

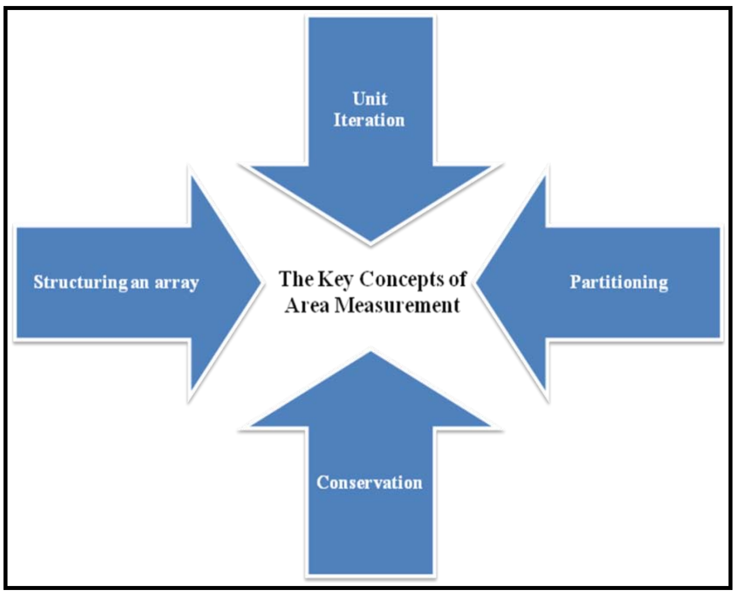


Figure 2.5 Key Concepts of Area Measurement

As stated previously, the study of length measurement includes basic concepts for area measurement as well as volume measurement. Therefore, the concept of partitioning, unit iteration and conservation requires the similar reasoning in length measurement. The concept of *partitioning* in the context of area measurement refers to "the mental act of cutting two-dimensional space with a two-dimensional unit"

(Stephan and Clements, 2003, p.11). *Unit iteration* means covering a region with two dimensional units without leaving gaps/overlaps. Another significant concept for area measurement is *conservation of area*. According to Piaget et al., (1981 as cited in Kordaki & Potari, 1998) conservation means “modification in form cannot produce change in an area” (p.406). When compared to other foundational concepts for area measurement, *structuring an array* requires more sophisticated thinking, particularly in the early years of schooling (Stephan & Clements, 2003). Outhred and Mitchelmore (2004) defined the understanding of array structure for rectangular area as:

> … the region must be covered by a number of congruent units without overlap or leaving gaps, and that a covering units can be represented by an array in which rows and columns are aligned parallel to the sides of rectangle with equal numbers of units in each (p. 465).

In a similar vein, Battista (2003) argued that students should acquire both the understanding of well-structured mental models and of meaningful enumeration of arrays of squares to construct powerful foundation for area measurement. Battista and his associates (1998; p.508-515) pointed out that students go through different levels when learning to measure and understand area. The first and lowest level is named as *complete lack of row-or column-structuring*. In this level, students cannot be able to use a row or column of squares as a composite unit. They neither accurately visualize squares in an array nor count square tiles that cover the interior of a rectangle. They only have the idea of a one-dimensional structuring which helps them to segment the rectangle, but in an unorganized manner. Secondly, in the *partial row- or column-structuring* level, students start to use a row or column as a composite unit, but cannot use it to correctly cover the entire rectangle. The Level 3 has three stages. The first stage is *structuring an array as a set of row-or column-composites* in which students comprehend the rectangular array as being covered by copies of row-or column- composites, yet they lack the coordination of these composites with orthogonal dimensions. The second stage of level 3 is v*isual row-or column-iteration.*

Students in this stage can make iteration of a row-as-composite and distribute them over the columns. Although they visually estimate the iterations in rows, the relationship between the number of squares in a column and the number of rows is fully developed in this stage. The last stage in the Level 3 is named as *row-by-column structuring: Iterative Process Interiorized.* In this final level, students correctly iterate a row and/or column by making use of the number of squares in orthogonal column or row to find out the iterations without concrete materials (i.e. square tiles).

In addition to the foundational concepts for area measurement identified by Stephan and Clements, Piaget and his colleagues (1960; as cited in Steffe, & Hirstein, 1976) designed several tasks on area and concluded that conservation of area was prerequisite for its measurement. They said "When measuring an area we assume, as we do for all measurement, that partial units are conserved and can be composed in a variety of ways to form invariant wholes" (Piaget et al., 1981, p. 262; as cited in Kordaki & Potari, 2002). Besides, they also claimed that students' conceptualization of area as a result of product of side lengths was developed approximately 12 to 13 years of age. Kordaki and Balomenou (2006) make a similar point with respect to the concept of conservation and maintained that students should be provided opportunities to explore the concept.

As stated previously, the study of area measurement requires for the integration of various concepts. In this respect, students should grasp the concept of unit, unit iteration, the counting of units and the calculation formulas so as to understand the concept of area measurement fully (Hirstein et al., 1978; Maher & Beattys, 1986; Piaget,Inhelder & Sheminska, 1981 as cited in Kordaki & Potari, 1998). In the light of above discussion, it is obvious that moving from one-dimensional conceptualization to two dimensional one entails more sophisticated thinking process.

A large body of research has attempted to shed light on students' conceptions of area measurement, the strategies used when measuring area, and the difficulties with the measurement of area. Nevertheless, the extensive amount of evidence indicated that not only elementary but also secondary school students have poor understanding of units and spatial features of area measurement.

In a study of 8 and 9 year old students' choice of a measuring unit, Héraud (1987) reported that the shape of the area to be measured played major role in the selection of the measurement unit which is usually the same shape as the measured area. Similarly, in their longitudinal study, Lehrer, et al., (1998a-b) found that a majority of students from first to third grade used units that resembled the area to be covered (e.g. squares for squares). They also observed that most of the students mixed units (e.g. squares and triangles) and reported the total number of the mixed units as the area of shape. Treating length measurement as a space-filling property and ignoring two dimensional structure of area are other important findings of Lehrer's study. Furinghetti and Paola (1999) explored 16 year old students' images and definitions of area through open-ended questions. Even though most of the students wrote various kinds of images and definitions for area, none of them provide mathematically acceptable definition of area. Another study done by Nunes, Light, and Mason (1993) explored six through ten years old children's reasoning about area. The results revealed that nine and ten years old children were much more successful to compare the areas of two shapes by using nonconventional tool, namely bricks, than by measuring length and width with the conventional tool, that is a ruler.

Kordaki and Portani (1998) attempted to investigate 6th grade students' approaches to area measurement through the project-based tasks. The results revealed that many of the students had difficulty with making connection between standard area units with standard length units. In addition, a majority of the student participated to the Kordaki and Portani's study thought that the ratio between areas is equal to the ratio between their corresponding sides.

Outhred and Mitchelmore (2000) conducted a research study focusing on students' strategies for structuring rectangular arrays. A sample of 150 students from first to fourth grades was interviewed individually on the array-based tasks. The researchers identified five developmental levels drawn from students' solution strategies explained below (p. 157-158).

Level 0: Incomplete Covering – Students couldn't completely cover the rectangle without leaving gaps or overlapping.

Level 1: Primitive Covering – Although student could be able to completely cover the rectangle without gaps or overlap, they arranged unit squares unsystematically.

Level 2: Array Covering, Constructed from Unit – Students indicated correct structure of array with equally arranged units in each row and column. However, neither the congruence between rows nor iteration of rows was fully realized by students.

Level 3: Array Covering, Constructed by Measurement – Measurement and drawing were used for determination of the number of units in direction. Iteration of rows was completely grasped by the students at this level.

Level 4: Array Implied, Solution by Calculation – Children could be able to calculate the number of units from the size of the unit and the dimensions of the rectangle without drawing. Outhred and Mitchelmore also claimed that the developmental levels indicate the achievement of four key principles for understanding of area measurement, namely, complete covering, spatial structure, size relations, and multiplicative structure.

Mulligan, Prescott, Mitchelmore, and Outhred (2005) conducted a study with 109 first grade students in order to examine students' imagery associated with the square grid pattern. The study highlighted the importance of understanding of grid structure for not only measuring area with square units but also understanding of the relation between measuring area and multiplication. According to the findings, students did not recognize the necessity of equal sized unit squares and the row-column structure of the grid. The authors stated that the instruction based on the structure of an area grid may likely eliminate students' misunderstanding and confusion of perimeter and area concepts. Battista and his colleagues (1998) made a similar point with respect to the measurement of area by arguing that understanding of equivalence of the array's rows/columns is crucial for students to construct a correct row-column structure for 2D arrays and without adequate understanding of row-by-column structure in arrays; it is too difficult for students to make sense of area formula.

Moreover, there is a great deal of research on students' understanding of area and perimeter and their relationships and the results have consistently indicated that most of the students across all grades, even college level, have difficulties when measuring the areas of two dimensional shapes as well as measuring perimeters. Twenty years ago, Hirstein, Lamb, and Osborne (1978) conducted a research study to identify students' common misconceptions about area. Totally 106 students in 3rd, 4th, 5th, and 6th grades were interviewed on the area-related items. They determined five common misconceptions specific to area measurement as (1) Using the length of one dimension to make area judgments; (2) Using primitive compensation methods; (3) Point-counting for area; (4) Counting around the corner; and (5) Point-counting linear units. They stated that the poor understanding of a unit, its space-covering feature, and the conservation of area were main causes for the students' misconceptions about area.

Further, Woodward and Bryd (1983) found that almost two-thirds of the 8th grade students involved in their study believed that rectangles with the same perimeter occupy the same area. Stone (1994) also interested in middle school students understanding of conceptual knowledge regarding area and perimeter and designed a classroom activity with using the Geometer's Sketchpad to help students deepen their understandings of area and perimeter and their relationships. Twenty-six 8th grade students and their teacher were involved in the study. At the beginning of the activity, students were given a problem which asked to find which shape has the largest area with the same perimeter and the students' answers indicated that they believed the shape with the same perimeter has the same area. Through using the Geometer's Sketchpad software and discussing the conjectures, Stone (1994) argued that the students had a strong conceptual knowledge of perimeter and area relationship at the end of the activity. Similarly, Cavanagh (2008) reported that 7^{th} grade students not only confused area and perimeter but also had struggles to understand the relationship between the areas of rectangles and triangles whose area is equal to the half of the rectangle sharing a common base and perpendicular height. Moyer (2001) expressed the importance of learning the concept of area and perimeter with understanding by stating:

> Students often confuse perimeter and area because the topics are learned only as sets of procedures. When children's understanding of perimeter and area rests only on procedures, they may misunderstand these important measurement ideas. If meaning is attached to each of these ideas, however, confusion can be eliminated because the measures are obviously different: one is the number of length units that fits around the figure, and the other is the number of square units enclosed by the figure (p.52).

Further, Vergnaud's study (1983) also revealed that 7^{th} grade students had trouble with linking the use of multiplication to spatial structuring of rectangular arrays of squares. A study done by Dickson (1989) clearly demonstrated the strong tendency among students to apply the rectangular area formula for all contexts, not considering the shape. Besides, using formula for area and perimeter correctly without knowing what length/width/height stands for becomes also evident in the Kidman and Cooper's study (1997) and the Zacharos' study (2006). In the former study, most of the middle grade students answer correctly the area and perimeter questions calling for use of formula, yet they confused the area concept with the concept of perimeter. The findings of the latter study indicated that although 11 year old students were good at using the formula to calculate the area of the rectangle, they could not be able to understand what this numerical result stands for. In the same study, Zacharos also categorized the most common error-prone strategies that students used for calculating the area under three groups: (a) the area=base × height (or length × width) strategy, (b) the area=base + height strategy, and (c) the strategy of finishing figures off.

Another research study carried out by Kamii and Kysh (2006) focused on the use of a square for area measurement. Totally 292 students from 4th, 6th, 8th, and 9th grades were interviewed individually through different tasks involving the use of a square for area and for space-covering. The results indicated that most of the students in 4th grade through 8th grade did not consider a square as a unit of area measurement. For the space-covering characteristic of a square, almost half of the eight grade students believed that a square has discrete characteristic without any space-filling function. Further, 33% of eight graders could not be able to conserve the area of a shape when it was rearranged. Based on the results, the authors believed that in order to understand the formula "length x width" first of all, students should have a clear and meaningful understanding of the continuous nature of lengths and areas. Otherwise, expecting students to make sense that how the multiplication of length and width can produce area is unrealistic.

Although the use of square units is often suggested solution for eliminating students' difficulty with the understanding of area formula, empirically covering different rectangles with squares and counting the number of squares covered a shape might not result in enabling students to think about the meaning of a square as a unit for area. However, Zacharos' study (2006) pointed out that using square units for measuring area was more effective than using ruler. Additionally, many students, even adults at least at first thought, might think that a fixed perimeter covers same area regardless of shapes (Wiest, 2005). Furinghetti and Paola's study (1999) revealed that 7th grade students believed that the relationship between area and perimeter is direct.

The large-scale tests have also outlined students' shallow knowledge about area measurement. For instance, only 19% of the fourth grades and 65% of the eighth graders correctly answered the following question "A rectangular carpet is 9 feet long and 6 feet wide. What is the area of the carpet in square feet?" (Kenney & Kouba, 1997). Another example taken among the TIMSS 1999 released items which asks 8th grade students to find the area of rectangle inside parallelogram. While the international average percentage of the correct response for this question is only 43, among those who failed to answer correctly 18% of them calculated the perimeter, instead of the area (TIMSS Report, 2001).

2.2.3 Studies on Volume Measurement

Like other domains of measurement, volume measurement is a significant topic in mathematics curricula from elementary to high school levels. The study of volume measurement provides rich context for extension of students' knowledge about arithmetic, geometric reasoning and spatial structuring (Battista, 1998; Battista & Clements, 1998; Lehrer, Jaslow & Curtis, 2003).

In a simple form, volume is defined as "… measure of the size of three-dimensional regions", "…the capacity of container" and "… the size of solid objects." (Van De Walle, 2007, p.387). According to Battista (2003), measuring volume refers to the total number of cubes in the region being measured. However, with the involvement of a third dimension, the measurement of volume requires more complex reasoning about the structure of space (Lehrer, 2003) than measuring two or one dimensional regions. In addition, the nature of the materials measured might cause difficulties in students' understanding of volume measurement, since "… solid units are "packed," such as cubes in three-dimensional array, whereas a liquid "fills" three-dimensional space, taking the shape of the container." (Sarama & Clements, 2009, p. 304).

For grasping any mathematical concept or skill, students need to make sense of the foundational principles behind them. As important as for the understanding of length and area measurement, conservation is also essential concept to internalize volume measurement. Piaget’s works (1960; as cited in Steffe and Hirstein, 1976, p.47-48) pointed out three kinds of volume, namely, internal volume (the number of units inside the boundary of a spatial region), occupied (the amount of room taken up by the total region), and displacement volume (the amount of water displaced by the region). As claimed by Piaget, conservation of volume including all types is achieved at about 12 years old.

Zembat (2007) underlined the importance of gaining competence in all of these types of volume and a coordination of them by stating “since they all refer to the measurement of the amount that quantifies an attribute (volume) of a three dimensional figure.” (p.208). Ben-Haim, Lappan, and Houang (1985) pointed out that the study of volume measurement directs students to visualize and to read the information embedded in the representations of solid objects and thus, the ability of spatial visualization, that is being able to mentally manipulate rigid figures, is considered as one of the vital skills.

Furthermore, Battista and his colleagues (1996; 1998; 1999; 2003) attributed a fundamental role to enumeration of arrays of cubes for gaining competence in volume measurement. Besides, it is also asserted by Battista (2003, p.122) that meaningful enumeration of arrays requires four mental processes which are forming and using mental models, spatial structuring; units-locating, and organizing-by-composites.

The forming and using mental models enable learner to create, use, or recall previously-experienced mental representations so as to visualize, comprehend, and reason about situations. Secondly, spatial structuring is “the mental act of constructing an organization or form for an object or set of objects.” (Battista, 1999, p.418). Unit-locating is another fundamental process for students to understand three-dimensional array structure. It assists learner to locate cubes and their composites through coordinating their locations along the dimensions of an array. The last mental process for establishing properly structured and enumerated arrays of cubes is organizing-by-composites which is defined as " combines an array's basic units into a more complicated, composite units that can be repeated or iterated to generate the whole array" (Battista, 2004; p.192). The following figure (Figure 2.6) summarizes the foundation for developing competence with measuring volume.

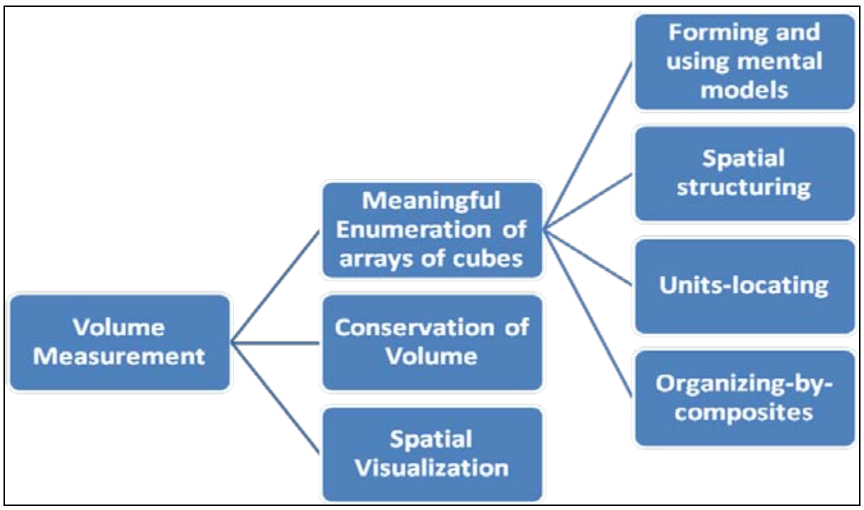


Figure 2.6 Foundations of Volume Measurement

In the field of mathematics education, it is apparent that the small amount of research on volume measurement has been conducted so far, when compared to the studies on area and length measurement. According to Owens and Outhred (2006), not only three-dimensional nature of the quantity, but also the involvement of both liquid and cubic units might be the reasons for limited number of research on volume measurement. Despite of this, an emerging body of research has been addressed to various aspects related to volume measurement.

Focusing on the effect of spatial visualization activities on volume measurement, Ben-Haim, et al., (1985) conducted a study to investigate middle school students' (in grade 5-8) performance on typical cube enumeration tasks (e.g. asking how many unit cubes are needed to build rectangular solid). The results indicated that about 25% of fifth graders, 40-45% of sixth and seventh graders, and 50% of eight graders gave the correct answer for these questions. The authors also reported that those who failed to answer the tasks correctly used such incorrect strategies as (a) counting the actual number of faces indicating in the diagram; (b) counting the actual number of faces showing and doubling that number; (c) counting the actual number of cubes showing; and (d) counting the actual number of cubes showing and doubling that number (p.397). Based on the evidence gathered from students' responses, Ben-Haim, et. al., asserted that especially treating three-dimensional figures as two-dimensional ones and focusing on visible faces/unit cubes are directly related to students' incompetent skills in spatial visualization.

From a different point of view, Hirstein (1981) argued that students' poor understanding related to volume measurement were also related to the confusion between volume and surface area. In their study of elementary students' (in years 2 to 6) conceptualization of volume that was described according to the SOLO-Taxonomy (Structure of the Observed Learning Outcome), Campbell, Watson, and Collis (1992) produced similar evidence that counting the number of individual unit cubes in diagrams of rectangular solids is common strategy among elementary students, yet most of them pay no attention to the invisible unit cubes.

Using the same taxonomy, Voulgaris and Evangelidou (2004) also examined 90 fifth and sixth grade students' understanding of volume. They found the close relationship between conservation of volume and understanding of the structural complexity of the blocks in the measurement tasks which support to correct use of volume calculation. Additionally, they shared the similar conclusion with the study done by Ben-Haim, et. al., (1985) concerning students' difficulties in relating isometric type drawings to rectangular solids they represent.

Furthermore, Battista and Clements (1996) conducted a research study to examine the students' solution strategies and errors related to 3-D cube arrays. The data were collected from 45 third graders and 78 fifth graders through interviews. The authors classified the students' strategies used for enumerating 3-D cube arrays under six main categories as presented in Table 2.5.

Table 2.5

Classification of Students' Enumeration Strategies for 3-D Cube Arrays (Battista & Clements, 1996, p.262)

Category	*Description*
Category A	The student conceptualizes the set of cubes as a 3-D rectangular array organized into layers. Cubes are enumerated by counting (individually or by skip counting), adding, or multiplying.
Category B	The student conceptualizes the set of cubes as space-filling, attempting to count all cubes in the interior and exterior, but did not consistently organize the cubes into layers.
Category C	The student conceptualized the set of cubes in terms of its faces, s/he counted all or a subset of the visible faces of cubes.
Category D	The students explicitly used the formula L x W x H, but with no indication that s/he understood the formula in terms of layers.
Category E	This category includes other strategies such as multiplying the number of squares on one face time the number on another face.

Battista and Clements's study also pointed out that meaningful enumeration of cubes in 3-D arrays is the fundamental aspect of understanding of volume. Indeed, a majority of the students cannot be able to correctly enumerate the cubes, because of lack of structuring array notion. With regard to the formula for volume, a few number of fifth graders who had been introduced the formula at school could use it and only one understood it. Although Lehrer, Strom and Confrey (2002) highlighted the importance of engaging students with different spatial structuring experiences and representation of volume, all of the third grade students in their sample structured correctly space as three-dimensional arrays and a majority of them considered volume as a product of area and height. Moreover, in his study on fourth grade students' thinking about rectangular solids composed of unit cubes, Olkun (2003) yielded supportive results not only with Battista and Clements' classification of students' enumeration strategies for 3-D cube arrays and also with the study done by Ben-Haim, et, al., (1985) in terms of the effect of presenting rectangular solids pictorially on students' spatial structuring. Another interesting observation comes from research done by Saiz (2003) which focused on primary teachers' conceptions of volume. According to the teachers, the volume-measurable objects were those that have three lengths and volume was perceived as a number produced by multiplying the length, width and height of an object.

As far as large-scale studies are concerned, the results of 2nd NAEP revealed that only 7 percent of the 9-year-olds and 24 percent of the 13-year-olds found the correct number of cubes in a rectangular solid (Carpenter, et. al., 1981). Those who missed this question either counted the faces of the cubes in the picture or calculated the surface area of the solid. Based on the findings, Carpenter and his colleagues (1981) concluded that students did not make sense of volume measurement and they employed inappropriate unit of measure. More recent study, it is reported that almost half of the eight graders involved in the TIMSS 2003 study responded correctly for the following released item (TIMSS Report, 2003).

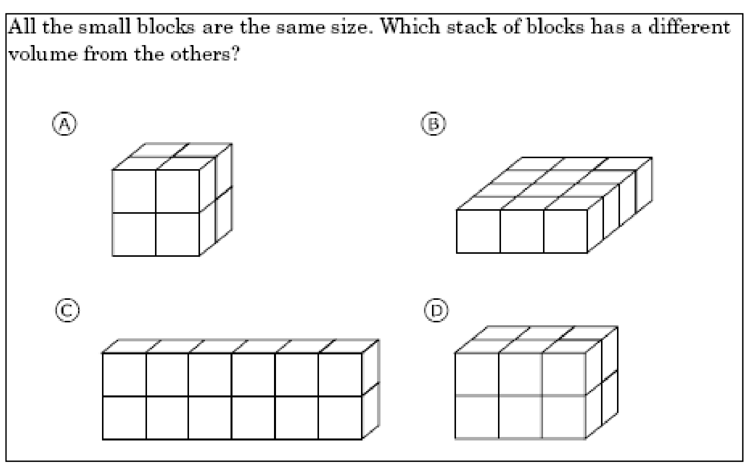


Figure 2.7: The Released TIMSS 2003 Item

2.2.4 Studies on Length, Area, and Volume Measurement in Turkey

It is apparent that research on teaching and learning measurement is an emerging area of study in Turkey. When compared to the studies on measurement conducted abroad, a few numbers of researches has been done so far in Turkey. Arı, Bal, Tugrul, Uzmen, and Aydogan (2000) designed an experimental study to explore 6-year-old children's concept of conservation including length. The pre-test findings indicated that only 11% of the children in the experimental group and 13.6% of the children in the control group achieved the tasks involving the conservation of length. After the intervention, the post-test results revealed that 81.5% of the children in the experimental group acquired the concept of length conservation whereas no difference was observed in the control group.

Another study was done by Çapri and Çelikkaleli (2005) with sixty children aged 7-11, thirty of them were living with their parents and the remaining was living in one of state orphanages. He investigated whether there were significant differences between these two groups of students in terms of the acquisition of conservation including length, area, and volume. Although the results did not produce any significant differences between two parties in terms of the conservation of length, area and volume, the findings clearly indicated that the conservation of length and area achieved by the age of 10 and the volume conservation was by the age of 11. According to the results of Emekli’s study (2001), among 744 seventh and eighth grade Turkish students, only 20% of them could be able to find the total number of unit cubes needed to fill up the rectangular box. About 52% of the students believed that area changes under partitioning and/or decomposition into smaller areas. A majority of the students confused the formula for area with the formula for perimeter. The results also revealed that students had misconceptions about comparing length measurements, using ruler when measuring, using of fraction in measurement, conservation of area, and estimating of measurement.

Furthermore, the research study was conducted by Kültür, Kaplan and Kaplan (2002) to assess length, area, and volume measurement instruction in 4^{th} and 5^{th} grade classrooms through the achievement test. The findings demonstrated that 5^{th} grade students performed better than 4^{th} grade students in all three domains of measurement. The authors also found the close relationship between students' learning and socioeconomic status, teacher's educational background and teaching experience.

In order to study the effects of the remedial instruction on students' learning difficulties in measurement topic, Köse (2007) conducted an experimental study with a sample of 122 sixth grade students. The researcher concluded that the remedial instruction had positive effect on students' learning of measurement. Considering pre and post-test results of both the control and the experimental group, 6^{th} grade students performed exceedingly well on the questions related to the perimeters of triangle, square, and rectangle. With regard to the lowest mean score, the students in the experimental group had difficulties in solving the tasks involving the volume of cubes and rectangular prisms during the pre-test, yet the units of area measurement and their relationships were the lowest mean score in the post-test. Similarly, the students in the control group also performed poorly on the tasks related to the units of area measurement and their relationships both in pre and post-test. In addition, Erdogan and Sagan (2002) carried out a study with 4^{th} grade students to investigate the effects of constructivist approach in teaching of the calculations of perimeter of square, rectangle, and triangle. They concluded that constructivist way of teaching was more effective than traditional instruction. Moreover, Olkun (2003) conducted a research study to investigate 4-5-6 and 7^{th} grade students' performance and the strategies the students used for finding the number of unit cubes in rectangular solids. The results indicated that although the students' success increased and their strategies became more complex from 4^{th} grade to 7^{th} grade, the author argued that even 7^{th} graders were not ready to construct the meaning of volume formula.

Focusing on the volume formula, Zembat (2007) carried out an action research study with twenty two 7th grade art school students who have not been introduced to the formula for volume. Based on the Reflection on Activity-Effect Relationship framework, he designed instruction aiming to enable students to internalize the underlying idea for the rectangular right prisms' volume formula. The instruction was sequenced from finding the number of unit cubes in the given box to adding up a number of layers to completely fill up the box. The author claimed that asking students to reflect their ideas on the purposefully-designed and sequenced activities promoted students' construction of the volume formula in a meaningful manner.

Kılcan (2005) conducted a study to find out the effect of thematic instruction on the sixth grade students' performance in the measurement topic with respect to the selected variables such as attitudes toward mathematics, socioeconomic status, etc. As reported by the researcher, the sixth grade students who were taught to the study of measurement in the thematic instructional approach were more successful than those who learned the same topic in the traditional instruction.

Another research study carried out by Pinar (2007) was aimed to investigate the effects of implementing technology-supported instruction, cooperative learning and traditional instruction in teaching of measurement topics on sixth grade students' learning and memory levels. The findings indicated that although cooperative learning method was more effective than traditional instruction; there is no difference between technology-supported instruction and cooperative learning method in terms of students' success.

With the focus of seventh grade students' misconceptions about geometrical concepts, Akuysal's study (2007) also pointed out most of the students had difficulties in understanding the measurement concepts. For instance, while asking to find out the perimeter of a deltoid whose side lengths were given, only 22% of them could gave the correct answer. Besides, some of the students failed to make connection between the area of a trapezoid and its height. The confusion the formula for area with the perimeter was another misconception as reported by the researcher. Tan-Sisman and Aksu (2009a) make a similar point with respect to the students' poor understanding of area and perimeter concepts. Their research indicated that a majority of the seventh grade students had serious problems with the concept of area and perimeter, had some misconceptions, and had difficulties in using the formulas for area and/or perimeter effectively.

In their study of the investigation of fifth grade students' understanding of measurement, Albayrak, Isik, and Ipek (2006) reported that most of the students distinguished the measurable and non-measurable attributes of objects (e.g. the width of a book and eye color) and chose the appropriate unit for the attribute being measured, yet their performances were quite low on the tasks related to unit conversions and expressing measures in terms of another standard units. The researchers also found that only 20% of the students calculated the perimeter of a polygon. Based on the results, it was concluded that although a majority of the students involved in the study grasped the meaning of measurement, they did not have procedural competence in measurement.

Additionally, Tan-Sisman and Aksu (2009b), in their study designed for the examination of the length measurement topic in the written elementary mathematics curriculum (1^{st} - 5^{th} grade) in terms of its potential to support students' understanding, pointed out that the length measurement content in the Turkish elementary mathematics curriculum seems to provide meaningful opportunities for young children to develop the concepts and skills involved in length measurement. However, they emphasized that conceptually-oriented instruction is employed in the length measurement content in order to reach its procedurally-dominated learning expectations.

2.3 Studies on Word Problem Solving in Mathematics Education

Obviously, almost all areas of life require a broad range of skills, among them; problem solving is one of the most important aptitudes in order to cope with a rapidly changing world. Particularly, the ability to solve a problem in mathematics education is "a hallmark of mathematical activity and a major means of developing mathematical knowledge" (NCTM 2000, p.116). From the Silver's (1986) point of view, mathematical problems are important vehicles for the development of both conceptual and procedural knowledge, as problem solving process entails the making use of both type of knowledge. Among the mathematical tasks, word problems have continued to be a special part of almost all mathematics curricula, instruction, and textbooks (Jonassen, 2003).

Word problems were appeared even in ancient times (Verschaffel, Greer, & De Corte, 2000). While explaining the purposes of extensive inclusion of word problems in mathematics curricula, Verschaffel, et al., (2000) stated that word problems create a context for the development of new concepts and skills if they are carefully selected and sequenced. In other words, with the help of word problems, students are expected to develop when and how to apply the mathematical ideas, principles, concepts, and skills into different situations and contexts.

In several documents, word problems are defined in different ways under different names (e.g. story problems, verbal problems, etc.). For instance, according to Briars and Larkin (1984), word problems are "the primary context in which children are asked to apply mathematical knowledge in useful situations, rather than simply to execute algorithms." (p.245). In a simple form, Semadeni (1995; as cited in Nortvedt, 2007) characterized word problems as "verbal descriptions of problem situations." However, Verschaffel et al. (2000) provided a detailed definition for word problems as "verbal descriptions of problem situations wherein one or more questions are raised the answer to which can be obtained by the application of mathematical operations to numerical data available in the problem statement." (p.ix). Based on the definition, Verschaffel et al. (2000) explained four main characteristics of word problems summarized in Table 2.6.

Table 2.6

Main Characteristics of Word Problems

Main characteristics	*Definitions*
The use of words	Imaginary or real situations embedded in meaningful contexts are described by words. Thus, verbally-stated numerical problems are not considered as word problems.
The content	Not necessarily related to the study of algebra, yet cover any other mathematical content area such as geometry, logic, etc.
The form of problems	Not essentially require written form. The forms of a combination of written text and tables, pictures, figures, etc. as well as orally-presented form such as use of intonation, gestures, etc. are considered as word problems.
The degree of difficulty	Not necessarily ask for a learner to use higher order thinking skills.

Verschaffel et al. (2000, pp. x-xi) also asserted that word problems are composed of four structural components:

- *The mathematical structure:* " The nature of the given and unknown quantities involved in the problem, as well as the kind of mathematical operation(s) by which the unknown quantities can be derived from the givens."
- *The semantic structure:* "The way in which an interpretation of the text points to particular mathematical relationships."
- *The context:* "What the problem is about"
- *The format:* "How the problem is formulated and presented, involving such factors as the placement of the questions, the complexity of grammatical structure, the presence of superfluous information, etc."

Reusser and Stebler (1997) expressed the vital importance of word problem solving skills for students in the following way:

> Word problems not only provide an opportunity to study the interplay among and between language processes, mathematical processes, and situational reasoning and inferencing between text comprehension, situation comprehension and mathematical problem solving (Reusser, 1985, 1989), they also provide pupils and students with a basic sense and experience in mathematization, especially mathematical modeling (p.309).

Furthermore, the process of solving mathematical problems has also been one of the extensively investigated research areas in mathematics education. Various researchers have attempted to explain the process as students go through. Polya (1962), known as the father of problem solving, described four-step approach to problem solving as follows: (a) understanding the problem (b) devising a plan (c) carrying out the plan, and (d) looking back. He also expressed the ideal process of solving word problems as

> In solving a word problem by setting up equations, the student translates a real situation into mathematical terms: he has an opportunity to experience that mathematical concepts may be related to realities, but such relations must be carefully worked out (p. 59).

Shoenfeld (1985; as cited in De Corte, Verschaffel & Eynde, 2000), one of the well-known figure in mathematics education, also suggested five-phase problem solving strategy. His approach to teaching problem solving is composed of the following steps:

1. Analysis oriented toward understanding the problem by constructing an adequate representation.
2. Designing a global solution plan.
3. Exploration oriented toward transforming the problem into a routine task.
4. Implementing the solution plan.
5. Verifying the solution. (De Corte, Verschaffel & Eynde, 2000, p. 703)

Another influential model for solving word problems was proposed by Verschaffel, et al., (1999). Like Shoenfeld's approach, their model has five steps:

1. Building a mental representation of the problem
2. Deciding how to solve the problem
3. Executing the necessary calculations
4. Interpreting the outcome and formulating an answer
5. Evaluating the solution (Verschaffel, et al., 1999; p.202)

Additionally, Koedinger and Nathan (2004) also stated that word problem solving process composed of two steps, namely, the comprehension and the solution steps. During the first step, the comprehension, students "process the text of the story problem and create corresponding internal representations of the quantitative and situation-based relationships expressed in that text" (p.131). In the second step, the solution, students "use or transform the quantitative relationships that are represented both internally." (p.131).

Similar to Koedinger and Nathan's ideas, Jitendra, et al., (2007) asserted that being able to solve word problems correctly, students, first of all, should comprehend the language and factual information embedded in the problem situation, then, translate the given information into mental representation, and then, propose and examine a solution plan, finally, they should make necessary calculations.

Since word problems are vital for promoting students' mathematical understanding in terms of connecting different meanings, interpretations, and relationships with mathematics operations (Van de Walle, 2007), there is a considerable body of the research regarding mathematical word problems with many themes such as students' thinking, solutions strategies, struggles while solving mathematical word problems, the types of word problems, the effects of the mathematical structure, semantic structure, the context, and the format of word problems on students' performances (e.g. Caldwell & Goldin, 1979; Cummins, et al., 1988; Galbraith & Haines, 2000; Gerofsky, 1996; Verschaffel, Greer, & De Corte, 2000). With regard to the topics studied in this area, arithmetic, especially focusing on addition and subtraction, seems to be mostly-investigated mathematical strand (Greer, 1992).

In their study, Reusser and Stebler (1997) portrayed a relatively coherent picture of students' struggles in word problems. Based on the data drawn from previous research studies (e.g. Baruk, 1989; Bobrow, 1964; Nesher, 1980; Nesher & Teubal, 1975; Paige & Simon, 1966; Raddatz, 1983; Reusser, 1984; Stern, 1992; Schoenfeld, 1989, 1982; Wertheimer, 1945; as cited in Reusser & Stebler, 1997), the authors stated that most of the students have difficulties with comprehending the problem situation, generally use key word methods and thus, solve problems without understanding them.

In addition, a majority of students have not pay attention to the relationship between what the problem text is talking about and the necessary mathematical operations executed. Thus, some of the students have attempted to solve unsolvable, absurd problems presented in ordinary classroom contexts. For instance, Radatz's studies (1983, 1984; as cited in Verschaffel et al., 2000) produced interesting results regarding the students' (from kindergarten to 5^{th} grade) performances on word problem solving tasks that both included the solvable (e.g. traditional textbook problems) and unsolvable problems (finding the age of Katja with the help of the number of children invited to her birthday party and the date of the party). The author asserted that students who had received less instruction on mathematics seemed to examine the problem more cautiously than older ones.

Further, Cummins, Kintsch, Reusser, and Weimer (1988) carried out a study to explore thirty-eight 1^{st} grade students' success on the word- and numeric-format problems. The findings clearly revealed the huge difference in performance on word-format and numeric format problems. According to the authors, correct recall of problem structure with generation of suitable question was the reason for students' correct answers, whereas students' mistakes were due to misinterpretation of problems. In other words, those who had difficulties for solving word problems did not correctly match linguistic form of the problem with the schemata (Moreau & Coquin-Viennot, 2003).

Another study indicating the vital role of semantic structure of word problems on students' effectiveness in solving process was done by De Corte, Verschaffel, and De Win (1985). The authors designed two different word problem solving tests, one of which included in the traditional word problems appeared in common mathematics textbooks and the other one composed of the similar problems, yet reworded for explicitness and administered to 89 first-grade and 84 second grade students. The results revealed that students' success on solving word problems mostly depended on the degree to which the semantic structure of the problem were presented explicitly or implicitly.

Indeed, the reworded mathematical word problems whose linguistic relations were stated explicitly without changing their semantic and mathematical structure assisted students to comprehend and solve the problem correctly. Focusing on both rewording and personalization of word problems, Daxds-Dorsey, Ross and Morrison (1991) also conducted a research study with second and fifth grade students. They observed that the combination of personalization and rewording had improved second graders word problem solving scores, but fifth graders only benefited from personalization. Considering the semantic structure of the word problem as a chief factor in solution process, Carpenter and Moser (1983; as cited in García, Jiménez, & Hess, 2006) grouped types of word problems under four categories as change, combine, compare and equalize problems. Table 2.7 shows the problem types and their characteristics.

Table 2.7

Word Problem Types and Their Characteristics

Type of Word Problem	Problem Characteristics
Change problems	There is an initial quantity and a direct or implied action that causes an increase or decrease in that quantity. *Example:* "Pablo had 18 stickers. His friend Juan gave him 6 more stickers. How many stickers does Pablo have altogether?"
Combine problems	There is a static relationship existing between a particular set and its two disjoint subsets. *Example*: "There are 12 sheep in a van; 4 are black, and the rest are white. How many white sheep are there?"
Compare Problems	There is a static relationship in which there is a comparison of two distinct, disjoint sets. *Example*: "Olivia's bicycle has 14 gears, and Alba's bicycle has 9 gears. How many less gears does Alba's bicycle have than Olivia's?"
Equalize problems	There is an initial quantity and a direct or implied action that causes an increase or decrease in that quantity based on the comparison of two disjoint sets. *Example*: "My dress has 12 buttons. If my sister's dress has 5 buttons more, it will have the same number of buttons as my dress. How many buttons does my sister's dress have?"

Several research studies conducted on the difficulty level of kind of word problems so far and some of them indicated that compare problems are harder than others, Stigler, Fuson, Ham, and Kim, (1986; as cited in Xin, 2007), argued that the semantic structure of the problem, the position of the unknown quantity and the way in which the problem is written were the chief factors to see whether students solve the problem easily or not.

In a similar vein, Verschaffel and his colleagues (2000) put strong emphasis on the notion that "a word problem does not necessarily constitute a problem (in the cognitive-psychological sense of the word) for a particular student, and consequently does not necessarily require the use of higher-order thinking and problem-solving skills" (p.xi), however, the widespread belief in the difficulty of word problems has also been reported in the literature. For instance, Nathan and Koedinger's surveys

(2000a, 2000b) indicated that a majority of the mathematics teachers and the mathematics scholars in the sample believed that solving problems stated in words were harder than those presented as equations. Furthermore, a recent study by Griffin and Jitendra (2009) was aimed to compare the effects of schema-based instruction and general strategy instruction on third grade students' word problems-solving performances and computational skills. The findings indicated that both types of instruction had positive effect on students' computational skills and word problem solving performance. Although the findings did not produce any significant difference with regard to the effects of the instructional strategies on students' performance, the results supported the view that if students are provided with fruitful experiences on word problem solving, their performance will improve.

In addition to external factors related to the structure of tasks or instruction, Bernardo (1999) asserted that there are also student-related or internal factors affecting students' understanding of word problems and these factors are closely related to students' pervious experiences in mathematics, and consequently their competence in accessing and transferring the relevant/necessary knowledge and skills into the problem solving process. For instance, MacGregor, and Stacey (1996) carried out a research study in order to examine 14-16 year-old students' success on writing equations for mathematical word problems. A majority of the student in their sample solved the problem by non-algebraic methods yet, they had trouble formulating equation for the problems. The authors concluded that students' low performance were not related to the difficulties on comprehension of the problem context, instead they were due to the poor understanding of the use of algebraic notions.

With regard to the research studies carried out in Turkey, it can be said that the findings gathered from Turkish educational context tend to support the studies conducted abroad. In her study, Aksu (1997) compared 6^{th} grade students' performances in terms of understanding of fractions, computations with fractions, and solving word problems involving fractions. The results indicated that the lowest performance was observed in word-problem-solving test and the highest on the computations test. Ubuz and Ersoy (1997) conducted an experimental study to explore whether the problem-solving method with handout material is effective on the college students' solving word problems involving the concept of maximum-minimum in calculus. Based on the Polya's four-step-approach to problem solving, the instructional materials were developed and administered to 161 freshman students. The analysis of the data indicated that the students who were taught the min-max concept thorough the use of handout material was more successful on the complete solution of the word problems than those who received traditional lecture method. The authors also reported that reading comprehension is one of the most critical factors in successful word problem solving.

Another study done by Dede (2004) with 287 freshman students from different departments of faculty of education was aimed to determine the solution strategies in writing an equation for algebraic word problems. The data were collected through a test including five open-ended questions. The results indicated that although the college students' strategies to translate algebraic word problems into equations varied from following a routine equation procedure to providing an example, they had serious problems due to the insufficient mathematical knowledge and skills, and limited of knowledge about converting real-life language to symbolic format. In addition, the students from secondary mathematics education and elementary mathematics education gathered higher scores on the test than those who were majoring in music education, social studies, and early childhood and elementary education.

Ozsoy (2005) designed a study to seek the relationship between mathematical achievement and problem solving skills of 5th grade students. The two multiple choice mathematical achievement tests, one of which evaluated students' general achievement in mathematics and the other one assessed students' problem solving skills, were administered to 107 fifth grade students. The researcher found a significant and positive relation between students' mathematical achievement and their problem solving skills. Indeed, it was reported that the low-achieving students in general mathematics test had troubles in designing, implementing a solution plan and verifying the solution. However, it was also found that although the high-achieving students scored well in problem solving test, they scored poorly on implementing a solution plan and evaluation of the solution tasks.

Focusing specifically on multiplication and division, Kartallioglu (2005) carried out a research study to find out third and fourth grade students' word problem solving strategies and their reasons for choosing these strategies. A word problem solving test involving multiplication and division operations were developed and administered to thirty 3^{rd} graders and twenty-four 4^{th} graders. The findings showed that third graders did better than fourth graders on the multiplication and division word problem solving test. Considering the strategies that the students used, 85% of the word problems were solved through the use of procedurally-dominated strategies, only 7% of them were solved by mathematical modeling strategy. Another interesting finding gathered from Kartallioglu's study is that the students who used mathematical modeling strategy solved all word problems correctly, whereas those who used procedurally-dominated strategies were usually unsuccessful at solving word problems.

Soylu and Soylu's research study (2006) on second graders' troubles and mistakes in problem solving process revealed that most of the students performed well on the tasks requiring procedural knowledge, yet they had troubles in solving the problems involving conceptual and procedural knowledge. It was also found that the students mostly made errors in multi-step problems. In her study with fifth grade students, Balci (2007) found the significant relationship between meta-cognitive skill levels and problem solving skill levels of the students.

In her doctoral dissertation, Cakir-Balta (2008) investigated the effects of personalized and non-personalized mathematical word problems on seventh graders' performance with regard to the delivery of mathematics instruction in two different learning environments, namely, computer-based and classroom-based. Totally 90 seventh grade students participated to the study and assigned to the following classes as Computer-based personalized on computer environment, Non-personalized computer environment, Personalized on class environment, Non-personalized on class environment. The results did not produce any significant difference with regard to the effects of personalized mathematical word problems taught in two different learning environments, yet, the students' scores differed significantly in the pre and post-test regardless of the type of the learning environment and of word problems.

A recent study conducted by Oktem (2009) was aimed to investigate 6^{th}, 7^{th}, and 8^{th} grade students' achievement in solving mathematical word problems involving real-world situations. The results showed that most of the students (about 63%) across grades used procedurally-dominated approach and only 5% of them followed realistic strategies to solving real-life word problems. The author also found a direct relationship between solving word problems through use of realistic strategies and grade level.

2.4 Studies on Gender, Previous Achievement and the Use of Materials in Mathematics Education

In the mathematics education literature, several factors influencing students' competency in mathematics were reported. Among these factors, gender differences, previous mathematics achievement, and the use of materials in mathematics are explained in a detailed manner as the variables of this study through conducted studies.

2.4.1 Studies on Gender Differences

In the field of mathematics education research, gender differences have been one of the subjects receiving serious attention from scholars over the years. A majority of the research studies carried out so far has generally supported the view that boys perform better than girls in mathematics (e.g. Hyde, Fennema & Lamon 1990; Maccoby & Jacklin, 1974; Reis & Park 2001). However, research has currently been reported that gender differences in mathematics success has declined over past decades (Ercikan, McCreith, & Lapointe, 2005; Ding, Song,& Richardson, 2007).

In 1980, the results of Benbow and Stanley's longitudinal study with nearly 10,000 gifted middle school students revealed large gender differences in mathematics favoring boys. Similarly, Armstrong (1981) pointed out that 13-year-old boys performed better than girls on the problem solving tasks. As reported by Fennema and Carpenter (1981), the girls at the age of 9 and 13 years fall behind the boys at the same age cohort in terms of all cognitive levels (e.g. knowledge, skill, application, etc.) with regard to the study of geometry and measurement. Another study done by Ben-Haim, et al., (1985) also supported the common belief that boys indicate greater performance on the tasks requiring spatial visualization.

Singh Kaeley, (1995) mentioned the result of the meta-analysis on gender gap in mathematics achievement and concluded that making generalization about the superiority of females over males and vice versa is impossible due to the involvement of several other variables. Particularly, ability, attitude, beliefs, motivation, interest, genetic differences, socialization, socioeconomic status, curriculum, and instruction are the mostly-used variables to examine the possible factors associated with gender gap in mathematics (Ding, Song, Richardson, 2007). In the same way, Fennema & Sherman (1978) underlined that confidence in learning mathematics, spatial visualization, mathematics computation, comprehension, application, problem-solving, verbal ability, parental involvement and teacher had a great effect on students' mathematics achievement regarding to gender differences. Another meta-analysis study portraying correlational studies on spatial and mathematics skills in relation to gender differences was conducted by Friedman (1995). The findings revealed that the relationship patterns favored males.

The recent report based on the secondary analysis of the TIMSS data highlighted that the girls tended to fall behind the boys in mathematics and science (Mullis & Stemler, 2002). Indeed, the boys constituted the majority of the high-achievers group and those boys who performed well in mathematics seemed to gain a more sophisticated abilities and understanding than the average of high-achieving girls. Another important finding emerged from Mullis and Stemler's analysis is that the gender gap was smaller among low-achieving students.

Considering the common observations related to gender differences in mathematics achievement, girls seem to perform better than boys in computational, numerical, perceptual-speed tasks, and symbolic relations (Beaton et al., 1999; Brandon, Newton, & Hammond, 1987; Fennema & Carpenter, 1981; Singh Kaeley, 1995). Besides, Hackett (1993) found out that female students scored better than males in mathematics in one of the British national examination for secondary education.

However, research studies yielded the results indicating that boys generally demonstrate higher performance on spatial visualization, problem-solving, proportionality, geometry, measurement, and mathematical applications (Battista, 1990; Ben-Haim, et al., 1985, Fennema & Carpenter, 1981; Lummis & Stevenson, 1990, Xu & Farrel, 1992, as cited in Singh Kaeley, 1995). In their meta-analysis study, Hyde, Fennema and Lamon (1990) claimed that males appeared to perform better than females in mathematical problem solving during high school years yet females showed better performance on computational tasks.

On the other hand, there are published evidences indicating that there is no difference between girls and boys in terms of mathematics achievement. Armstrong (1981) stated that no difference was observed between sixth grade boys and girls in the study of geometrical applications, measurement, and probability. In a similar vein, Fennema and Sherman (1978) reported that the difference between boys and girls in spatial visualization was not statistically significant. According to the results of Hyde and Linn's meta-analysis study (2006) no difference between boys and girls both at elementary and middle school level were found in understanding of complex mathematical concepts. Nonetheless, Lubienski (2003) examined the results of the previous NAEP exams and reported that measurement is the only content area in which the largest gender differences have been observed since 1990. Annsell and Doerr (2000; as cited in Lubienski, 2003) also analyzed the data on the seventh NAEP results in terms of gender, and highlighted the similar trend favoring boys especially in spatial-related tasks and using/reading measurement instruments.

Gender disparities in mathematics have also been one of extensively-investigated area in Turkey. In contrast to the current literature on the issue, most of the research studies conducted in the Turkish context yielded no gender differences in mathematics, particularly at primary and high school levels (Bulut, Gur, & Sriraman, 2010). Aksu (1997) reported that there was no significant difference between sixth grade boys and girls' performances on fractions. Similarly, Karaman's study (2000) with sixth grade students resulted in no mean differences between girls and boys in their understanding of plane geometry. In his research study aimed to examine the relationship between mathematics performance, attitudes toward mathematics, grade level and gender, Acikbas (2002) observed no difference in mathematics achievement among middle school students.

There have been other studies conducted with 7^{th}, 8^{th}, and 9^{th} grade students indicating neither gender differences in mathematical understanding nor relationship between mathematics achievement and gender (Acikgoz, 2006; Duru, 2002; Israel, 2003; lsiksal & Askar, 2005; Ubuz, Ustun & Erbas, 2009). The similar pattern, almost no mathematics achievement difference across gender, has also been found in the results of the international studies. For instance, the TIMSS 2007 study indicated Turkish girls and boys scored equally in mathematics, in other words, no gender disparities in mathematics performance was found in Turkey (Mullis, Martin & Foy, 2008).

With regard to the studies examining the students' performances on the domains of measurement in relation to gender, Olkun's study (2003) revealed that although the boys (4-5-6 and 7^{th} grade) males scored relatively higher than girls in the tasks finding the number of unit cubes in rectangular solids, the difference was not statistically significant. In her study, Kamışlı-Erol (2007) investigated eight grade students' mathematical skills of circle and stated that whereas female students did slightly better than male students in procedural, conceptual and problem solving tasks, the difference was not significant. Similarly, the results of Köse's experimental study (2007) on students' learning difficulties in measurement topic revealed no gender differences. In another research study aimed to find out the effect of thematic instruction on sixth grade students' performance in the measurement topic, Kılcan (2005) concluded that there was no difference between boys and girls in terms of mathematical understanding.

2.4.2 Studies on Previous Mathematics Achievement

As a school subject mathematics is one of the interrelated and cumulative subject matters in which mathematical ideas, concepts, skills, etc. are highly-connected with each other and build on one another (NCTM, 2000). Indeed, understanding of mathematics meaningfully requires a strong base that is constructed through the connections between existing knowledge and new information. As stated by Cooper and Sweller (1987; as cited in Chinnappan, 2003), if a learner develops a well-structured mathematical knowledge schema, s/he has not only higher level of understanding in mathematics, but also can store this knowledge for a long time and retrieve when it is necessary. At this point, it is obvious that students' previously learnt concepts, skills, and the relations between them play a crucial role in making sense of mathematics. In other words, prior math achievement has of utmost importance in students' subsequent mathematical attainment. Kabiri and Kiamanesh (2004) carried out a research study with 366 eighth grade students to examine direct and indirect effects of mathematics self-efficacy, mathematics attitude, prior mathematics achievement and mathematics anxiety on students' mathematics achievement. The findings indicated that previous math achievement had the highest correlation with students' mathematics performance. Bandura (1997) also underlined the importance of previous mathematics achievement and stated that it clearly affects students' future learning in mathematics.

Besides, Pajares (1996; Pajares & Kranzler 1995; Pajares & Miller, 1994) conducted a series of studies on the relationship between such variables as self-efficacy beliefs, anxiety, cognitive ability, prior achievement and mathematics attainment of students. He found that students' prior achievement in mathematics is one of the strong predictors for their subsequent success in mathematics. Further, according to the past NAEP data, a noticeable relationship between 8^{th} graders' score in mathematics and their mathematics scores at school was observed (Spielhagen, 2006).

Aksu's research study (1997) on 6^{th} grade Turkish students' performance on fractions also confirmed the vital importance of prior experience in mathematics. She found the direct relationship between students' previous mathematics scores and their performance on the tasks involving fractions.

Furthermore, the study of measurement has also sequential and cumulative structure and it requires the combinations of spatial, numerical, and geometrical competencies. Therefore, students' prior learning of measurement possibly affects their future achievement. Bragg and Outhred (2000) noted that students' understanding of length measurement is crucial for understanding of rulers, scales, perimeter, area, and volume measurement. Battista (2003) also underlined the importance of area measurement for understanding of volume measurement.

2.4.3 Studies on the Use of Materials in Mathematics Education

The use of materials in mathematics education goes back to the Pestalozzi's times, namely, 19th century (Sowell, 1989). Since then, almost all of mathematics curriculum, especially elementary school level, strongly suggests the use of materials in teaching and learning mathematics. In the mathematics education literature, several research studies into the use of materials and their assistance for teaching mathematics has been carried out so far. The findings have revealed that use of materials in teaching mathematics has positive impact on students' understandings of mathematical concepts and skills. Using meta-analysis, Parham (1983) examined sixty-four studies on use of materials in mathematics instruction at the elementary school level. It was concluded that students from those classrooms in which materials were the part of mathematics instruction were more successful than those who did not use manipulatives as part of instruction. Another meta-analysis study done by Sowell's (1989) also indicated that the long-term use of materials in mathematics instruction increased students' performance.

In a similar vein, Clements (1999) argued that students' performances might be increased through the use of materials in mathematics classes, yet the benefits may depend on grade level, topic, ability level, etc. He also mentioned that material use in math instruction generally improves students' performance on retention and problem solving tests. Cramer, Post, and delMas (2002) investigated 4th and 5th graders' understanding of fractions. Through using different curricula in one of which special attention is given to the use of materials, they compared the students' performance. The findings confirmed that the use of materials had great impact on students' learning.

Considering measurement as a subject matter, the use of instructional materials held a unique place in students' understanding of concepts and skills involving in measurement. In the NCTM's Principles and Standards for School Mathematics document (2000), the importance of instructional materials in teaching and learning measurement is expressed as follows:

> Measurement lends itself especially well to the use of concrete materials. In fact, it is unlikely that children can gain a deep understanding of measurement without handling materials, making comparisons physically, and measuring with tools (p.44).

Indeed, the Turkish mathematics curriculum (1^{st}-8^{th} grade) also pays special attention to the use of materials such as rulers, paper clips, tiles, unit cubes while teaching measurement. Like studies on measurement conducted in Turkey, studies examining the use of manipulative in teaching and learning measurement are almost nonexistent in the Turkish mathematics education literature. In their study on analysis of length measurement topic in Turkish elementary school mathematics curriculum, Tan-Sisman and Aksu (2009b) reported that most of the teaching and learning activities suggested in the guide require the use of different manipulatives and materials. A paper clip, pencil, toothpick, etc. are introduced as non-standard units of measure and rulers, tape measurement, etc. are standardized tools.

Lastly, Kültür, Kaplan and Kaplan (2002) designed a study to assess length, area, and volume measurement instruction in 4^{th} and 5^{th} grade classrooms. Based on the data collected from primary schools with different socio-economic status, the authors concluded that classrooms should be equipped with the necessary tools and materials for teaching and learning of measurement.

2.5 Summary

This chapter reviewed the relevant literature on conceptual and procedural knowledge; word problem solving; length, area, and volume measurement; gender differences, previous mathematics achievement, and the use of materials by addressing both theoretical and empirical perspectives in mathematics education.

The first issue reviewed was the place of conceptual and procedural knowledge in students' mathematics learning. In the last twenty years, mathematics educators have characterized types of knowledge under various names (e.g. Mechanical knowledge vs. Meaningful knowledge by Baroody & Ginsburg, 1986); put different emphasis and value on one type of knowledge over the other (e.g. the acquisition of procedural knowledge is more important than the conceptual knowledge) and produced different models explaining the way of relationship between mathematical concepts and skills (e.g. Iterative Model by Rittle-Johnson, et al., 2001). In such diversity, most of the scholars in the field of education have assigned the crucial roles to both conceptual and procedural knowledge in learning and doing mathematics. On the one hand, the knowledge of mathematical concepts and principles assists a learner to understand why a mathematical idea is important, to make meaningful and logical organizations among bits of information and, consequently, to apply a mathematical concept or principle into different contexts.

The knowledge of mathematical symbols and algorithms, on the other hand, enables a learner to perform mathematical tasks successfully and through practicing a learner is most likely to gain flexibility in the selection and application of procedures, formulas, strategies for various kinds of problems. However, in the light of the reviewed literature, the critical point here is the links between conceptual and procedural knowledge and vice versa. The bulk of theoretical and research-based arguments clearly indicate that building links between types of knowledge is the most effective way of learning mathematics with understanding which is one of the ultimate goals of almost all mathematics curricula. In this respect, it is obvious that drawing a clear picture about conceptual and procedural knowledge still remains an unsolved problem in the field of mathematics education, probably due to different educational contexts, student abilities, various teaching approaches and topics chosen for studies. Figure 2.8 (p.92) summarizes the main points related to conceptual and procedural knowledge in mathematics education drawn from the literature review.

Furthermore, measurement and its three domains, namely length, area, and volume constitute one of the fundamental parts of the literature review in this study. In the case of teaching and learning mathematics, it can be concluded that the study of measurement provides significant opportunities for students not only to make sense of their world but also to be a learning context for other mathematical strands as well as non-mathematical subject areas. Like other strands, measurement involves the specific concepts and skills. Indeed, its domains also require particular knowledge in order to understand both the meaning and doing of measurement. The literature has many studies indicating both elementary and middle school students' difficulties to understand the concepts and skills of measurement. However, it is also documented that serious difficulties experienced by students generally occur in learning length, area, and volume measurement.

What research has found about student mistakes while learning linear measurement is as follows: (a) starting from 1 rather than 0; (b) ignoring the idea of unit iteration, so believing that a tool/unit used to measure should be longer than an object being measured; (c) incorrect alignment with a ruler; (d) counting hash marks or numbers on a ruler/scale instead of intervals; (e) focusing on end point while measuring with a ruler; (f) mixing units of length with other units of measurement; and confusing the concept of perimeter with area.

As far as area measurement is concerned, a majority of students usually struggle (a) to realize how length units produce area units; (b) to grasp the conservation of area; (c) to understand array and grid structure; (d) to comprehend two dimensional structure of area (e) to understand the difference between not only the concept of area and perimeter, but also the formulas for these concepts.

Moreover, measuring volume is another measurement domain in which students have hard times to make sense of it. The followings are reported by many researchers as students' mistakes related to volume measurement: (a) treating three-dimensional figures as two-dimensional ones; (b) counting visible faces/unit cubes while finding the number of unit cubes in rectangular solids; (c) enumerating the cubes in 3-D arrays incorrectly; (d) confusing the concept of volume with the surface area and the formulas for them; (e) employing inappropriate units of measure for volume.

Most of the mathematics educators have agreed on the reason behind students' poor understanding of measurement is putting more emphasis on how to measure rather than what to measure means. There have also been research studies attempted to categorize students' understanding and strategies in length, area, volume measurement under hierarchical steps. The summary of the literature review on length, area, and volume measurement is presented in Figure 2.9 (p.93).

Another issue included in the literature review part is mathematical word problems. Holding a unique part in mathematics education, a commonly-shared argument about word problems is that they provide learning opportunities for students to apply mathematical knowledge in various situations, rather than just performing algorithms. Indeed, a well-constructed word problem challenges students to use their two mental equipments as conceptual and procedural knowledge in order to reach a correct solution of the problem.

Most of the scholars in the field have interested in mathematical word problems and their potential to contribute students' understanding in mathematics. Some of them particularly focused on the structure, the types, the main features of word problems and others worked on how word problems should be solved, namely the solving process, the kind of mistakes or difficulties that students face with, what are the reasons for students' mistakes in solving word problems.

The related literature clearly indicated that elementary and middle school students, even college students, generally got higher scores in achievement test including only numerical tasks than word problem solving tests. Furthermore, among the external factors, the semantic structure of word problems is only one that plays critical role in solving process.

As highlighted in many research studies, explicitly stated word problems have positive effect on students' performance on solving word problems. It might be argued that unless students comprehend and interpret the problem text in terms of mathematical relationships embedded in it, they probably fail to solve the problem. For instance, students usually tend to only rely on key words (e.g. "more" "altogether" refer to "addition") in the text, and thus they attempt to solve a problem without understanding it.

In addition to the external factors, there are also student-related or internal factors affecting students' performance in solving mathematical word problems. Such factors are closely related to students' prior learning in mathematics and their available conceptual and procedural knowledge schema. The results of the studies in the field indicate that difficulties with poor understanding of mathematical topics often lead to errors, because it is found that students' success highly depend on how they apply and transfer their available conceptual and procedural knowledge into the problem solving process.

It is also important to note that internal and external factors might interact with each other. Figure 2.10 (p.94) summarizes the main points related to word problems in mathematics education as highlighted in the literature review.

The literature review lastly included gender differences, pervious mathematics achievement and material use in mathematics education as factors affecting students' understanding of mathematics. Considering gender issues, the achievement gap between girls and boys has been declining over the years. Indeed, most of the research studies indicates that the common belief "boys are better than girls in mathematics" will be replaced by the notion "no gender differences in mathematics" soon.

Nonetheless, there have been evidences revealing boys' superiority over girls in spatial visualization, problem-solving, proportionality, geometry, measurement, and mathematical applications; and girls' superiority over boys in computational, numerical, and symbolic relations. Another important point drawn from the literature is that the involvement of such variables as ability, attitude, motivation, genetic differences, etc. is associated with gender gap in mathematics.

Further, being one of the cumulative and highly-related subject areas, mathematics requires a well-structured knowledge base in which concepts, skills, ideas, facts, and principles should be constructed with the help of the links between new and existing information. In this respect, students' prior knowledge in mathematics plays an important role in their future learning and success. What research has found is the direct relationship between student's previous mathematics achievement and their subsequent success in mathematics. Thus, prior experience in mathematics is generally considered as one of the strong predictors for students' future mathematics learning.

Moreover, the importance of the instructional materials in students' learning, particularly in mathematics, is emphasized in the literature. For instance, NCTM's PSSM book which is one of the influential documents in mathematics education community encourages teachers to use instructional materials in the context of teaching and learning mathematics. Besides, the studies have also confirmed the positive impact of using materials on students' performance in mathematics. Figure 2.11 (p.95) summarizes the related literature on gender gap, previous mathematics achievement and the use of materials in mathematics education.

In the light of above-mentioned ideas, investigating students' conceptual and procedural knowledge as well as word problem solving skills in length, area, and volume measurement with respect to gender, prior mathematics achievement and the use of instructional materials might shed light on the issues uncovered previously.

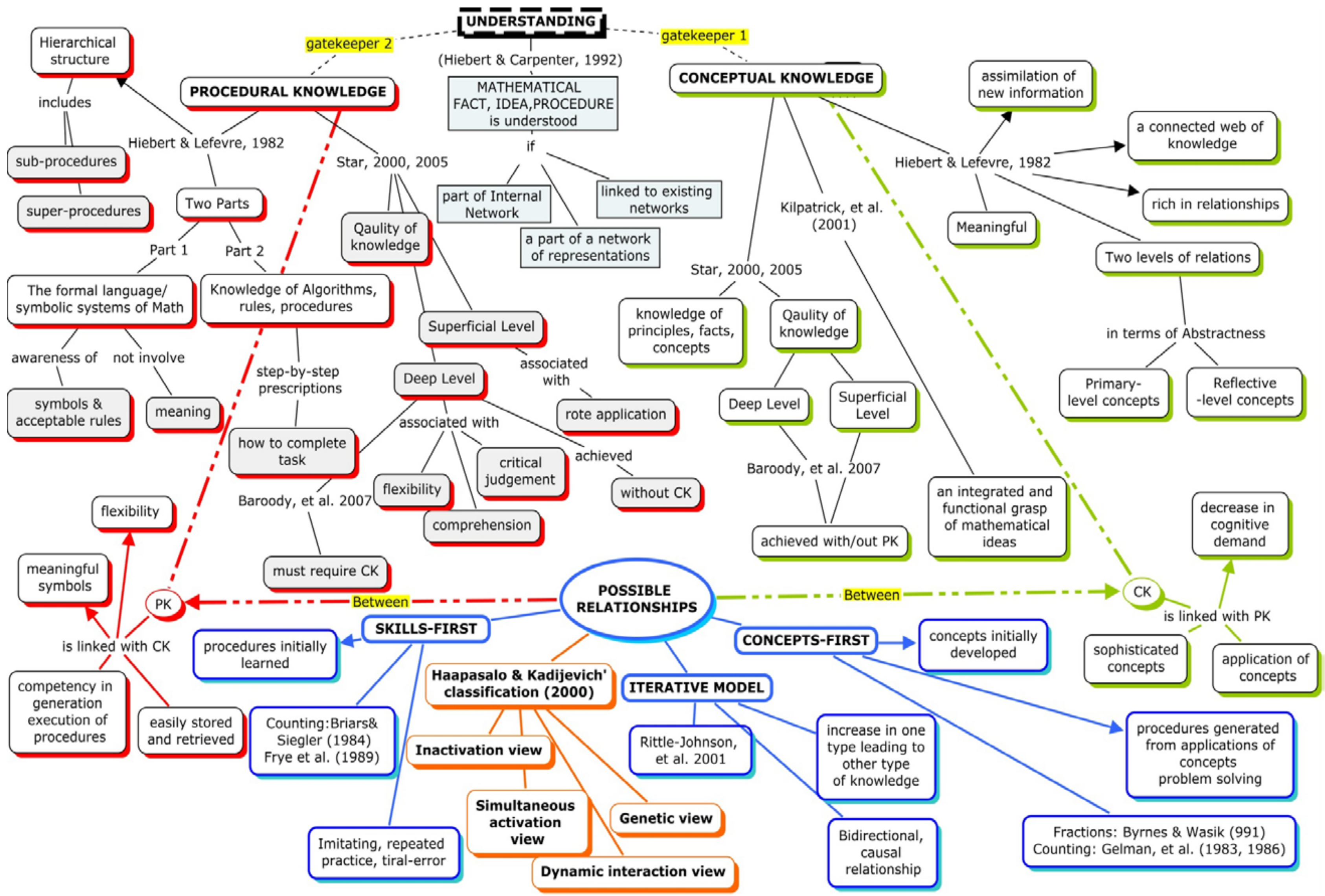


Figure 2.8 Summary of the Literature Review on Conceptual and Procedural Knowledge

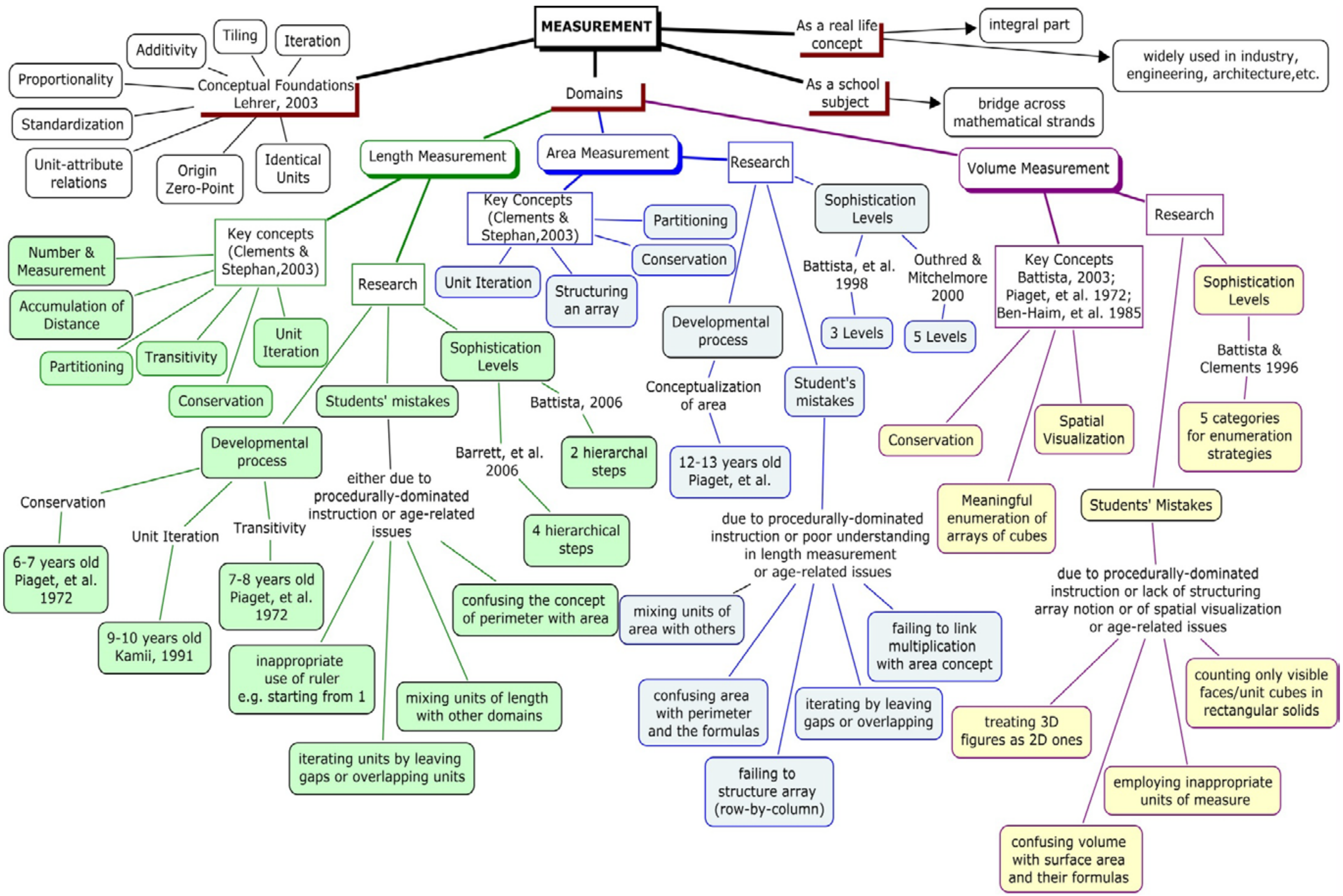


Figure 2.9 Summary of the Literature Review on Length, Area, and Volume Measurement

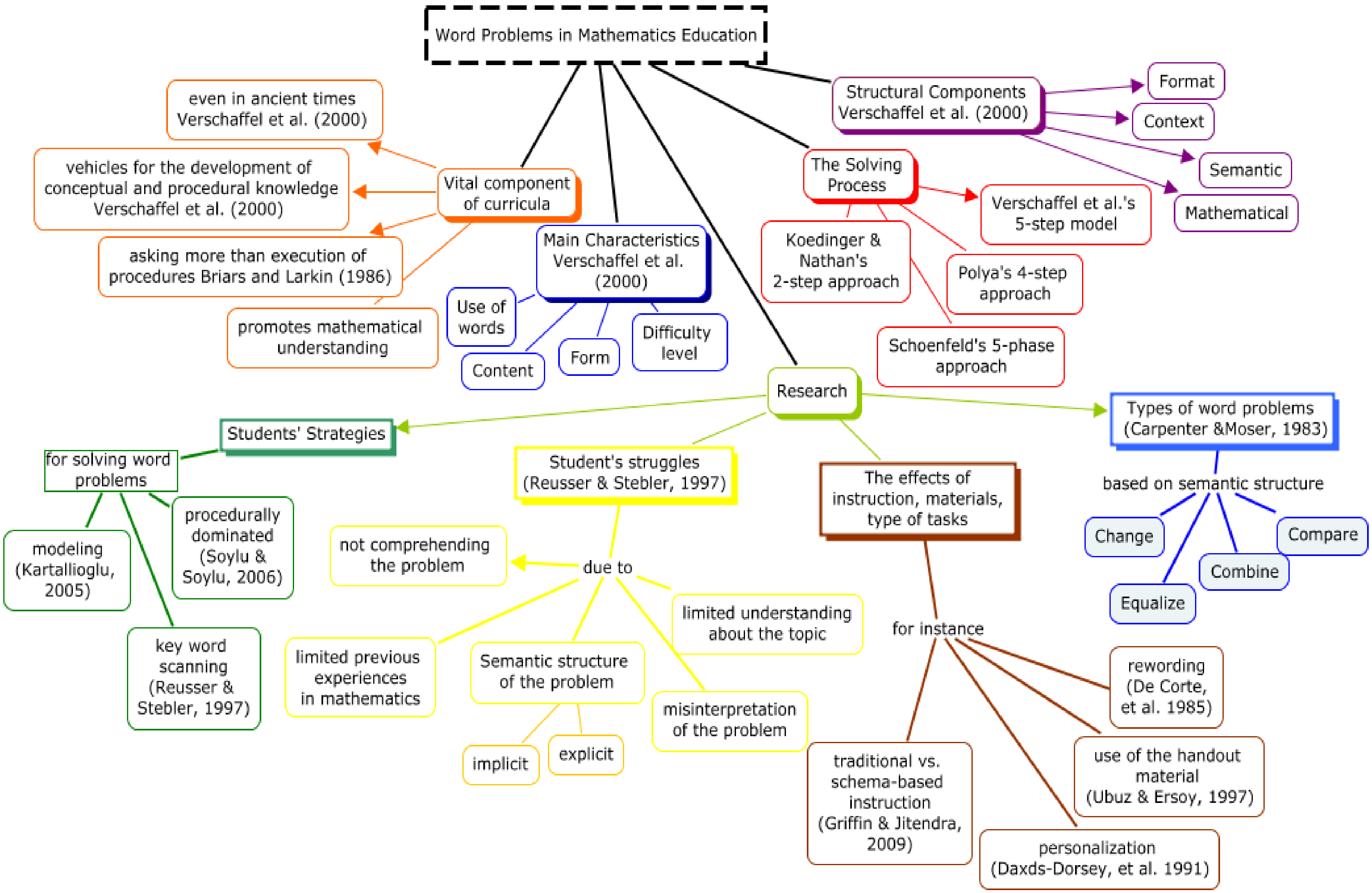


Figure 2.10 Summary of the Literature Review on Word Problems in Mathematics Education

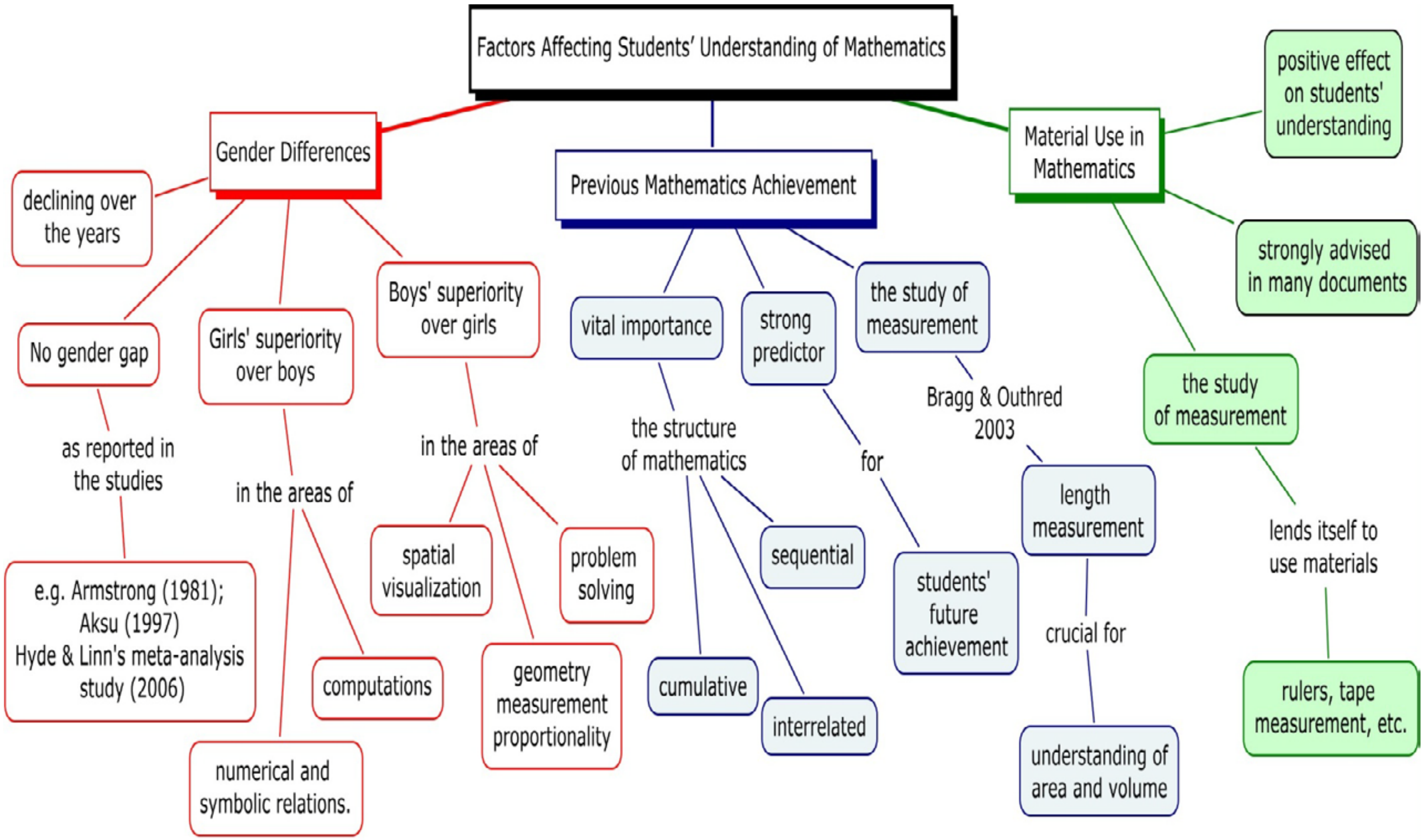


Figure 2.11 Summary of the Literature Review on Gender, Previous Math Achievement and Use of Materials in Mathematics

CHAPTER III

METHOD

This chapter explains the method and procedure that were used to investigate sixth grade students' conceptual and procedural knowledge and word problem solving skills in the domain of length, area, and volume measurement. Particularly, the chapter provides a detailed description of the subjects of the study, the data collection instruments, the pilot study of the data collection instrument, the procedures that were used for data collection, the data analysis procedure, and finally the limitations of the study.

3.1 Overall Design of the Study

The purpose of this study was to investigate sixth grade students' conceptual and procedural knowledge and word problem solving skills in the domain of length, area, and volume measurement with respect to gender, previous mathematics achievement, and the use of materials. Through synthesizing the information gathered from the existing literature, from the content and the learning objectives of length, area, volume measurement topics in sixth grade mathematics curriculum, three tests, namely, the Conceptual Knowledge test, the Procedural Knowledge Test, and the Word-problem Solving test that assess 6^{th} grade students' performances on length, area, and volume measurement were developed by the researcher. In addition to the tests, the Student Questionnaire was also developed by the researcher and used to collect data about the students' demographic information and the materials or tools used while teaching and learning measurement. All of the data collection instruments were prepared with and reviewed by the supervisor, and given to nine experts for further revisions. The instruments approved by the Human Subjects Ethics Committee at Middle East Technical University were pilot tested with 134 seventh grade students. The subjects of this study were 445 sixth grade students attending public schools located in four different central districts of Ankara. The tests and the questionnaire were administered to the students by the researcher in different sessions after the completion of the measurement unit. The collected data were analyzed by making use of Predictive Analytics Software (PASW). Both descriptive (means, standard deviations, and percentages) and inferential statistics techniques (MANOVA) were used in the study.

3.2 Subjects of the Study

The study was carried out with 6th grade students attending public schools in Ankara. There are several reasons for selecting sixth grade as a target level. First of all, the learning objectives of length, area, and volume measurement in the Turkish National Mathematics Curriculum from first to sixth grades include the fundamental concepts and skills, but in seventh and eighth grades the learning objectives become more specific and detailed in terms of the geometrical shapes. For instance, students are expected to develop strategies and use formulas to find the areas of rhombus, parallelograms, trapezoids, and circles in the seventh grade.

The second reason is also related to the mathematics curriculum itself. As stated previously, the nation-wide implementation of the updated elementary school curricula for 1st - 5th grades was started in 2005. In addition, the revised curriculum for the 6th - 8th grades has been implemented across the nation since 2006 in a step-by-step approach (starting from the 6th grade). Therefore, the sixth grade students have at least 2-year-experience in the updated curriculum and are considered as being familiar with the new approach of the curriculum when compared to upper grade levels.

Lastly, the age of students in this grade level is classified by Piaget as formal operational stage where students become more scientific in thinking and are able to solve abstract problems in a logical fashion when compared to younger students (Wadsworth, 1996). Particularly in the case of mathematics, the reviewed literature indicates that the development of mathematical understanding as well as understanding in measurement both related to age and the ability to process information. Besides, the literature also reveals that a majority of 12 year old students are generally considered as being mature enough to demonstrate the fundamental ideas in measurement such as unit iteration, conservation, and transitivity, etc. For these reasons, sixth graders seem to be the most appropriate group serving the purpose of this study.

In order to select a representative sample for the present study, the public schools' average mathematics scores in the Selection Examination for Secondary Education Institutions (OKS) was used as the main criteria. One of the reasons of this is that the OKS is a highly-competitive nationwide examination administered at the end of eighth grade. It is also mandatory for those who would like to enroll in one of the well-resourced, qualified and prestigious high schools.

Additionally, the performances of the schools on the OKS exam were perceived by parents as a strong indicator of the quality of education provided in primary schools (Sahin 2004), since the exam covers the content of primary education curriculum (1^{st} - 8^{th} grades) subjects including mathematics as well as other subject areas as Turkish language, science, etc. There are totally 100 multiple-choice questions, 25 of which are questions on mathematics. During the sample selection time, the only available recent data on the OKS was the exam administered in 2006. Thus, the sample selection of the present study was based on the results of the OKS-2006. From the official records of MONE, all public primary education schools in Ankara participated in the OKS-2006 (N= 685) and their mathematics scores in the OKS-2006 were obtained. In order to classify OKS-2006 schools in Ankara, the mean, range, minimum and maximum scores were calculated by making use of the mathematics scores obtained from MONE. As seen in Table 3.1, the average mathematics score of OKS-2006 schools in Ankara was 1.43 out 25.

Table 3.1

Descriptive Statistics of the Schools Participated in the OKS 2006

N	*Mean*	*SD*	*Minimum*	*Maximum*	*Range*	*Possible Maximum Score*
685	1.43	1.90	-3.00	9.32	12.32	25

Based on the range, the minimum and the maximum scores, totally 685 public primary schools in Ankara were classified as low, medium, and high-achieving schools. Three groups and their score ranges are presented in Table 3.2.

Table 3.2

Achievement Levels of the Schools Participated in the OKS 2006

Schools	*N*	*Mean*	*Maximum*	*Minimum*
High-achieving Schools	35	6.25	9.30	5.20
Medium-achieving Schools	285	2.6	5.19	1.10
Low-achieving Schools	365	.05	1.09	-3

Afterwards, the primary education schools which were participated in the OKS 2006 and located in the central districts of Ankara were listed according to the achievement levels as presented in Table 3.2.

Finally, two schools from each achievement level were selected for the study by considering the school size. All sixth grade students attending the selected public schools constituted the participants of this study. The detailed information about the schools and the students selected for the study is presented in the Table 3.3.

Table 3.3

Distribution of the Schools and the Students Selected for the Study according to the Achievement Levels and the Districts

Achievement levels	Selected schools	Average Math Scores in the OKS 2006	Central Districts	School size	Number of 6^{th} grade classes & students	Number of 6^{th} graders participated in the study
High	X School	7.27	Cankaya	1077	4 x ~ 30	81
	Y School	6.65	Cankaya	1099	4 x ~ 30-35	81
Medium	Z School	4.51	Y.mahalle	1073	4 x ~ 30	83
	F School	3.31	Kecioren	1056	5 x ~ 30	67
Low	L School	0.59	Kecioren	1010	2 x ~ 40	50
	K School	-0.58	Altindag	1000	4 x ~ 30	83

In this respect, the sample of the study was selected among the public primary schools in Ankara through the use of purposive sampling method and consisted of totally 445 sixth grade students attending the public primary schools located in four central districts of Ankara. Figure 3.1 indicates the sample selection process of the study.

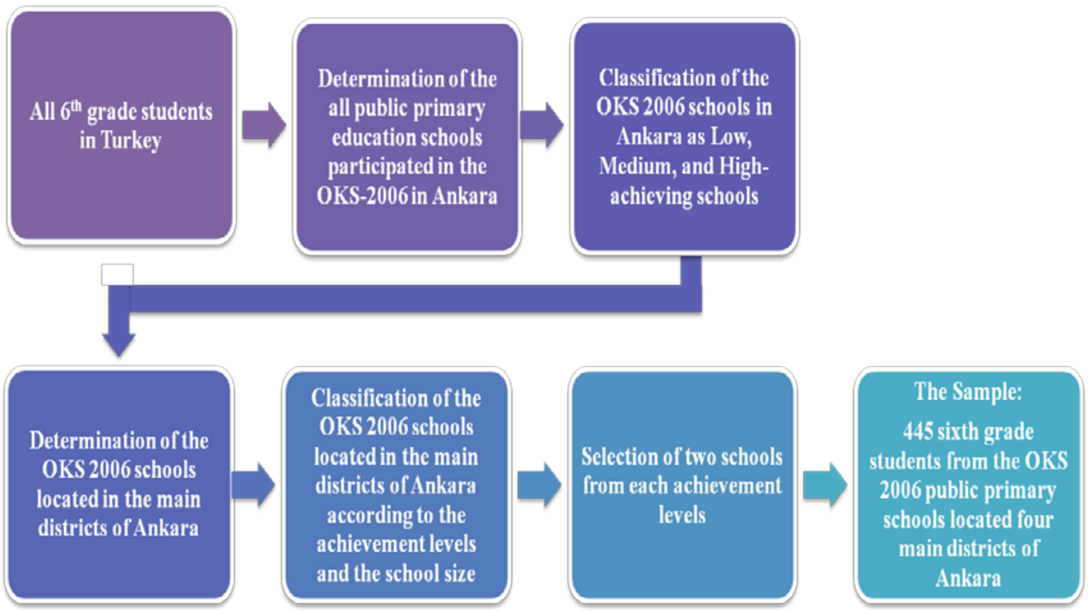


Figure 3.1 Sample Selection Process

As indicated in Table 3.4, among 445 sixth grade students participated to the study, 203 of them were male (45.6%) and 242 were female (54.4%). Their ages ranged between 11 – 14 and most of them (n=387, 87%) were 12 years old.

Table 3.4

Demographic Characteristics of Students

Background information	*f*	%
Gender		
Female	242	54.4
Male	203	45.6
Age		
11 years old	7	1.6
12 years old	387	87
13 years old	49	11
14 years old	2	.4

Table 3.4

Demographic Characteristics of Students (cont'd)

Background information	*f*	%
*Mathematics Report Card Grade in 5th Grade**		
High-achievers (4-5)	377	84.7
Average-achievers (3)	50	11.2
Low-achievers (1-2)	18	4
Enrollment of Out-of-school Mathematics Training		
Dershane's (Cram schools)	201	45.2
Supplementary math course offered by their school	94	21.1
Private mathematics tutor	36	8.1
Educational Level of Mothers		
Primary school	114	25.6
Middle School	60	13.5
High school	126	28.3
Higher Education	97	21.8
Graduate Education	17	3.8
Educational Level of Fathers		
Primary School	59	13.3
Middle school	78	17.5
High school	126	28.3
Higher Education	118	26.5
Graduate Education	31	7

** The students' mathematics report card grade ranges from 5 to 1 and descriptors for 5 - 4 (high-achievers) is great, 3 (average-achievers) is satisfactory, and 2-1 (low-achievers) is need improvement*

In relation to the students' previous mathematics achievement (mathematics report card grade in 5th grade), 18 of them (4%) were low-achievers, 50 were average-achievers (11.2%) and 377 were high-achievers (84.7%). Among the 445 students involved in the study, 201 of them (%45.2) reported that they were attending

Dershane's (cram schools), 94 of them (21.1%) were attending the supplementary mathematics course offered by their schools, and 36 (8.1%) of them had private mathematics tutor.

When the data on the educational level of participants' fathers were examined, 126 of them (28.3%) were graduated from high school, 118 (26.5%) were from higher education, 78 (17.5%) were from middle school, 59 (13.3%) were from primary school, and 31 of them (%7) had graduate degree. For the education level of mothers, 126 of them (28.3%) were graduated from high school, 114 (25.6%) were from primary school, 97 (21.8%) were from higher education, 60 (13.5%) were from middle school, and 17 of them (3.8%) had graduate degree.

3.3 Data Collection Instruments

In the present study, the Student Questionnaire (SQ) and three tests, namely, Conceptual Knowledge Test (CKT), Procedural Knowledge Test (PKT), and Word Problems Test (WPT), were used as the main data collection instruments. The detailed information about each instrument and the development process are provided in the following sections.

3.3.1 The Development of Student Questionnaire

As outlined in the literature, instructional materials used in mathematics education, particularly in the study of measurement lend themselves to enhancing and facilitating students' understanding. Therefore, the use of materials in measurement instruction was selected as one of the variables of this study. Student Questionnaire (SQ) developed by the researcher aimed to investigate whether the instructional materials were used during the measurement instruction. More specifically, the items of the questionnaire were aimed to gather information about not only the frequency of material use, and also by whom the materials were used. In order to determine what kinds of materials should be used in the study of measurement, both the related literature and the Turkish Elementary School Mathematics Curriculum guide was analyzed. According to the suggestion in the guide and the literature, the list including the following materials was prepared: (1) Ruler, (2) Isometric paper, (3) Unit cubes, (4) Dot paper, (5) Pattern blocks, (6) Square blocks, (7) Tangram, (8) Cubes blocks, (9) Volume blocks and (10) Geometry stripes.

The first draft of the questionnaire was prepared by the researcher and revised with the supervisor. In order to get feedback on the physical layout, the appropriateness and the clarity of items, the questionnaire was given to three experts, one from the field of educational sciences and others from the mathematics education. After revising some of the items according to the experts' suggestions, the final version of the questionnaire (see Appendix A) consisted of three parts. The first part consisted of the items related to students' background information as gender, 5^{th} grade mathematics achievement (grade point average in 5^{th} grade), age, enrollment in Dershane's (cram schools) or supplementary mathematics course offered by their schools, having private mathematics tutor, and parent education level. The first two background items were the variables of this study and the others were asked to reach more detailed information about the students.

The second part of the questionnaire was consisting of three-point Likert-scale ranging from "always" to "never". The list of suggested tools/materials in the Turkish Mathematics Curriculum guide was given and students were asked to indicate the frequency of the material use while they were learning/ taught length, area, and volume measurement. The list included in 10 materials (e.g. ruler, tangram, unit cubes, etc.) and also blank items for additional tools not mentioned in the list.The third part was composed of the items asking students to indicate "who" ("Myself", "Teacher", and "As a group") used the materials while learning/teaching length, area, and volume measurement. The questionnaire was also piloted with the seventh grade students during the pilot study of the tests.

3.3.2 The Development of the Tests

During the development process of three tests, namely CKT, PKT, and WPT, four phases were followed by the researcher given in Figure 3.2 (p.106). The first phase of the development process was the construction of the theoretical framework. Two major sources used to construct the theoretical framework were as follows: (a) existing research on the learning and teaching of spatial measurement, on conceptual and procedural knowledge in mathematics education; and (b) the study of measurement in the Turkish Primary Mathematics Curriculum.

The review of literature on conceptual knowledge and procedural knowledge in mathematics education indicated that the conceptual tasks were generally characterized as non-routine and novel tasks that require the use of understanding of underlying principles or concepts in a mathematical domain, not necessarily involving computations. However, procedural tasks are generally defined as routine tasks that require the use of previously learned step-by-step solution methods, mathematical computations, algorithms, or formulas (Hiebert & Lefevre, 1986; Kajidevic, 1999; Kulm, 1994; Rittle-Johnson, et al., 2001).

The literature also underlines that it is difficult to design procedure-free items to assess conceptual knowledge in mathematics and vice versa. Furthermore, three tests were also grounded in the previous research on students' understanding the measurement, the theoretical bases of measurement, and students' mistakes and misconceptions about measurement.

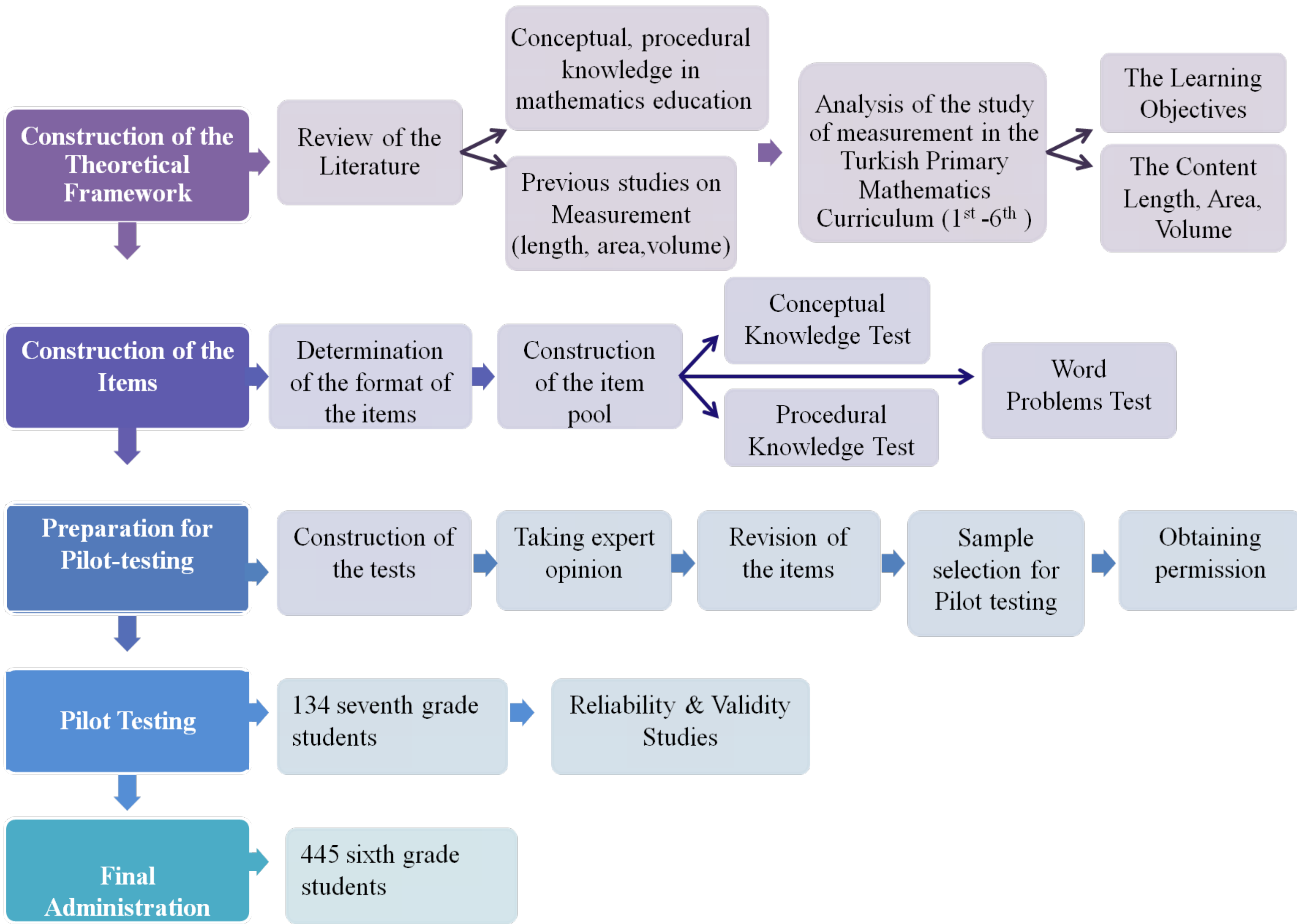


Figure 3.2 Development Phases of the Tests

It was observed in the literature that teaching and learning measurement was generally dominated with the procedural knowledge. Indeed, students' poor competence in measurement was mostly associated with partial or lack of knowledge about of the relationship between "what measurement means" and "how to measure". Put in differently, students are not aware of what they are doing when measuring. At this point, the fundamental principles of measurement in general and the others are specific to length, area, and volume measurement have very significant role in meaningful understanding in measurement. No matter whether a principle is common or specific to domains of measurement, all of them are related to each other and they are vehicles for the development of meaningful understanding in measurement. Figure 3.3 presents the foundational principles of measurement and its three domains.

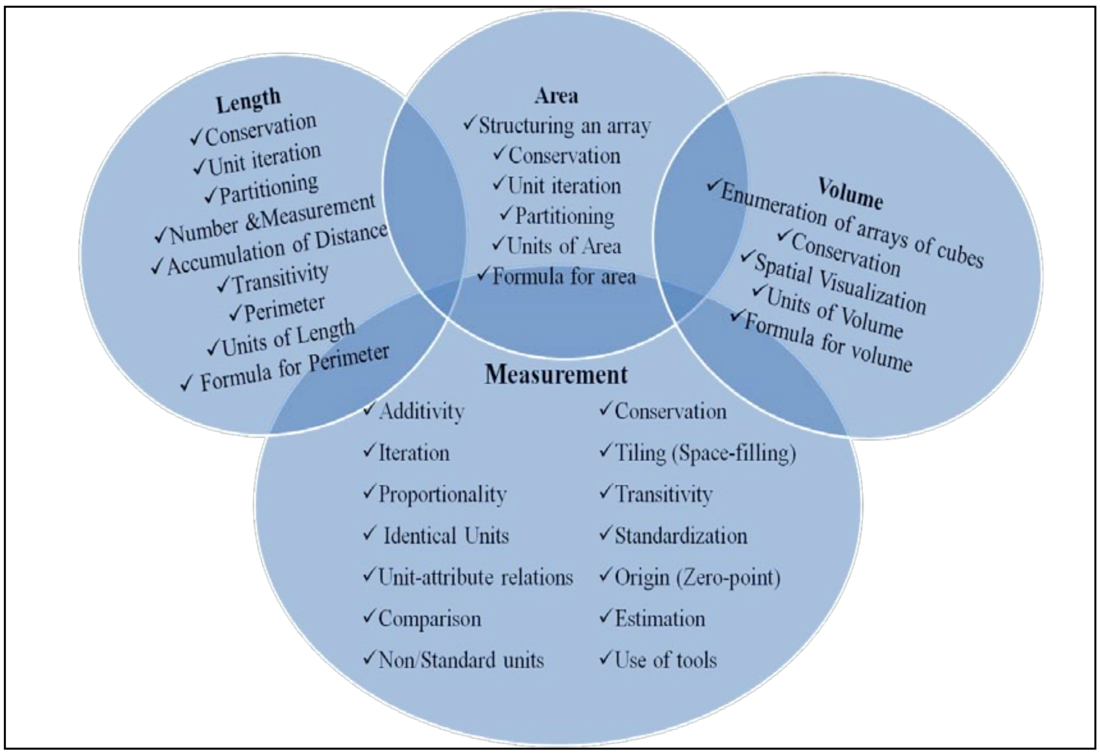


Figure 3.3 Underlying Principles of Measurement and Three Domains

All three tests used in this study were developed by taking the fundamental principles outlined above into consideration, since the acquisition and coordination of them establish the basis for a full understanding of measurement as well as for future mathematics learning.

Another main source for the theoretical framework for the data collection instruments was the study of measurement, especially length, area, and volume, in the Turkish Primary Mathematics Curriculum (K-8). From the learning objectives to the content, the mathematics curriculum was analyzed in a detailed manner so as to develop achievement tests which should be parallel to students' developmental levels and should cover the content of three domains of measurement in six-year of schooling period. The study of measurement in the curriculum is one of the main learning areas and taught to students from 1st grade to 8th grade. Measurement learning area covers:

1. Length Measurement,
2. Money,
3. Time Measurement,
4. Weight,
5. Liquid Measurement,
6. Perimeter,
7. Area Measurement, and
8. Volume Measurement.

Length measurement is first topic introduced to young students and taught in a spiral manner till 8th grade. The instruction of area measurement begins in the 3rd grade and continues until 8th grade. During the fifth grade, students are introduced with volume measurement. Like area, students are taught the study of volume measurement till 9th grade. The results clearly indicated that the contents of measurement in 7th and 8th grades become more specific to geometrical shapes and thus, they were not included in the present study. The detailed information about the content of length, area, and volume measurement in the Turkish Mathematics Curriculum (1st - 6th grade) is presented in Table 3.5.

Table 3.5

Domains of Measurement in terms of Learning Objectives, Allocated Time, and Proportion by Grade

Grade Levels	*Domains of Measurement*	*Number of Learning Objectives*	*Time devoted*	*Proportion %*
1st Grade	Length	4	6	4
2nd Grade	Length	6	11	8
3rd Grade	Length	5	10	7
	Perimeter	3	5	4
	Area	1	3	2
4th Grade	Length Measurement	6	6	4
	Perimeter	4	6	4
	Area	3	6	4
5th Grade	Length	2	3	2
	Perimeter	4	5	3
	Area	5	5	3
	Volume	2	3	2
6th Grade	Length	5	8	5,5
	Area	5	8	5,5
	Volume	4	8	5,5
	Total	59	93	47

Regarding to the learning objectives in length measurement from 1st to 6th grade, the curriculum analysis indicated that in a gradual and spiral process, the study of measurement started with comparing lengths and moves progressively from measuring with nonstandard units, to standard units, to measuring with standardized tools, to the concept of perimeter, area, volume, and the use of their formulas. Although the learning objectives of the three domains of measurement from 1st to 5th grade were taken into consideration, the items of the tests used in this study were principally developed according to the 6th grades' learning objectives specified in the curriculum. Table 3.6 shows the learning objectives in length, area, and volume measurement in the sixth grade level. The learning objectives of length, area, and volume measurement for grades 1st – 5th grades are presented in Appendix B.

Table 3.6

Learning Objectives of Length, Area, and Volume measurement in the 6th Grade

Domains of Measurement	Learning Objectives
Length *Students will*	✓ explain the units of length measurement and make conversions using them. ✓ estimate the perimeter of planar shapes by using strategies. ✓ solve and generate problems related to perimeter. ✓ explain the relationship between the perimeter of polygons and their side lengths.
Area *Students will*	✓ explain the units of area measurement and make conversions using them. ✓estimate the area of planar shapes by using strategies. ✓solve and generate problems related to area. ✓calculate the surface area of rectangular and square prisms, and cubes. ✓solve and generate problems involving the surface area of rectangular and square prisms, and cubes.
Volume *Students will*	✓generate the relational connections with regard to the volume of cubes, rectangular and square prisms. ✓estimate the volume of cubes, rectangular and square prisms by using strategies. ✓solve and generate problems related to the volume of cubes, rectangular and square prisms. ✓ explain the units of volume measurement and make conversions using them.

Second phase of the development process was the construction of the items for each test. The main focus of this phase was to design conceptual, procedural knowledge and word problem solving tasks and then, to choose those tasks which serve well the purposes of this study. In this respect, the following sub-steps were followed: the determination of items' format and the construction of the item pool. In order to eliminate the possibility of obtaining correct answer by guessing and to collect detailed information about what a student knows /understands and does not know /understand, the format of all three achievement tests were the constructed response items. More specifically, the test items in the Conceptual Knowledge test were in the format of short answer and/or essay items, apart from the one which was the matching question. Similarly, both Procedural Knowledge test and Word Problems test were consisted of the essay items.

For the construction of the item pool, the large-scale studies' released items (e.g. TIMSS) and the tasks and/or tests used in the small-scale studies were analyzed in terms of the key concepts and skills in length, area, and volume measurement as outlined above. In the same manner, the researcher, under the guidance of her supervisor, prepared items for each domains of measurement by considering the learning objectives of 6^{th} grade specified in the curriculum and the key concepts and skills derived from the mathematics education literature. Afterwards, the item pool was constructed among those which closely matched with the purposes of the present study.

Third phase was the preparation of pilot-testing. Since the main purpose of this study is to investigate 6th grade students' performance on conceptual, procedural knowledge and word problem solving skills in measurement, three kinds of tests were developed. In the Conceptual Knowledge test, the items were designed to assess students' understanding of measurement (length, area, volume). The items of Procedural Knowledge test were aimed to evaluate the students' procedural knowledge about measurement. For this reason, the test involved only the computational questions about measurement. The Word Problems test was developed to assess the students' word problem solving skills in measurement. It consisted of the items involving the same numbers and requiring the same operations included in the Procedural Knowledge test, but the items were stated in the form of verbal statements.

Afterwards, three tests were given to three academicians from the field of mathematics education, two academicians from the field of educational sciences, three mathematics teachers to obtain content-related and face validity evidences. The experts were kindly asked to examine whether the items of the tests were in line with the learning objectives in the 6th grade measurement unit and were representing the content specified in the curriculum, whether the sample of items was representative, whether the wording and language of items were understandable for the age group of this study. Based on the reflections and feedback taken from the experts, the tests were revised accordingly.

Further, a pilot-study school was selected according to the same criteria followed during the sample selection of the present study. Among the OKS-2006 public elementary schools, one of the medium-achieving schools located in one of the main districts of Ankara was selected for the pilot study. Seventh grade students at this school participated in the the pilot-study.

The main reason behind selecting 7th grade was due to the time constraint, as sixth graders did not complete the instruction on measurement in the meantime. Thus, the only suitable grade level for pilot testing was seventh graders who already received the instruction on measurement during sixth grade, but were not taught to the content of 7th grade measurement. The following table (Table 3.7) shows the general information about the pilot-testing school.

Table 3.7

General Information about the Pilot-testing School

The Pilot-testing School's				
Achievement level	*Average Math Score in the OKS 2006*	*Main District*	*School size*	*The Number of 7th grade classes and students*
Medium-achieving	5.35	Etimesgut	1056	5 classes, about 30 students in each

After obtaining ethical approval from the Human Subjects Ethics Committee at METU and a permission letter from the Ministry of National Education, the pilot-testing of the tests, the last phase of the development process, was carried out with 134 seventh graders in February 2008.

3.3.3 The Pilot Study of the Instruments

The data collection instruments were piloted with 134 seventh grade students from one of the OKS-2006 public schools in Ankara. The following table 3.8 summarizes the background information about the students involved in the pilot study.

Table 3.8

Background Information about the Students Involved in the Pilot Study

Background information	*f*	%
Gender		
Female	68	50.7
Male	66	49.3
Age		
13 years old	112	83.6
14 years old	20	14.9
15 years old	2	1.5
Mathematics Report Card Grade in 5th Grade		
High-achievers	73	54.4
Average-achievers	32	24
Low-achievers	29	21.6

** The students' mathematics report card grade ranges from 5 to 1 and descriptors for 5 – 4 (high-achievers) is great, 3(average-achievers) is satisfactory, and 2-1(low-achievers) is need improvement*

The pilot study was carried out in the first two weeks of March 2008. Since administering all instruments in a one session was too long and tiring for students, it was completed in three different sessions in different days. Firstly the Procedural Knowledge test and the Student Questionnaire, then the Conceptual Knowledge test, and finally the Word Problems test were administered to 7th grade students by the researcher. The detailed information about the data collection instruments are presented in Table 3.9.

Table 3.9

Data Collection Instruments of the Study

Instruments	The number of questions	Time to complete	Maximum Score
CKT	16 question (53 sub-questions)	50-55 minutes	53
PKT	27 questions	45-50 minutes	27
WPT	27 questions	45-50 minutes	27
SQ	27 questions (3 three parts)	10 minutes	------

In all classes, the mathematics teachers also stayed with the researcher till the end of the each administration session. Further, the students were told by their teacher that the score they got from the tests would affect their mathematics grade at school. The teachers also warned students not to leave any response blank. The reason behind these announcements was to make sure that students showed great effort to answer the questions seriously and carefully.

For the scoring of the tests, a scoring key was prepared for each test and revised by the supervisor and three experts. In the key, 1 point was assigned for the correct answer and 0 for both the incorrect answer and blank question.

The Kuder-Richardson approach was used to assess internal consistency of the tests' items. As one form of coefficient alpha, this method is considered to be more appropriate for determining the internal consistency among the items scored as 1 indicating a correct answer and 0 indicating an incorrect answer (McDaniel, 1994; Fraenkel & Wallen, 2003; Freed, Hess, & Ryan, 2002). In this study, the interrelatedness of the dichotomous items was calculated by using the KR-20 formula, instead of KR-21 which assumes that the difficulty level of all items is equal (Fraenkel & Wallen, 2003). The KR-20 formula is given below where N=Number of items on the test, p = Proportion of correct responses, $q = 1 - p$ = Proportion of incorrect responses, and σ^2 = Variance of the total test.

$$\text{KR-20} = \frac{N}{N-1}\left(1 - \frac{\sum \rho q}{\sigma^2}\right)$$

In this respect, the internal consistency of three tests was obtained through the KR-20 formula. The Table 3.10 indicates the internal consistency values for each test.

Table 3.10

Internal Consistency Values for the Tests

Tests	N	$\sum \rho q$	σ^2	r
Conceptual Knowledge Test	53	10.5	76.2	.87
Procedural Knowledge Test	27	4.3	30.5	.88
Word Problems Test	27	4.5	34	.89

With regard to reliability of the Student Questionnaire, Cronbach's alpha correlation coefficient, which is considered to be more suitable for the Likert-type items, was used for this instrument and was found .78 indicating high internal consistency among the items.

3.3.4 Final Forms of the Instruments

After the pilot study, the need to make some changes and revisions in the data collection instruments emerged. Under the guidance of the supervisor of the study, the initial changes and adaptations were done and the final drafts were given to three experts from the mathematics education. After that all the feedback was collated by listing the suggestions and the changes offered for the data collection instruments. Finally, the data collection instruments were revised by taking into account the feedback collation and the necessary changes were made accordingly.

For the changes/adaptations made in the CKT, first of all, the researcher observed during the pilot study that students had trouble with the understanding of the figure given in the first question, and thus, the figure and the wording of the question were revised. Based on the similar reason, the wording and the figure of 10th question was also revised so that they were more explicit and meaningful for the subjects of this study.

Moreover, 15th question in the pilot version of CKT had four sub-questions related to the area and perimeter concepts. Two of them asking students to draw a different shape that has the same area/perimeter as the shape shown in the other sub-questions of 15th question were extracted from the instrument. The reason behind is that it was found in the pilot study that two questions were actually asking for the same thing with those were taken out of the instrument.

With regard to the changes in PKT, there were totally 27 items involving the tasks on length, area, and volume conversions. Due to the time limitation, the number of conversion items was reduced to 9 in the final version of PKT. Besides, one item requiring using a ruler to measure the line segment was added to the test. Since the questions in the WPT were consisted of the items involving the same numbers and requiring the same operations included in the in line with the PKT, the changes/revisions were also made accordingly. Lastly, the only change made in the SQ was related to its physical appearance. The following table (Table 3.11) provides detailed information about the final forms of the data collection instruments of the present study.

Table 3.11

General Information about Final Forms of the Data Collection Instruments

	CKT	PKT	WPT	SQ
Number of items	16	20	20	27
Number of sub-items	50	-	-	-
Item format	Essay items, Matching, Multiple-choice, Short answer	Essay items	Essay items	Background information, Likert type
Completion time	40-45 min.	35-40 min.	40-45 min.	10 min.
Maximum Score	50	20	20	-

The final forms of each data collection instrument of the present study are explained in the following sections.

3.3.4.1 Conceptual Knowledge Test

The Conceptual Knowledge Test (CKT) was developed by the researcher, apart from two questions [Question 1.c was adapted version of TIMSS-1999 released item Permanent ID M022168 and Question 7 was taken from Hart's study (1981)]. The main purpose of this test was to examine to what extent students comprehend/understand the conceptual underpinnings of measurement, and thus, the items neither asked students to determine the correct/incorrect answers among the alternatives nor required to carry out computational exercises. Instead, the items asked students to show understanding of measurement concepts by interpreting, applying, and transferring them correctly to different situations. The final version of the CKT (see Appendix C) was composed of totally 16 main questions, but together with their sub-questions, it consisted of 50 items. The measurement concepts assessed by the CKT and the related questions are presented according to domains of measurement in Table 3.12.

Table 3.12

Content of the Conceptual Knowledge Test

Measurement Domains	The Related Questions	Measurement Concepts
Length measurement *8 questions/ max.24 points*	Q1: The broken ruler [7 sub-questions] a1: Finding the length of the broken ruler a2: Explain How the length of the broken ruler is found. b1 - Is it possible to measure 2 meters of cloth with the broken ruler? b2 - Explain why is/not it possible to measure. b3 - Explain how the cloth can be measured with broken ruler. c1 - Length of the string placed on the broken ruler c2 - Explain how you found the length of the string. [adapted version of TIMSS 1999 released item Permanent ID M022168]	-Unit iteration (of a composite unit) -Understanding of how scales on formal measuring tools work -Understanding of the meaning of numerals on a ruler -The concept of Zero Point
	Q3.Perimeter [2 sub-questions] a - Does it change under partitioning or not? b - Explain Why does (not) it change?	-The concept of perimeter -Understanding of the notion that perimeter can change under partitioning
	Q5. Making a photo frame [2 sub-questions] a - Which one is needed perimeter or area b - Explain Why perimeter/area is needed.	-The concept of perimeter -Understanding of the difference between area and perimeter
	Q7. Comparison of the length of the strings taken from Hart (1981) [3 sub-questions] a - Comparing the strings measured by different tools b - Comparing the strings measured by same tools/units c - Comparing the strings measured by same tools/units	-Understanding the importance of a unit in measurement

Table 3.12

Content of the Conceptual Knowledge Test (cont'd)

Measurement Domains	Related questions	Measurement Concepts
Length measurement (cont'd) *8 questions max. 24 points*	Q8. Choosing the most appropriate units of measurement for the attribute being measured 1 - The distance between two cities [km] 5- The perimeter of your blackboard [m] 6 - The width of 1YTL [mm]	- Understanding of appropriateness of units of measurement -Understanding of relationship between the attribute and a unit of measurement
	Q15. Comparison of the perimeters/areas of two shapes drawn on dot paper b1 - Are the perimeters of two shapes equal? b2 - Explain Why the perimeters of two shapes equal.	-The concept of perimeter
Area measurement *6 questions max. 15 points*	Q2. The amount of wrapping material [2 sub-questions] a – Which one (surface area, volume, the total length of the box' dimensions) is need for finding amount of wrapping material? b - Explain why surface area is need for finding the amount of wrapping material.	-The concept of surface area
	Q8. Choosing the most appropriate units of measurement for the attribute being measured 2 - The area of football yard [m^2] 3 - The area of the palm of your hand [cm^2] 7 - The area of your blackboard [m^2]	-Given in length measurement Q8
	Q13. Conservation of area [2 sub-questions] a - Comparison of areas of two shapes made up with the same pieces b - Explain why the areas are the same or not.	-The concept of area - Conservation of area
	Q14. The surface area and volume of a cube [2 sub-questions] a - If the volume of a cube is halved, what would happen to its surface area? b - Explain Why.	-The concept of surface area and volume -Understanding of the relationship between volume and surface area

Table 3.12

Content of the Conceptual Knowledge Test (Cont'd)

Measurement Domains	Related questions	Measurement concepts
Area measurement (cont'd) *6 questions* *max. 15 points*	Q15. Comparison of the perimeters/areas of two shapes drawn on dot paper a1 - Are the areas of two shapes equal? a2 - Explain Why the areas equal or not.	The concept of area Enumeration of arrays of squares
	Q16. The net of a rectangular prism box a1 – Finding the correct net of the given rectangular prism box a2 - Explain Why this net. b1 - What is the total number of small squares in the net surface area or volume? b2 - Explain Why surface area or volume	-Spatial visualization -The concept of surface area and volume -Understanding of the difference between volume and surface area
Volume measurement *5 questions* *max. 11 points*	Q4. The volume of a prism through its net [2 sub-questions] a – Finding the volume of a prism through its net b - Explain how the volume is found.	-The concept of volume -Spatial visualization
	Q6. The volume and dimensions of a prism [2 sub-questions] a – If one is tripled, are others tripled too? b - Explain the relation between volume and dimensions.	-The concept of volume -Understanding of relationship between the volume and the dimensions of a prism
	Q8. Choosing the most appropriate units of measurement for the attribute being measured 4- The amount of water in a swimming pool [m^3] 8 -The volume of a matchbox [cm^3]	Explained in length measurement
	Q9. The number of unit cubes in the prism [2 sub-questions] a – Finding the number of unit cubes made up the prism b – Explain how to find the number of unit cubes in the prism.	-The concept of volume -Spatial visualization -Enumeration of arrays of cubes
	Q12.The number of unit cubes and the volume [3 sub-questions] a - Finding the number of unit cubes needed to completely fill the shape b - Finding the volume of the box c - Explain how the volume is found.	-The concept of volume -Spatial visualization -Enumeration of arrays of cubes

3.3.4.2 Procedural Knowledge Test

Another data collection instrument of the study was Procedural Knowledge Test developed by the researcher. It aimed to evaluate the students' procedural knowledge about measurement. In particular, the test was designed to investigate the extent to which students could apply measurement procedures (routine and complex), formulas, and use measurement tool, a ruler which is the most commonly used tool in real life. For this reason, the test only involved the computational tasks involving length, area, and volume measurement.

There were totally 20 questions in the PKT. When applying procedures, operations, and formulas to solve the questions, the students were asked to show all their work in the answer sheets. The final version of the PKT is presented in Appendix D. In Table 3.13, the content of the PKT, namely, the items of the PKT and the assessed measurement skills is presented in a detailed manner.

Table 3.13

Content of the Procedural Knowledge Test

Measurement Domains	Related Questions	Measurement Skills
Length measurement *7 questions* *max. 7 points*	Q1. Conversion: Units of Length – mm to cm	To carry out unit conversions within a system of measurement
	Q4. Conversion: Units of Length – km to m	
	Q8. Conversion: Units of Length – cm to m	
	Q10. The perimeter of a polygon [All side lengths were given]	To calculate perimeter
	Q12. The perimeter of a square [The side length was given]	To use the formula for perimeter
	Q18. Given the perimeter and the length, finding the width of a rectangle	To use the formula for perimeter
	Q20. Using a ruler to measure the line segment	To use a ruler

Table 3.13

Content of the Procedural Knowledge Test (Cont'd)

Measurement Domains	The Related Questions	Measurement Skills
Area measurement	Q3. Conversion: Units of Area – km^2 to m^2	To carry out unit conversions within a system of measurement
	Q6. Conversion: Units of Area– m^2 to km^2	
	Q9. Conversion: Units of Area – m^2 to cm^2	
8 questions max. 8 points	Q11. Given the surface area and the length, finding the height of a square prism	To use the formula for surface area
	Q14. Given the perimeter and the length, finding the area of a rectangle	To use the formula for area
	Q15. The Surface area of a rectangular prism [All dimensions were given]	To calculate surface area of a rectangular prism
	Q17. Determining the un-shaded area of a rectangular shape [All side lengths were given]	To calculate the un-shaded area of a rectangular shape
	Q19. The area of a rectangle [The length and the width were given]	To calculate the area
Volume measurement	Q2. Conversion: Units of Volume – dm^3 to m^3	To carry out unit conversions within a system of measurement
	Q5. Conversion: Units of Volume – m^3 to cm^3	
	Q7. Conversion: Units of Volume – dm^3 to Liter	
5 questions max. 5 points	Q13. Given the volume, length, and width, finding the height of a rectangular prism	To use the formula for volume
	Q16. The volume of a rectangular prism [All dimensions were given]	To calculate the volume of a rectangular prism

3.3.4.3 Word Problem Test

The Word Problem test was designed to assess the students' word problem solving skills in length, area, and volume measurement. It composed of the problems written in the form of verbal statements and each of them involved the same numbers and operations with the questions in the Procedural Knowledge test. In other words, each word problem has a pair in the PKT which was presented in the numerical form and had the same numbers and the operations needed to reach the solution. Figure 3.4 shows the questions taken from PKT and WPT.

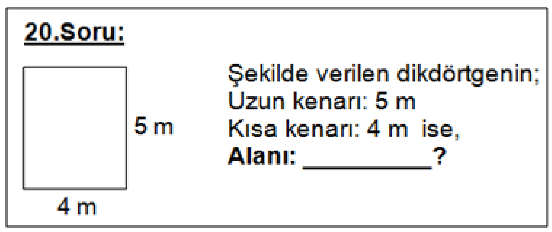
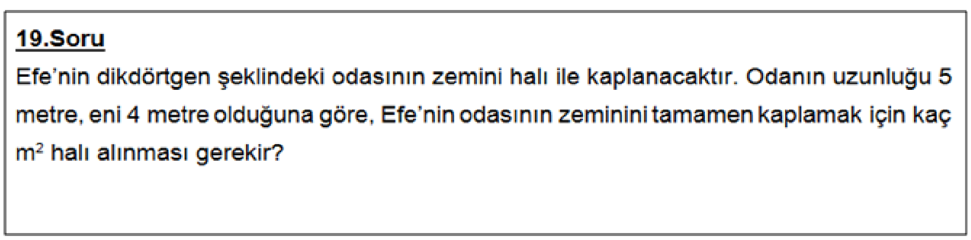


Figure 3.4a: The PKT question


19.Soru

Efe'nin dikdörtgen şeklindeki odasının zemini halı ile kaplanacaktır. Odanın uzunluğu 5 metre, eni 4 metre olduğuna göre, Efe'nin odasının zeminini tamamen kaplamak için kaç m^2 halı alınması gerekir?

Figure 3.4b: The WPT question

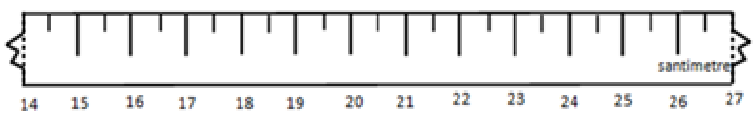
Figure 3.4 Paired Questions in the PKT and WPT

There were totally 20 questions in the WPT. Apart from one question, all of them were paired with the questions of the PKT. Both the 20th question of the WPT and of the PKT was related to the 1st question's sub-parts (a1 and a2) of the CKT. The former one was the verbal form and the latter one was the practical form of the CKT question.

As seen in Figure 3.5, although all three questions had the same answer, 13 centimeters, the type of knowledge embedded in each question and the way of assessment was different.

The CKT Question

Soru 1



a) Ceren'in matematik dersinde kırılan cetvelinden kalan parça yukarıda verilmiştir. Cetveli dikkatlice inceledikten sonra, aşağıdaki soruları yanıtlayınız.

➔ Kırık cetvelin başlangıç ve bitiş yerleri noktalı çizgilerle işaretlenmiştir. Bu **işaretlenmiş bölümün uzunluğu** kaç santimetredir? .... cm

➔ Kırık cetvelin uzunluğunu **nasıl** bulduğunuzu **açıklayınız**.

The PKT Question

20.Soru:

Yukarıda gösterilen şekildeki B ve C noktaları arasındaki uzunluğu **CETVEL** kullanarak ölçünüz. Bulduğunuz sonucu noktalı yere yazınız.

➔ B ve C noktaları arasındaki uzunluk: ....

The WPT Question

20.Soru

Ceren'in cetveli matematik dersinde kırılmıştır. Cetvelin şu anki başlangıç noktası 14 santimetre, bitiş noktası ise 27 santimetre olduğuna göre, cetvelin şimdiki uzunluğu kaç santimetredir?

Figure 3.5 Related Questions in the CKT, PKT, and WPT

The final version of the WPT is presented in Appendix E. Table 3.14 presents the items of the WPT in detail.

Table 3.14

Content of the Word Problems Test

Measurement Domains	Related Questions	Problem Solving Skills
Length measurement *7 questions max. 7 points*	Q1. Conversion: Units of Length – mm to cm	Solving problems involving unit conversions within a system of measurement
	Q4. Conversion: Units of Length – km to m	
	Q8. Conversion: Units of Length – cm to m	
	Q10. The perimeter of a polygon [All side lengths were given]	Solving perimeter problems
	Q11. Given the perimeter and the length, finding the width of a rectangle	
	Q12. The perimeter of a square [The side length was given]	
	Q20. Using a ruler to measure the line segment	Solving a word problem involving length measurement
Area measurement *8 questions max. 8 points*	Q3. Conversion: Units of Area – km^2 to m^2	Solving problems involving unit conversions within a system of measurement
	Q6. Conversion: Units of Area– m^2 to km^2	
	Q9. Conversion: Units of Area – m^2 to cm^2	
	Q14. Given the perimeter and the length, finding the area of a rectangle	Solving area problems
	Q15. The Surface area of a rectangular prism [All dimensions were given]	Solving surface area problems
	Q17. Determining the un-shaded area of a rectangular shape [All side lengths were given]	Solving area problems
	Q18. Given the surface area and the length, finding the height of a square prism	Solving surface area problems
	Q19. The area of a rectangle [The length and the width were given]	Solving area problems
Volume measurement *5 questions max. 5 points*	Q2. Conversion: Units of Volume – dm^3 to m^3	Solving problems involving unit conversions within a system of measurement
	Q5. Conversion: Units of Volume – m^3 to cm^3	
	Q7. Conversion: Units of Volume – dm^3 to Liter	
	Q13. Given the volume, length, and width, finding the height of a rectangular prism	Solving volume measurement problems
	Q16. The volume of a rectangular prism [All dimensions were given]	Solving volume measurement problems

3.4 Data Collection Procedure

After the data collection instruments were finalized, a set of documents explaining the aims, method, sample and instruments of the study was submitted to the Ministry of Education in order to obtain permission for the actual administration. The consent for permission received from the Ministry of Education is presented in Appendix F. In order to provide information about the study and administration of the instruments, the researcher arranged pre-interviews with the principals and the sixth grade mathematics teachers from each school included in the sample. Then, a time schedule for each school was prepared by considering the completion of teaching length, area, and volume measurement.

Upon the completion of the length, area, and volume measurement topics, the data collection instruments were administered to sixth grade students by the researcher over a period from May 2008 to June 2008. The procedure followed in the pilot study of the instruments was repeated in the actual administration process.

3.5 Data Analysis Procedure

In order to score the tests, a key was prepared for each of them and revised by the supervisor and the three experts. In the key, 1 point was assigned for the correct answer and 0 for both the incorrect answer and blank question. Before performing the statistical analysis procedure, the data cleaning and screening process was conducted to find out missing values. Since the administration of the tests and a questionnaire were done in different days, some of the students missed the sessions. Therefore, those who were not present during the data collection date, even missed one test, excluded from the data analysis process. Then, the quantitative data obtained both from the tests and the questionnaire were recorded on PASW.

The basic descriptive statistics including means, standard deviations, frequencies and percentages were carried out by means of this program in order to examine the overall performance of sixth graders on the tests. In addition to descriptive statistical methods, Multivariate Analysis of Variance (MANOVA) was also performed to find the answer to the research questions raised in the study.

For the analysis of students' written responses, the framework including common students' mistakes/errors related to three domains of measurement as highlighted in the review of literature was prepared. Then, each student' written responses was transformed into Word program and tabulated under the related questions one by one. Afterwards, the students' responses were tabulated according to the framework to produce categories of errors.

3.6 Limitations of the Study

This study is limited to 6^{th} grade students (n = 445) attending public primary schools located in four different central districts of Ankara. Thus, considering the scope and generalizability, the results of this study can be generalized only to the sixth grade students enrolled in public schools in Ankara.

In addition, as the study aimed at examining sixth graders' conceptual, and procedural knowledge and word problem solving skills in length, area, and volume measurement, only these topics were covered in this research study. Therefore, the results do not reflect the students' overall mathematics performance. Beside this, the results are limited with the data obtained through the tests on length, area, and volume measurement and the questionnaire used in the study.

Furthermore, subject characteristics and loss of subjects might be the possible threats to internal validity of the study. Since the sample of this study was drawn from different main districts of Ankara, the students possibly have had different socioeconomic status, ability levels, and attitudes toward mathematics, etc. which could affect the results of the study in unintended ways. To control this threat, the students were selected from the same grade level among public schools. In addition, during the sample selection process, school size (about 1000) and the average mathematics OKS scores of the schools were also taken into consideration.

Loss of subjects might be another threat for the study mostly due to the completion time of measurement unit and the Level Determination Exam (SBS). The instruction on measurement was completed in each school about two/three weeks before the end of the school year, as a result of this, the time for the administration of the instruments was restricted. Indeed, most of the students were mainly concentrated on preparation for the Level Determination Exam (SBS) which was replaced with the OKS exam in 2008. For that reason, some of them were absent during the administration process. To control this treat, the researcher arranged pre-interviews with the sixth grade mathematics teachers from each school included in the sample and a time schedule for each school was prepared.

CHAPTER IV

RESULTS

This chapter presents the results of the study on investigating the students' conceptual and procedural knowledge and word problem solving skills in the domain of length, area, and volume measurement with regard to gender, previous mathematics achievement, and the use of materials used in measurement instruction. The data gathered from 445 sixth grade students attending public primary schools in Ankara through three tests and a questionnaire were analyzed by making use of both descriptive and inferential statistics. The results are presented in line with the research questions in the following sections.

4.1 Results of the 6^{th} Grade Students' Performance on the Conceptual Knowledge, Procedural Knowledge, and the Word Problems Test

The first research question aimed to investigate 6^{th} grade students' overall performance on three tests. Descriptive analysis of the data revealed that 6^{th} grade students' overall scores for each tests were quite low (M_{CKT} = 19.6, SD_{CKT} = 9.2; M_{PKT} = 8.3 SD_{PKT} = 4.7; M_{WPT} = 7.7, SD_{WPT} = 4.8). The result of the students' overall performance on the tests is presented in Table 4.1.

Table 4.1

Results Concerning Students' Overall Performance on the CKT, PKT, and WPT (n=445)

Overall Score		*M*	*SD*	*Min.*	*Max.*
CKT	(out of 50 points)	19.6	9.2	0	46
PKT	(out of 20 points)	8.3	4.7	0	20
WPT	(out of 20 points)	7.7	4.8	0	20

With regard to the maximum and minimum scores, the students' overall performance on the CKT ranged from 0 to 46. Although no one obtained a perfect 100 percent score in the CKT, two students got 46 points which was the highest score of the CKT. Beside, only one student missed all CKT questions and thus, got the lowest score, zero. Similarly, only one student answered all questions correctly and obtained the highest score, 20, both in the PKT and WPT. Out of 445 students, three students in the PKT and twelve students in the WPT could not be able to correctly answer even one question and got the lowest score which was zero. In addition, the success rate of the students in each test was also calculated by dividing the mean score by the total score of the test. The results revealed that the 6th graders success rate in the CKT was thirty-nine percent (19.6/50 = .39); in the PKT was forty-one and one-half percent (8.3/20 = .41.5) and in the WPT was about thirty-eight and one-half percent (7.7/20 = .38.5).

Considering the students' performance on three domains of measurement, as indicated in Table 4.2, the highest performance was observed in length measurement on each test (M_{CKT} = 12.2, SD_{CKT} = 4.6; M_{PKT} = 4.7, SD_{PKT} = 1.7; M_{WPT} = 4.4, SD_{WPT} = 2); the lowest performance was observed in volume measurement (M_{CKT} = 2.7, SD_{CKT} = 2.5; M_{PKT} = 1.5, SD_{PKT} = 1.7; M_{WPT} = 1.5, SD_{WPT} = 1.7).

Table 4.2

Results Concerning Students' Performance on the Domains of Measurement according to the CKT, PKT, and WPT (n=445)

Students' Scores on		*M*	*SD*	*Min.*	*Max.*
Length Measurement					
CKT	(out of 24 points)	12.2	4.6	0	24
PKT	(out of 7 points)	4.7	1.7	0	7
WPT	(out of 7 points)	4.4	2	0	7

Table 4.2

Results Concerning Students' Performance on the Domains of Measurement according to the CKT, PKT, and WPT (n=445) (cont'd)

Students' Scores on		*M*	*SD*	*Min.*	*Max.*
Area Measurement					
CKT	(out of 15 points)	5	3.3	0	15
PKT	(out of 8 points)	2.1	1.9	0	8
WPT	(out of 8 points)	1.7	1.8	0	8
Volume Measurement					
CKT	(out of 11 points)	2.4	2.5	0	11
PKT	(out of 5 points)	1.5	1.7	0	5
WPT	(out of 5 points)	1.5	1.7	0	5

4.2 Results Concerning the Relationships among the Tests and the Domains of Measurement

The second research problem was asked to find out whether there is any significant relationship among the 6th grade students' overall performance on the Conceptual Knowledge, Procedural Knowledge and Word Problems Test.

Bivariate correlations were computed among three tests and Pearson correlation coefficient values indicated that there were statistically significant and strong relationships between all tests ($r_{PKT-WPT}$ =.84, $p < 0.5$; $r_{CKT-WPT}$ =.73, $p < 0.5$; $r_{CKT-PKT}$ =.70 $p < 0.5$) according to Cohen's criteria (Cohen, 1988).

The matrix emerging from the correlation analysis is presented in Table 4.3 which also shows that none of the correlations exceed .90, the indicator of the absence of multicollineairty (Tabachnick & Fidell, 2007).

Table 4.3

Correlation Matrix for the CKT, PKT, and WPT

Overall Score	CKT	PKT	WPT
CKT	1.00		
PKT	.70*	1.00	
WPT	.73*	.84*	1.00

*p<.05

Similarly, bivariate correlation was also run in order to see whether there is a significant relationship between the 6th graders performance on the tests with regard to domains of measurement. The results indicated a significant relationship between the students' performance on each test according to domain of measurement. Considering length measurement, the relationship between PKT and WPT was found as $r = .71$, $p < 0.5$; between WPT and CKT was found as $r = .59$, $p < 0.5$; between PKT and CKT was found as $r = .56$, $p < 0.5$. For area measurement, the relationship between PKT and WPT was found as $r = .75$, $p < 0.5$; between WPT and CKT was found as $r = .54$, $p < 0.5$; between PKT and CKT was found as $r = .51$, $p < 0.5$. For volume measurement, the relationship between PKT and WPT was found as $r = .82$, $p < 0.5$; between WPT and CKT was found as $r = .61$, $p < 0.5$; between PKT and CKT was found as $r = .61$, $p < 0.5$. According to Cohen's criteria (Cohen, 1988), all of the correlation coefficients values were quite strong and positive. Table 4.4 presents the matrix emerging from the correlation analyses.

Table 4.4

Correlation Matrix for the CKT, PKT, and WPT according to the Domains of Measurement

	CKT_{length}	CKT_{area}	CKT_{volume}	PKT_{length}	PKT_{area}	PKT_{volume}	WPT_{length}	WPT_{area}	WPT_{volume}
CKT_{length}	1								
CKT_{area}	$.62^{**}$	1							
CKT_{volume}	$.64^{**}$	$.61^{**}$	1						
PKT_{length}	$.56^{**}$	$.40^{**}$	$.48^{**}$	1					
PKT_{area}	$.56^{**}$	$.51^{**}$	$.58^{**}$	$.63^{**}$	1				
PKT_{volume}	$.57^{**}$	$.46^{**}$	$.61^{**}$	$.56^{**}$	$.73^{**}$	1			
WPT_{length}	$.59^{**}$	$.43^{**}$	$.55^{**}$	$.71^{**}$	$.60^{**}$	$.54^{**}$	1		
WPT_{area}	$.58^{**}$	$.54^{**}$	$.67^{**}$	$.50^{**}$	$.75^{**}$	$.71^{**}$	$.60^{**}$	1	
WPT_{volume}	$.55^{**}$	$.48^{**}$	$.61^{**}$	$.49^{**}$	$.67^{**}$	$.82^{**}$	$.59^{**}$	$.77^{**}$	1

$^{*}p<.05$

Furthermore, the results of the bivariate correlation analysis revealed that the students' performances on one type of tests in one domain of measurements significantly correlated with the other domains of measurement. As given in Table 4.4, a strong and positive relationship was observed between the students' performance on length measurement tasks and on area measurement ($r = .62$, $p < 0.5$) between volume measurement tasks and length measurement ($r = .64$, $p < 0.5$); and between area measurement tasks and volume measurement ($r = .61$, $p < 0.5$) in the CKT. Considering the PKT, there was a significant relationship between the students' performance on length measurement tasks and the tasks involving area measurement ($r = .64$, $p < 0.5$); between length measurement and volume measurement ($r = .56$, $p < 0.5$); and between area measurement tasks and volume measurement ($r = .73$, $p < 0.5$).

In addition, a strong and positive relationship was found between the students' performance on length measurement tasks and on area measurement ($r = .60$, $p < 0.5$); between volume tasks and length tasks ($r = .59$, $p < 0.5$); and between area measurement tasks and volume measurement ($r = .77$, $p < 0.5$) in the WPT. Likewise, all of the correlation coefficients values were fairly strong and positive.

4.3 Multivariate Analysis of Variance (MANOVA): Investigation of the Sixth Grade Students' Overall Performance on the Tests by Gender and Previous Mathematics Achievement

The third and fourth research problems aimed to explore whether the students' overall performance on the Conceptual Knowledge Test, Procedural Knowledge Test and Word Problems Test differ according to gender and previous mathematics achievement. For this purpose, a multivariate analysis of variance (MANOVA) was conducted by using Predictive Analytics SoftWare (PASW).

Prior to the analysis, the main assumptions which are independent observation, multivariate normality, and homogeneity of population covariance matrix for dependent variables (Field, 2009; Tabachnick & Fidell, 2007) were checked in order to explore the appropriateness of the data for running MANOVA.

First of all, independent observation was ensured during the data collection process. The researcher observed that the subjects responded to the tests independently of one another. Therefore, the data collected from the subjects were independent.

The second assumption of MANOVA is multivariate normality. Since univariate normality is a necessary condition for multivariate normality (Field, 2009), it was firstly checked through histograms with normality curves, Skewness and Kurtosis values, Kolmogorov-Smirnov, and Shapiro-Wilk tests. Histograms were visually inspected and all of them were seemed to be normally distributed. In addition, the Kurtosis and Skeweness values were examined in order to provide another evidence for univariate normality. Even though the Kurtosis and Skewness values were in the limit of normality, as stated by Tabachnick and Fidell (2007), Kurtosis and Skewness values between -3 and 3 are considered as approximately normal. Further, Kolmogorov-Smirnov and Shapiro-Wilk tests were also conducted for the univariate normality assumption. The values reported by the tests indicated that the distribution is normal. As univariate normality assumptions were verified, multivariate normality was finally checked through Mardia's test which yielded non-significant result ($p > .05$) that confirmed multivariate normality.

The last assumptions for MANOVA, homogeneity of variance and covariance matrices were tested by Levene's Test and Box's *M* Test respectively (Field, 2009). The results of Levene's test indicated that variances of all dependent variables of the present study were significantly different at an alpha level of .05 which shows the violation of homogeneity of variance assumption. Thus, Bonferroni-type- adjustment which is "a correction applied to the α-level to control the overall Type I error"

(Field, 2009, p.782) was performed. Therefore, the α-level (.05) was divided into the number of dependent variables, which were three (α=.05/3) (Coakes & Steed, 2001; Tabachnick & Fidell, 2007), then the criterion of significance of the α-level for interpreting each result of the univariate F-test was set as .017.

In addition, Box's *M* test also resulted in a non-significant value at .001, though it was significant at .05 level of alpha. As stated by Tabachnick and Fidell (2007), if Box's *M* test is significant at $p < .001$ and cell size are different which is the case of this study, robustness cannot be assumed. In this respect, the assumption for the homogeneity of variance was not violated in this study, as the Box's *M* test was found as non-significant at an alpha level of .001 indicating that population covariance matrix for each of the dependent variables are homogenous.

After the assumption check process was completed, descriptive statistics were run to portray the 6th grade students' performances on three tests in terms of gender and previous mathematics achievement and are presented in Table 4.5.

Table 4.5

Results of Descriptive Statistics (MANOVA)

Tests	Gender	Previous math achievement	*M*	*SD*	*N*
CKT *(out of 50 points)*	Male	Low	9	4.9	6
		Average	15.1	8	24
		High	20.5	9.1	173
		Total	19.5	9.2	203
	Female	Low	13.4	4.8	12
		Average	15.6	7.3	26
		High	20.5	9.4	204
		Total	19.6	9.3	242
	Total	Low	12	5.1	18
		Average	15.4	7.6	50
		High	20.5	9.2	377
		Total	19.6	9.2	445

Table 4.5

Results of Descriptive Statistics (MANOVA) (cont'd.)

Tests	Gender	Previous math achievement	*M*	*SD*	*N*
PKT (*out of 20 points)*	Male	Low	3.1	.9	6
		Average	5.4	3.8	24
		High	8.7	4.7	173
		Total	8.1	4.7	203
	Female	Low	5.2	4.1	12
		Average	5	4.1	26
		High	9.2	4.6	204
		Total	8.5	4.7	242
	Total	Low	4.5	3.5	18
		Average	5.2	4	50
		High	9	4.6	377
		Total	8.3	4.7	445
WPT (*out of 20 points)*	Male	Low	2.8	3	6
		Average	5	4.1	24
		High	8.4	4.7	173
		Total	7.8	4.8	203
	Female	Low	3	2.9	12
		Average	4.6	3.9	26
		High	8.3	4.8	204
		Total	7.6	4.9	242
	Total	Low	2.9	2.9	18
		Average	4.8	4	50
		High	8.3	4.8	377
		Total	7.7	4.8	445

The results indicated that the mean scores of girls (*M* = 19.6, *SD* = 9.3) and boys (*M* = 19.5, *SD* = 9.2) did not excessively differ in the CKT. As far as the mean scores of the students in the PKT is concerned, girls (*M* = 8.5, *SD* = 4.7) and boys (*M* = 8.1, *SD* = 4.7) scored relatively in the same manner. Moreover, no superiority was observed between the mean scores of girls (*M* = 7.6, *SD* = 4.9) and boys (*M* = 7.8, *SD* = 4.8) in the WPT.

Regardless of gender, the results of the descriptive analysis showed that students' mean scores on the tests differed in terms of previous mathematics achievement levels. In other words, high-achieving students (M_{CKT} = 20.6, SD_{CKT} = 9.2; M_{PKT} = 9, SD_{PKT} = 4.6; M_{WPT} = 8.3, SD_{WPT} = 4.8) had higher mean scores than average-achievers (M_{CKT} = 15.4, SD_{CKT} = 7.6; M_{PKT} = 5.2, SD_{PKT} = 4; M_{WPT} = 4.8, SD_{WPT} = 4) and low-achieving students (M_{CKT} = 3.1, SD_{CKT} = .9; M_{PKT} = 4.5, SD_{PKT} = 3.5; M_{WPT} = 2.9, SD_{WPT} = 2.9) in all tests. Besides, the results also indicated a superiority of the low-achieving girls over the low-achieving boys in the CKT (M_{girls} = 13.4, SD_{girls} = 4.8; M_{boys} = 9, SD_{boys} = 4.9) and the PKT (M_{girls} = 5.2, SD_{girls} = 4.1; M_{boys} = 3.1, SD_{boys} = .9).

It is also worth to note that the descriptive statistics output was clearly indicating the unequal cell sizes. As a way of solving the problem of unequal sample size in each cell suggested by Tabachnick and Fidell (2007), Type III Adjustment was run to eliminate the possible error in MANOVA. In addition, the result of Pillai's Trace Test was reported in this study so as to yield robust statistic against unequal sample sizes (Field, 2009; French, & Poulsen, 2008; Tabachnick & Fidell, 2007).

MANOVA was conducted with the aim of investigating whether the 6th grade students' overall performances on CKT, PKT, and WPT differ according to gender (male and female), and previous mathematics achievement (low-, average-, and high-achievers).

Using Pillai's Trace Test, there were significant differences in the students' overall performances on the combination of three dependent variables: CKT, PKT, and WPT by previous mathematics achievement V = .104, F (6,876) = 8, p < .05, η^2 = .052 indicating a small effect that approximately 5% of the variance in the combined dependent variables (CKT, PKT, and WPT) is explained by previous mathematics achievement. Nonetheless, no significant difference was observed in the students' performance on the tests in terms of gender, V = .008, F (3,437) = 1.22, p > .05.

After multivariate tests, univariate statistics were conducted in order to investigate the differences in the students' overall performance on three tests due to previous mathematics achievement and gender separately. Before running univariate analysis of variance ANOVA, Bonferroni-type- adjustment to decrease Type I error was set to .017. The results of univariate analysis revealed non-significant difference between students' performances on CKT, PKT, and WPT in consideration with gender, and following F values were found for each test: F_{CKT} (1,439)= .87, p >.017,; F_{PKT} (1,439)= .63, p >.017,; F_{WPT} (1,439)= .009, p >.017.

Furthermore, the univariate analysis indicated that the students' performances on the tests differed significantly according to previous mathematics achievement. F values were found for each test: F_{CKT} (2,439) = 14.46, p <.017, η^2 =.062; F_{PKT} (2,439) = 22.1, p <.017, η^2=.091; F_{WPT} (2,439) = 21.9, p <.017, η^2=.091. Table 4.6 illustrates F-statistics for both multivariate and univariate analysis.

Table 4.6

Multivaritate and Univariate Analysis of Variance: CKT, PKT, and WPT by Gender and Previous Mathematics Achievement

		ANOVA		
	MANOVA	CKT	PKT	WPT
Gender	V= .01, F(3, 437)	F(1,439)=.87	F(1,439)=.63	F(1,439)=.009
PMA	V= .10, F(6, 876)*	F(2,439)=14.46**	F(2,439)=22.10**	F(2,439)=21.90**

Note. F ratios are Pillai's Trace approximation. *p<.05, **p<.017
PMA: Previous Math Achievement

In order to find out whether students' overall performance in three tests differ significantly according to the levels of previous mathematics achievement, post hoc comparisons were performed with Scheffe's test, considered as the most conservative post-hoc test if sample size is unequal (Field, 2009; Tabachnick & Fidell, 2007). The results of the post-hoc test are presented in Table 4.7.

Table 4.7

Post Hoc Comparison Table

	6th Grade Students						
	Low (1)		Midde (2)		High (3)		
	M	*SD*	*M*	*SD*	*M*	*SD*	*Post hoc*
CKT	11.9	5.1	15.4	7.6	20.5	9.2	3>1, 3>2
PKT	4.5	3.5	5.2	3.9	9	4.6	3>1, 3>2
WPT	2.9	2.9	4.8	4	8.3	4.8	3>1, 3>2

Note. The numbers in parentheses in column heads refer to the numbers used for illustrating significant differences in the last column titled "Post hoc."

As given in Table 4.7, the results yielded that significant differences were observed in each test not only between the low-achieving and high-achieving students but also between the average-achieving and high-achieving students.

More specifically, the results showed that there was a statistically significant difference between the low-achieving (M_{CKT} = 11.9, SD_{CKT} = 5.1; M_{PKT} = 4.5, SD_{PKT} = 3.5; M_{WPT} = 2.9, SD_{WPT} = 2.9) and high-achieving students (M_{CKT} = 20.5, SD_{CKT} = 9.2; M_{PKT} = 9, SD_{PKT} = 4.6; M_{WPT} = 8.3, SD_{WPT} = 4.8) as well as average-achieving (M_{CKT} = 15.4, SD_{CKT} = 7.6; M_{PKT} = 5.2, SD_{PKT} = 3.9; M_{WPT} = 4.8, SD_{WPT} = 4) and high-achieving students. Nonetheless, the difference between low-achievers and average-achievers was statistically non-significant.

4.4 Results Concerning the Students' Common Mistakes in the CKT, PKT, and WPT

In the fifth research problem, the common mistakes/errors made by sixth grade students in three tests with regard to length, area, and volume measurement were investigated. Each item on the tests was analyzed one by one and then, the common mistakes were tabulated in order to answer the following research question "What are the 6th grade students' common mistakes/errors in three tests with regard to length, area, and volume measurement". As identified through their written explanations, the common errors committed by the sixth grade students are presented in a detailed manner according to three tests in the following sections.

4.4.1 Results Concerning the Students' Mistakes in the Conceptual Knowledge Test

The students' written explanations in the CKT indicated that they had serious difficulties related to three domains of measurement. Considering length measurement, although 60% of them (N = 268) found the length of the broken ruler correctly, only 38 % of them (*N* = 168) could be able to find the length of the string placed above the same ruler and not aligned with the beginning of the ruler. Moreover, 45.4% of the students (*N* = 202) correctly explained why and how the broken ruler can be used for measuring a 2-meter-long cloth, so they indicated the comprehension of both the concept of unit iteration and of zero-point. Besides, the sixth grade students were also asked to compare the length of the four strings, two of which were measured by the wooden stripe and other two were measured by the metal stripe. The analysis of the results indicated that whereas the number of students who paid attention to the measuring tool while asked to compare the length of two strings measured by different tools (Q.*7a*) is only 181 (40.7%), a majority of the students (*Q.7b* N=342, 77%; Q.*7c* *N*= 346, 78%) correctly compared the strings which were measured by the same tool.

In the 10th question of the CKT, about 90% of the students (*N*=397) stated that the given ruler was not constructed correctly, but only 17.5% of them (*N*=78) correctly explained why the ruler is made inaccurately. In Table 4.8, the students' mistakes related to the length questions in the CKT are presented with the frequencies and percentages of correct and incorrect answers.

Table 4.8

Students' Mistakes Related to Length Measurement in the CKT

Questions	*Answers*	***f***	***%***
Q1. The Broken ruler	Correctly explained	268	60.2
	Incorrectly explained	177	39.8
	Students' Mistakes	***f***	***%***
Explain how to find the length of the broken ruler.	Counting the numbers on the ruler	105	23.6
	Believing "all rulers are 30 cm long"	19	4.3
	Adding first and last numbers on the ruler	19	4.3
	First number + (plus) last number on the ruler- (minus)1	15	3.4
	Reporting the last number on the ruler as its total length	10	2.2
	Adding all numbers on the ruler	5	1.1
	First number + (plus) last number on the ruler + (plus) 1	4	.9
	Answers	***f***	***%***
	Correctly explained	202	45.4
Explain whether the broken ruler can be used for measuring a 2-meter-long cloth	Incorrectly explained	243	54.6
	Students' Mistakes	***f***	***%***
	It cannot be used, because		
	the ruler is too short to measure the cloth	112	25.3
	the ruler is broken and lost its function	64	14.4
	cm is not suitable unit to measure in meters	29	6.5
	200 cm cannot be divided by 13 cm	18	4.0
	The ruler is not starting from 0 (zero)	20	4.4

Table 4.8

Students' Mistakes Related to Length Measurement in the CKT (cont'd.)

Questions	*Answers*	***f***	***%***
Q1. The Broken ruler (cont'd)	Correctly explained	168	38
	Incorrectly explained	277	62
	Students' Mistakes	***f***	***%***
Explain how to find the length of the string placed above the broken ruler	Starting from 1	149	33.5
	Ignoring the curved parts of string	83	18.7
	Reporting the number on the ruler where the string end	25	5.6
	Adding either all the numbers between the end and the beginning points or adding the numbers where the string begins and ends as the length of the string	20	4.2
Q7. Comparison of the length of the strings [Hart, (1981)]	*Answers*	***f***	***%***
	Correct	181	40.7
	Incorrect	264	59.3
	Students' Mistakes	***f***	***%***
Is the length of the string A (11 wooden stripe long) equal to the string C (11 metal stripe long)?	*Yes*, the lengths of two strings are equal.	189	42.5
	No, the lengths of two strings are *not* equal.	75	16.8
	Answers	***f***	***%***
Is the length of the string D (14 metal stripe long) longer than the string C (11 metal stripe long)?	Correct	342	77
	Incorrect	103	23
	Students' Mistakes	***f***	***%***
	No, the length of the string D is *not* longer than the string C.	24	5.5
	No comments will be made about the lengths of the strings.	79	17.5

Table 4.8

Students' Mistakes Related to Length Measurement in the CKT (cont'd.)

Questions	*Answers*	*f*	*%*
Q7. Comparison of the length of the strings (cont'd)	Correct	346	77.8
	Incorrect	99	22.2
	Students' Mistakes	***f***	***%***
Is the length of the string B (9 wooden stripe long) shorter than the string A (11 wooden stripe long)?	*No*, the length of the string B is *not* shorter than the string A.	45	10.1
	No comments will be made about the lengths of the strings.	54	12.1
	Answers	*f*	*%*
Q10. Ruler Construction	Correctly explained	78	17.5
	Incorrect explained	367	82.5
	Students' Mistakes	***f***	***%***
Explain whether the ruler constructed correctly or not.	*It is wrong because,*		
	unequally-partitioned intervals	203	45.6
	the beginning point of the ruler is 1	48	10.8
	the physical appearance of ruler (e.g. numbers were written outside of the ruler)	50	11.3
	both the beginning point of the ruler and its physical appearance	9	2.0
	both unequally-partitioned intervals and its physical appearance	9	2.0
	It is correct, because the numbers on the ruler is in order	48	10.8

In addition, the written explanations for the concept of perimeter indicated that most of the students (*N* = 383, 86.1%) believe that perimeter is constant although the shape is changed. Beside this result, only 5% of them (*N* =21) could be able to explain why perimeter might change under partitioning (Q.3). Further, 64% of the sixth grade students (*N*=283) correctly explained why the perimeter of the photo, instead of area, should be known to make a frame. Additionally, the students were also asked to compare the perimeters of four different shapes which were enclosed by using the same amount of material (Q.11). The results revealed that about half of the students (51.5%, N = 229) answered the question correctly. However, only 42% of them (N = 187) provided the correct explanation for the question.

In the sub-parts of the 15th question, two shapes drawn on dot paper were given and the students were asked to find out whether the perimeters were equal. The results showed that forty-nine percent (N = 217) of the sixth grade students answered the question correctly. Nonetheless, among 445 students, only 157 of them (%35.3) correctly explained why the perimeters of two shapes are equal. The categories of students' mistakes related to perimeter are provided in Table 4.9 with the frequencies and percentages of correct and incorrect answers.

Table 4.9

Students' Mistakes Related to Concept of Perimeter in the CKT

Questions	*Answers*	***f***	***%***
Q3. The perimeter of two shapes	Correctly explained	21	4.7
	Incorrectly explained	424	95.3
	Students' Mistakes	***f***	***%***
Explain whether perimeter change under partitioning or not?	Believing that the perimeters are equal, since both are made up with the same pieces.	151	33.9
	Making visual comparison	85	19.1
	Believing that two perimeters are equal, only their pieces were arranged differently.	67	15.1
	Focusing on geometrical features of the shapes	63	14.2
	Believing that two shapes are equal only their shapes were changed	58	13.0

Table 4.9

Students' Mistakes Related to Concept of Perimeter in the CKT (cont'd)

Questions	*Answers*	***f***	***%***
Q5. A Photo Frame	Correctly explained	283	64
	Incorrectly explained	162	36
Which one should be known perimeter or area? Why?	***Students' Mistakes***	***f***	***%***
	Believing that area should be known, since the photo covers the area of the frame	62	13.8
	Believing that perimeter should be known since it's impossible to find its area without knowing its perimeter	45	10.1
	Believing that area should be known, since it's impossible to find its perimeter without knowing its area	33	7.3
	Believing that area should be known, since finding the area of frame is easier	15	3.4
	Believing that perimeter should be known, since finding the perimeter of frame is easier	7	1.4
Q11. The perimeters of four different shapes	*Answers*	***f***	***%***
	Correctly explained	157	35
	Incorrectly explained	258	58
Explain whether they are equal. No, they're not equal because	***Students' Mistakes***	***f***	***%***
	The shape X seems bigger/smaller	124	27.9
	Focusing on geometrical features of the shapes	81	18.2
	Confusing perimeter with area	53	11.9
Q15. The perimeters of two shapes drawn on dot paper	*Answers*	***f***	***%***
	Correctly explained	157	35.3
	Incorrectly explained	288	64.7
	Students' Mistakes	***f***	***%***
	Counting the square units	84	18.9
Explain whether they are equal.	Using units of area/volume measurement	50	11.2
	Believing that the area and the perimeter or vice versa should be equal	48	10.8
	Focusing on physical appearance of the shapes	48	10.8
	Counting the dots	38	8.5
	Not counting all lines surrounding the shape	20	4.5

Similarly, the analysis of the students' written responses to the questions involving area measurement also highlighted their serious difficulties. Among 445 sixth grade students, 187 of them (42%) stated that modifications in the form of a shape cannot produce change in area (Q.13), yet 155 of them (35%) could be able to explain the idea of area conservation correctly.

Moreover, in the sub-parts of the 15th question, the students participated to the study were asked to compare the areas of two shapes drawn on a dot paper. Whereas almost sixty percent of them (*N* = 259) marked the correct answer that the areas of two shapes are different, only 148 sixth grade students (33.3%) explained why the areas of two shapes are not equal. In table 4.10, the students' mistakes related to area measurement are presented with the frequencies and percentages of correct and incorrect answers.

Table 4.10

Students' Mistakes Related to Area Measurement in the CKT

Questions	*Answers*	***f***	***%***
Q13. Conservation of Area	Correctly explained	155	35
	Incorrectly explained	290	65
	Students' Mistakes	***f***	***%***
Explain why the areas of A and C which is made from the pieces of A are the same or not.	C< A, because A was cut and C was constructed from A. [area will change, if the shape is rearranged]	115	25.7
	C>A, because C has more sides than A (zigzag's) [confusing the area with the perimeter concept]	77	17.3
	C>A, because C seems to bigger [visual comparison]	36	8.1
	C<A, because A is square and C is different [focusing on geometrical features of the shapes]	32	7.2
	C=A, because they seems to be similar/same [visual comparison]	30	6.7

Table 4.10

Students' Mistakes Related to Area Measurement in the CKT (cont'd)

Questions	*Answers*	***f***	***%***
Q15. The areas of two shapes drawn on dot paper	Correctly explained	148	33.3
	Incorrectly explained	297	66.7
	Students' Mistakes	***f***	***%***
Explain whether the areas of two shapes are equal.	Counting the lines around the shape [perimeter]	161	36.2
	Using units of length/volume measurement while reporting area	67	15.1
	Focusing on physical appearance of the shapes [visual comparison]	42	9.3
	Believing that if the perimeters of shapes are equal, their areas are equal too.	27	6.1

Concerning the students' mistakes related to the concept of surface area, the results of the second question indicated that 52.8% of the sixth grade students (*N* = 235) stated that the surface area of the box was the most helpful information about the amount of wrapping material to wrap up a box, yet only 32.4% of them (*N* = 144) could be able to explain the relationship between the amount of wrapping material and the surface area of the box.

Beside of this, in the 14^{th} question, only 12.4 percent of the students (*N* = 55) reported that if the volume of a cube is halved, its surface area does not reduce in the same proportion (½). Nonetheless, among 445 students, 14 of them (3%) gave the correct explanation for this question.

Another question, 16^{th} question, related to surface area in the CKT was finding the net of a rectangular box which is made by unit cubes. A few number of the students (*N* = 120, 27%) could be able to match the rectangular box with its nets successfully and about 23% of them (*N* = 101) provided reasonable explanations for their matching. In addition, more than half of the students (*N* = 239, 54%) reported that the total number of square units in the box's net refers to the surface area of the box.

Among those who stated that square units in the net represent the surface area of the box, 22% of them (N = 97) explained why surface area is equal to total number of the square units in the net of a box. The categories of the students' mistakes related to the surface area are presented with the frequencies and percentages of correct and incorrect answers in Table 4.11.

Table 4.11

Students' Mistakes Related to Surface Area in the CKT

Questions	*Answers*	***f***	***%***
Q2. The Amount of Wrapping Material	Correctly explained	144	32.4
	Incorrectly explained	301	67.6
	Students' Mistakes	***f***	***%***
Explain which surface area, the sum of all side lengths, or volume gives the most helpful information in order to find out the amount of wrapping material needed for the box?	*I need to know the volume of the box*, because it is the amount of space covering the outside of the box [Confusing volume with surface area]	84	19
	I need to know the sum of all side lengths, because it is equal to the inside area of box.	65	14.5
	I need to know the surface area of the box, because its surface areas will be wrapped. [Believing the box has more than one surface areas]	42	9.3
	I need to know the sum of all side lengths, because multiplying the sum with 6 gives the surface area.	32	7.2
	I need to know the sum of all side lengths, because it is easier to find out than others.	27	6.1
	I need to know the surface area of the box, because its calculation is more important than others.	20	4.5
	I need to know the surface area of the box, because it indicates how many meters/centimeters of material needed. [Using units of length measurement for surface area]	19	4.3
	I need to know the surface area of the box, because its calculation is easier than others	12	2.7

Table 4.11

Students' Mistakes Related to Surface Area in the CKT (cont'd)

Questions	*Answers*	***f***	*%*
Q14. The surface area and volume of a cube	Correctly explained	14	3
	Incorrectly explained	431	97
If the volume of a cube is halved, explain what would happen to its surface area?	***Students' Mistakes***	***f***	***%***
	Surface area depends on volume, thus it is halved too.	321	72.1
	There is no relationship between surface area and volume, so surface area stays constant.	70	15.7
	Only the side lengths (dimensions of a cube) will change, so surface area is not halved.	40	9.0
Q16. The net of a rectangular prism box	*Answers*	***f***	*%*
	Correctly explained	22.7	101
	Incorrectly explained	77.3	343
Finding the correct net of the given rectangular prism box and explain why?	***Students' Mistakes***	***f***	***%***
	Net-IV – Counting unit cubes in the box (16 br^3) as square units in the net (16 br^2) [confusing volume with surface area]	158	35.6
	Net-III – Ignoring the dimensions of the box, only focusing on the number of square units in the net (40 br^2)	63	14.2
	Net-I – Counting the unit cubes only in the base (4 unit cubes) and the side of box (2 unit cubes) [visual comparison]	57	12.8
	Net-III – Counting unit cubes in the left and right sides of box (4 unit cubes in each) as square units in the net (4 unit squares)	46	10.3
	Net-II – Using units of length/volume measurement for surface area	19	4.4

Table 4.11

Students' Mistakes Related to Surface Area in the CKT (cont'd)

Questions	Answers	*f*	*%*
Q16. The total number of square units in the net (cont'd)	Correctly explained	97	22
	Incorrectly explained	348	78
	Students' Mistakes	***f***	***%***
	Volume – The square units indicate the amount of space of the box	107	24.0
Explain what is the total number of square units in the net, Surface area or Volume?	*Volume* – The total number of square units are equal to the volume of the box.	97	21.8
	Surface area – Unit cubes constitute the surface area of the box	53	11.9
	Volume – The square units are placed inside the box	26	5.8
	Surface area – The square units indicate the surface *areas* of the box	26	5.8
	Surface area – It is easy to calculate.	16	3.6
	Surface area – Counting lines/sides of unit squares (perimeter) gives the surface area of the box	14	3.1
	Volume – Multiplying the total number of square units with 6 gives the volume of the box	9	2.0

With regard to the results concerning the students' understanding of volume measurement, the similar pattern with length and area measurement was observed. The fourth question asked students to find out the volume of a prism through its net. The findings indicated that only 33 (7.4%) students gave the correct answer. Nevertheless, the number of the students who could be able to explain their process of finding the volume correctly is 29 (6.5%).

The analysis of the students' written responses to the sixth question also indicated that although 16% of them (N = 70) understand that if the volume of a prism is tripled, all dimensions are not tripled, too. Besides of this, only 7% of them (N = 30) made clear explanation for why all dimension are not tripled.

In an another question, 9th question, students were presented pictorial rectangular prism (3x4x5) and asked not only to find the number of unit cubes in prism but also explain how they find the answer. A total of 445 students, 26 % of them (N = 116) both determined the number of units cubes in the prism and gave a correct explanation. Furthermore, evidence obtained from the written responses to 12th question in the CKT revealed that 94 of the sixth grade students (21%) could be able to find the number of unit cubes needed to completely fill the box, 114 of them (25.6%) calculated the volume of the box, and 110 of them (24.7%) explained correctly how the volume of the box was found. With the frequencies and percentages of correct and incorrect answers, Table 4.12 indicates the students' mistakes about the concepts of volume measurement in the CKT.

Table 4.12

Students' Mistakes Related to Volume Measurement in the CKT

Questions	*Answers*	***f***	***%***
Q4. The volume of a prism through its net	Correctly explained	29	6.5
	Incorrectly explained	416	93.5
	Students' Mistakes	***f***	***%***
Explain how the volume is found.	Counting the square units [surface area]	222	49.9
	Using the volume formula with wrong dimensions of the prism	84	18.9
	Counting the lines around the prism	64	14.4
	Counting all square units and then multiplying the total number with 4	36	8.1
	Using the correct formula, but reporting the volume with units of length/area measurement	10	2.2

Table 4.12
Students' Mistakes Related to Volume Measurement in the CKT (cont'd)

Questions	Answers	*f*	*%*
Q6. The volume and dimensions of a prism	Correctly explained	30	7
	Incorrectly explained	415	93
	Students' Mistakes	***f***	***%***
If the volume of a prism is tripled, are all dimensions tripled too?	*All dimensions of a prism are tripled, too*; because volume is calculated through the multiplication of all dimensions.	331	74.3
	There is no change in dimensions, because only the volume is tripled, so the dimensions stay constant.	44	9.7
	Not all dimensions are tripled, because each dimension is different.	19	4.3
	Not all dimension is tripled, because if all dimensions are tripled, volume will be increased by 9 (3x3=9)	14	3.1
	Not all dimensions are tripled, because only the volume is tripled.	7	1.6
Q9. The number of unit cubes in the prism	*Answers*	***f***	***%***
	Correctly explained	116	26
	Incorrectly explained	329	74
	Students' Mistakes	***f***	***%***
Explain how to find the number of unit cubes in the prism.	Counting the faces of unit cubes and doubling that number	145	32.6
	Counting the faces of unit cubes	84	18.9
	Counting only visible unit cubes	23	5.2
	Counting the faces of unit cubes in two sides of a prism and multiplying them (e.g. 20x12)	22	5
	Counting the visible unit cubes at the top of a prism and multiplying that number with 3 because a prism is 3D.	20	4.5
	Counting the visible unit cubes in one side of a prism and multiplying that number with six, because a prism has 6 surfaces.	14	3.1
	Using correct formula with wrong dimension (e.g.6x5x4)	9	2.0
	Using the formula for the volume of a cube	8	1.8
	Using units of length/area measurement reporting the volume	4	.9

Table 4.12

Students' Mistakes Related to Volume Measurement in the CKT (cont'd)

Questions	*Answers*	***f***	**%**
Q12.The number of unit cubes and the volume	Correctly explained	110	24.7
	Incorrectly explained	335	75.3
	Students' Mistakes	***f***	**%**
	Counting the faces of unit cubes given in the picture and doubling that number	72	16.1
Explain how the volume of the box is found	Counting the faces of unit cubes given in the picture and multiplying that number with 3 because a prism is 3D.	48	10.8
	Using wrong formula for volume (e.g. base x height x 2)	47	10.6
	Counting the unit cubes given in the picture and filling the box (by drawing unit cubes) in a wrong manner (double counting)	47	10.6
	Counting the number of unit cubes given in the picture and multiplying that number with 3 because a prism is 3D.	43	9.7
	Using correct formula with wrong dimension (e.g.3 x 5 x3)	42	9.4
	Counting the faces of unit cubes given in the picture and multiplying that number with 6, because a prism has 6 surfaces.	28	6.3
	Using units of length/area measurement reporting the volume	8	1.8

Furthermore, the results also indicated that the sixth graders participated to this study had difficulties with the understanding of appropriateness of units of measurement and understanding of relationship between the attribute being measured and a unit of measurement being used. Table 4.13 summarizes the results of the matching-type question (Q.8) on choosing the most appropriate units of measurement for the attribute being measured.

Table 4.13

Students' Performance on the Tasks Related to Choosing Appropriate Units of Measurement for the Attribute Being Measured

Domains of Measurement	Questions	*f*	%
Units of Length Measurement	Q8.1. The distance between two cities		
	Correct (km)	370	83.1
	Incorrect	75	16.9
	Q8.5. The perimeter of your blackboard		
	Correct (m)	230	51.7
	Incorrect	215	48.3
	Q8.6. The width of 1YTL		
	Correct (mm)	201	45.2
	Incorrect	244	58.4
Units of Area Measurement	Q8.2. The area of football yard		
	Correct (m^2)	184	41.3
	Incorrect	261	58.7
	Q8.3. The area of the palm of your hand		
	Correct (cm^2)	139	31.2
	Incorrect	306	68.8
	Q8.7. The area of your blackboard		
	Correct (m^2)	173	38.9
	Incorrect	272	61.1
Units of Volume Measurement	Q8.4.The amount of water in a swimming pool		
	Correct (m^3)	229	51.5
	Incorrect	216	48.5
	Q8.8. The volume of a matchbox		
	Correct (cm^3)	133	29.9
	Incorrect	312	70.1

4.4.2 Results Concerning the Students' Mistakes in the Procedural Knowledge Test

Procedural knowledge test (PKT) was developed to evaluate 6th grade students' competencies related to applying and using operations and procedures of length, area, and volume measurement. In general, the results indicated the students' shallow knowledge of procedures in the three domains of measurement. Putting it differently, the procedural knowledge that students have represents only surface-level information that limits them to deal with different situations.

Considering the length measurement tasks in the PKT, the analysis of the tenth question showed that majority of the students (N = 278, 62.5%) successfully calculated the perimeter of a polygon whose all side lengths were given.

In the 12th question, the students were asked to calculate the perimeter of a square. Among 445 sixth graders, the eighty-six percent of them (N = 383) correctly calculated the perimeter of a square. In another question in the PKT, the 18th question, given the perimeter and the length, the students were asked to calculate the width of a rectangle. The results indicated that more than half of the students (N = 279, 62.7%) gave the correct answer.

Moreover, the 20th question was related to use of a ruler. According to the findings, 76.6% of the sixth graders (N = 341) could be able to use a ruler correctly to measure the line segment which is 13 cm long. The following Table 4.14 summarizes the students' mistakes in the PKT tasks involving length measurement with the frequencies and percentages of correct and incorrect answers.

Table 4.14

Students' Mistakes Related to Length Measurement (including perimeter questions) in the PKT

Questions	*Answers*	***f***	***%***
Q10. The perimeter of a polygon *All side lengths were given*	Correctly calculated	278	62.5
	Incorrectly calculated	167	37.5
	Students' Mistakes	***f***	***%***
	Using the correct formula, but making addition mistakes	64	14.3
	Using area formula	39	8.7
	Not adding all sides	25	5.6
	Adding the length of the polygon to the width [not multiplying with 2]	21	4.7
	Adding all sides and multiplying that number by 2	18	4.2
Q12. The perimeter of a square *The side length was given*	*Answers*	***f***	***%***
	Correctly calculated	383	86
	Incorrectly calculated	62	14
	Students' Mistakes	***f***	***%***
	Mistakes in addition/multiplication	24	5.3
	Adding only two side lengths [not multiplying with 2]	18	4.2
	Using units of area measurement	11	2.4
	Multiplying all side lengths (4x4x4x4)	9	2.1
Q18. Finding the width of a rectangle *The perimeter and the length were given*	*Answers*	***f***	***%***
	Correctly calculated	279	62.7
	Incorrectly calculated	166	37.3
	Students' Mistakes	***f***	***%***
	Width= Perimeter – (2 x length)	53	12
	Width= Perimeter – length	39	9
	Width= Length / 2	21	5
	Width= Perimeter + (2 / length)	19	4.1
	Mistakes in addition/multiplication	11	2.4
	Width= Perimeter + length	8	1.7
	Width= Perimeter + (2 x length)	5	1.1
	Width= Length x 2	4	0.8
	Width= Perimeter / length	4	0.8
	Width= Perimeter x length	2	0.4

Table 4.14

Students' Mistakes Related to Length Measurement (including perimeter questions) in the PKT (cont'd)

Questions	*Answers*	***f***	*%*
Q20. Using a ruler to measure the line segment	Correctly explained	341	76.6
	Incorrectly explained	104	23.4
	Students' Mistakes	***f***	*%*
	Counting the numbers on the ruler	56	12.6
	Incorrect alignment	34	7.6
	Reporting the last number matching the end point of the segment (C) as the length	9	2.1
	Adding all numbers on the ruler between the points of C and B	5	1.1

For the tasks involving area measurement (see Table 4.15), the results of the 14th question of the PKT revealed that 295 of the students (66.3%) correctly calculated the area of a rectangle where both the perimeter and the length were provided in the question.

Table 4.15

Students' Mistakes Related to Area Measurement in the PKT

Questions	*Answers*	***f***	*%*
Q14. Finding the area of a rectangle *The perimeter and the length were given*	Correctly explained	295	66.3
	Incorrectly explained	150	33.7
	Students' Mistakes	***f***	*%*
	Area = Perimeter – length	42	9.5
	Using the number that will give the width of a rectangle, if it is divided by 2	28	6.5
	Mistakes in addition/multiplication	22	5
	Area = Perimeter + width	17	3.8
	Using the formula for perimeter	15	3.3
	Area = Perimeter x length	11	2.4
	Area = Length x 4	8	1.7
	Area = Perimeter / width	7	1.5

Table 4.15

Students' Mistakes Related to Area Measurement in the PKT (cont'd)

Questions	*Answers*	***f***	***%***
Q17. Determining the un-shaded area of a rectangular shape *All side lengths were given*	Correctly calculated	132	30
	Incorrectly calculated	313	70
	Students' Mistakes	***f***	***%***
	Using the perimeter formula	82	18.4
	Area= Width + Length	79	17.6
	Mistakes in addition/multiplication	52	11.6
	Calculating the shaded area and reporting it as an un-shaded area	31	7
	Calculating the total area and reporting it as an un-shaded area	26	5.8
	Area = Length x Length	21	4.6
	Using units of length measurement	13	3
	The un-shaded area = All area / 4	9	2
Q19. The area of a rectangle *The length and the width were given*	*Answers*	***f***	***%***
	Correctly calculated	287	64.5
	Incorrectly calculated	158	35.5
	Students' Mistakes	***f***	***%***
	Using the perimeter formula	71	16
	Area= Width + Length	37	8.3
	Using units of length measurement	25	5.6
	Mistakes in addition/multiplication	17	3.9
	Area= Width x Length/2	8	1.7

In the question 17th, as indicated in Table 4.16, only thirty percent of the sixth graders (N = 132) could be able to find the un-shaded area of a rectangular shape in which all side lengths were given. Furthermore, the 19th question of the PKT was also related to area measurement and the results showed that a majority of the students (64.5%, N = 287) calculated the area of a rectangle in which the length and the width were provided in the question.

In relation to the tasks involving surface area, among 445 students, only 11 of them (2.5%) correctly answered the 11th question asking to calculate the height of a square prism where the surface area and the length of a prism were given. Besides, the students were asked, in the 15th question, to find a rectangular prism's surface area in which all dimensions were given. Apart from 28 students (6.3%), all of them missed the question. The students' mistakes in the PKT questions involving surface area are presented with the frequencies and percentages of correct and incorrect answers in the table below.

Table 4.16

Students' Mistakes Related to Surface Area in the PKT

Questions	*Answers*	***f***	***%***
Q11. Finding the height of a square prism	Correctly calculated	11	2.5
	Incorrectly calculated	434	97.5
	Students' Mistakes	***f***	***%***
	The height of a square prism = Surface area x length	153	34.4
	The height of a square prism = Surface area / length	117	26.2
	The height of a square prism = Surface area + length	43	10
	The height of a square prism = length	37	8.3
	The height of a square prism = (Surface area x length)/4	25	5.6
The surface area and the length were given	The height of a square prism = Surface area – (2 x length)/2	19	4.2
	The height of a square prism = length x 6 (# of surfaces)	18	4
	The height of a square prism = Surface area x 2	12	2.6
	The height of a square prism = $length^2$	10	2.2
Q15. The Surface area of a rectangular prism	*Answers*	***f***	***%***
	Correctly calculated	28	6.3
	Incorrectly calculated	417	93.7
	Students' Mistakes	***f***	***%***
	Surface area = length + width + height	103	23.5
	Surface area = length x width x height	87	19.5
All dimensions were given	Surface area = length x width	76	17
	Surface area = (length x height) + width	51	11.4
	Surface area = length + width	32	7.3
	Surface area = (length + width + height) x 6	19	4.2
	Surface area = length x height	19	4.2
	Surface area = length x 4	11	2.4
	Surface area = (length x height)/2	9	2
	Surface area = (length x width)/ height	6	1.4
	Surface area = (2 x width) + (2 x length)	4	0.8

Considering volume measurement, the number of students who was successful at finding the height of a rectangular prism whose volume, length, and width were given, the 13th question, was only 121 (27.2%), out of 445. Additionally, the 16th task asking to the students for calculating the volume of a rectangular prism whose all dimensions were given had also very low percentage of correct response which was about 29% (N = 128). The mistakes that students made while answering the questions of volume measurement are given with the frequencies and percentages of correct and incorrect answers in Table 4.17.

Table 4.17

Students' Mistakes Related to Volume Measurement in the PKT

Questions	*Answers*	***f***	***%***
Q13. Finding the height of a rectangular prism	Correctly calculated	121	27.2
	Incorrectly calculated	324	72.8
	Students' Mistakes	***f***	***%***
	Height = width x length	74	16.7
	Height = width + length	72	16.2
	Height = width + length – volume	59	13.2
Volume, length, and width, were given	Height = width + length + volume	43	9.7
	Height = width x length x volume	31	7
	Height = length	15	3.4
	Height = volume / 2	12	2.7
	Height = width + length / volume	8	1.7
	Height = width x length + volume	5	1.1
	Height = length – width	5	1.1
Q16. The volume of a rectangular prism	*Answers*	***f***	***%***
	Correctly calculated	128	28.8
	Incorrectly calculated	317	71.2
	Students' Mistakes	***f***	***%***
	Volume = length + width + height	107	24
All dimensions were given	Volume = length x width + height	81	18.1
	Mistakes in multiplication	53	12
	Volume = 3 x (length + width + height)	34	7.6
	Volume = 3 / (length + width + height)	18	4.1
	Volume = length x height	11	2.4
	Volume = length x width	7	1.6
	Volume = length + width	6	1.4

In addition to the students' mistakes, the findings also indicated that the sixth graders performances on making the conversions with the units of length, area, and volume measurement were relatively low. Table 4.18 displays the results of the conversion questions with percentages and frequencies.

Table 4.18

Results of the Conversion Questions in the PKT

Domains of Measurement	Questions	*f*	%
Units of Length Measurement	Q1. Conversion from mm to cm		
	Correct	283	63.6
	Incorrect	162	36.4
	Q4. Conversion from km to m		
	Correct	236	53
	Incorrect	209	47
	Q8. Conversion from cm to m		
	Correct	298	67
	Incorrect	147	33
Units of Area Measurement	Q3. Conversion from km^2 to m^2		
	Correct	140	31.5
	Incorrect	305	68.5
	Q6. Conversion from m^2 to km^2		
	Correct	77	17.3
	Incorrect	368	82.7
	Q9. Conversion from m^2 to cm^2		
	Correct	112	25.2
	Incorrect	333	74.8
Units of Volume Measurement	Q2. Conversion from dm^3 to m^3		
	Correct	179	40.2
	Incorrect	266	59.8
	Q5. Conversion from m^3 to cm^3		
	Correct	146	32.8
	Incorrect	368	82.7
	Q7. Conversion from dm^3 to Liter		
	Correct	126	28.3
	Incorrect	319	71.7

4.4.3 Results Concerning the Students' Mistakes in the Word Problem Test

The Word Problem test was designed to investigate the 6th grade students' word problem solving skills in length, area, and volume measurement. Apart from 20th question, all of the problems involved the same numbers and operations with the questions in the Procedural Knowledge test.

Regarding to length measurement, the findings indicated that a majority of the students (N = 303, 68.1%) calculated the perimeter of a polygon whose all side lengths were provided in the 10th problem. Besides, although the perimeter and the length of a rectangle were given in the 11th word problem, the number of the students who found its width correctly was 242 (54.4%), out of 445. Similarly, the 12th problem, most of the students were successful at finding the perimeter of a square (N = 346, 77.8%). In another word problem, 20th, the sixth graders were asked to find the length of the broken ruler and 258 of them (58%) could be able to answer correctly. The students' mistakes on the word problems involving length measurement are presented in the following table with the frequencies and percentages of correct and incorrect answers.

Table 4.19

Students' Mistakes Related to Length Measurement (including the questions on perimeter) in the WPT

Questions	*Answers*	***f***	***%***
Q10. The perimeter of a polygon	Correctly solved	303	68.1
	Incorrectly solved	142	31.9
	Students' Mistakes	***f***	***%***
All side lengths were given	Using area formula	52	11.7
	Adding the length of the polygon to the width [not multiplying with 2]	37	8.3
	Using the correct formula, but making addition mistakes	33	7.4
	Adding all sides and multiplying that number by 2	20	4.5

Table 4.19

Students' Mistakes Related to Length Measurement (including the questions on perimeter) in the WPT (cont'd)

Questions	Answers	*f*	*%*
Q11. Finding the width of a rectangle	Correctly solved	242	54.4
	Incorrectly solved	203	45.6
	Students' Mistakes	***f***	***%***
The perimeter and the length were given	Width= Perimeter – (2 x length)	68	15.2
	Width= Perimeter – length	49	11
	Mistakes in addition/multiplication	37	8.3
	Width= Perimeter + length	35	7.8
	Width= Perimeter x length	10	2.3
	Width= Perimeter / length	4	1
Q12. The perimeter of a square *The side length was given*	*Answers*	*f*	*%*
	Correctly solved	346	77.8
	Incorrectly solved	99	22.2
	Students' Mistakes	***f***	***%***
	Mistakes in addition/multiplication	36	8.1
	Using units of area measurement	29	6.5
	Adding only two side lengths [not multiplying with 2]	22	5
	Multiplying all side lengths (4x4x4x4)	7	1.5
	(Length x length) x 2	5	1.1
Q20. The length of the broken ruler	*Answers*	*f*	*%*
	Correctly solved	258	58
	Incorrectly solved	187	42
	Students' Mistakes	***f***	***%***
	Adding the beginning point and ending point of the ruler (14+27)	92	20.7
	Multiplying the beginning point with ending point of the ruler (14 x 27)	43	9.6
	Mistakes in subtraction	21	4.8
	Believing "all rulers are 30 cm long"	14	3.3
	Counting the numbers on the ruler	9	2
	Dividing the ending point by beginning point of the ruler (27 / 14)	8	1.8

According to the results of analyses related to the word problems involving area measurement, only a few number of students (*N* = 79, 17.8%) found the area of a rectangle correctly, even though the length and the perimeter were given the question 14. Likewise, the 17th word problem asking the students to find the un-shaded area of a rectangular shape in which all side lengths were given had also very low percentage of correct response which is 21.3% (*N* = 95). Further, in the 19th question, 243 sixth graders (54.6%), out of 445, were successful at finding the area of a rectangle whose length and width were given in the word problem. Students' mistakes on the word problems involving area measurement are presented with the frequencies and percentages of correct and incorrect answers in Table 4.20.

Table 4.20

Students' Mistakes Related to Area Measurement in the WPT

Questions	*Answers*	***f***	***%***
Q14. Finding the area of a rectangle	Correctly solved	79	17.8
	Incorrectly solved	366	82.2
	Students' Mistakes	***f***	***%***
	Area = Perimeter + length	87	19.5
	Only finding the width of a rectangle	85	19.1
	Area = Perimeter – length	54	12.4
The perimeter and the length were given	Using the formula for perimeter	32	7.1
	Mistakes in addition/multiplication	28	6.2
	Using the number that will give the width of a rectangle, if it is divided by 2	19	4.2
	Area = Perimeter x length	15	3.4
	Area = Length / 4	14	3.2
	Area = Perimeter / length	11	2.4
	Area = (Perimeter / 4) + length	9	2.1
	Area = Perimeter + width	7	1.5
	Area = Length x 2	5	1.1

Table 4.20

Students' Mistakes Related to Area Measurement in the WPT (cont'd)

Questions	*Answers*	***f***	***%***
Q17. Determining the un-shaded area of a rectangular shape	Correctly solved	95	21.3
	Incorrectly solved	350	78.7
	Students' Mistakes	***f***	***%***
	Using the perimeter formula	101	22.7
	Area= Width + Length	95	21.3
All side lengths were given	Mistakes in addition/multiplication	72	16.2
	Using units of length measurement	41	9.2
	Reporting the shaded area as the un-shaded	20	4.5
	Reporting the total area as the un-shaded area	13	3
	Area = Length – width	8	1.8
Q19. The area of a rectangle	*Answers*	***f***	***%***
	Correctly solved	244	54.8
The length and the width were given	Incorrectly solved	201	45.2
	Students' Mistakes	***f***	***%***
	Area= Width + Length	71	16
	Using the perimeter formula	62	14
	Using units of length measurement	32	7.2
	Mistakes in addition/multiplication	20	4.5
	Area= (Length x width) x 2	16	3.5

With regard to the surface area word problems, only 16 of the sixth graders (3.6%) could be able to solve the problem asking to find out the surface area of a rectangular prism whose all dimensions were given in the 15th question. Similarly, the 18th word problem related to calculating the height of a square prism where the surface area and the side length were given had quite low percentage of correct response which is 2.7% (N = 12). With the frequencies and percentages of correct and incorrect answers, the students' mistakes in the questions of surface area are presented in Table 4.21.

Table 4.21

Students' Mistakes Related to Surface Area in the WPT

Questions	*Answers*	***f***	***%***
Q15. The Surface area of a rectangular prism	Correctly solved	16	3.6
	Incorrectly solved	429	96.4
	Students' Mistakes	***f***	***%***
	Surface area = length + width + height	136	30.5
	Surface area = length x width x height	121	27.1
All dimensions were given	Surface area = (length + width + height) x 2	52	11.6
	Surface area = length x width	33	7.5
	Surface area = (length x height) + width	29	6.5
	Surface area = length + width	17	4
	Surface area = (length x width)+ (length x height)+ (height x width)	13	3
	Surface area = 2 x (length + width)	10	2.3
	Surface area = width x height	7	1.5
	Surface area = width x length + height	6	1.3
	Surface area = (2 x width) + (2 x length)	5	1.1
Q18. Finding the height of a square prism	*Answers*	***f***	***%***
	Correctly solved	12	2.7
	Incorrectly solved	433	97.3
	Students' Mistakes	***f***	***%***
The surface area and the length were given	The height of a square prism = Surface area / length	157	35.3
	The height of a square prism = Surface area + length	82	18.4
	The height of a square prism = Surface area x length	63	14.2
	The height of a square prism = Surface area – length	48	10.8
	The height of a square prism = Surface area/(2 x length)	27	6.1
	The height of a square prism = Surface area - (2xlength)	22	5.1
	The height of a square prism = (Surface area - length)/4	16	3.5
	The height of a square prism = length x 2	11	2.4
	The height of a square prism = length	7	1.5

Considering volume measurement, in the 13th word problem the length, width, and the volume were given and the students were asked to the height of a rectangular prism. The results revealed that 105 of them (23.6%) correctly solved the problem. Beside this, only 122 of them (27.4%) correctly calculated the volume of a rectangular prism whose dimensions were given in the 16th word problem. With the frequencies and percentages of correct and incorrect answers, the detailed information about the mistakes made by the students while solving volume measurement word problems is given Table 4.22.

Table 4.22

Students' Mistakes Related to Volume Measurement in the WPT

Questions	*Answers*	***f***	***%***
Q13. Finding the height of a rectangular prism	Correctly solved	105	23.6
	Incorrectly solved	340	76.4
	Students' Mistakes	***f***	***%***
	Height = width x length	71	16
	Height = width + length + volume	64	14.3
	Height = width + length – volume	41	9.2
	Height = width + length	38	8.6
Volume, length, and width, were given	Height = length + volume	26	5.9
	Height = (2 x width) + (2 x length) - volume	24	5.4
	Height = width x length x volume	18	4
	Height = width x length – volume	18	4
	Height = volume – length	13	2.9
	Height = length + volume	11	2.5
	Height = length / width	8	1.8
	Height = volume + length – width	8	1.8
Q16. The volume of a rectangular prism	*Answers*	***f***	***%***
	Correctly solved	122	27.4
	Incorrectly solved	323	72.6
	Students' Mistakes	***f***	***%***
	Volume = length + width + height	127	28.5
All dimensions were given	Volume = length x width	94	21.2
	Mistakes in multiplication	39	8.8
	Volume = length x width + height	25	5.6
	Volume = (length x width) + (height x width) + (length x height)	18	4
	Volume = length + width	14	3.2
	Volume = 3 / (length + width + height)	6	1.3

As reported in the other two tests used in the study, the findings also indicated that 6th grade students did not perform well in solving word problems related to the conversions with the units of length, area, and volume. Table 4.23 summarizes the results with regard to the conversions word problems asked in the WPT.

Table 4.23

Results of the Conversion Questions in the WPT

Domains of Measurement	Questions	*f*	%
Units of Length Measurement	Q1. Conversion from mm to cm		
	Correct	295	66.3
	Incorrect	150	33.7
	Q4. Conversion from km to m		
	Correct	230	51.7
	Incorrect	215	48.3
	Q8. Conversion from cm to m		
	Correct	309	69.4
	Incorrect	136	30.6
Units of Area Measurement	Q3. Conversion from km^2 to m^2		
	Correct	149	33.5
	Incorrect	296	66.5
	Q6. Conversion from m^2 to km^2		
	Correct	72	16.2
	Incorrect	373	83.8
	Q9. Conversion from m^2 to cm^2		
	Correct	128	28.8
	Incorrect	317	71.2
Units of Volume Measurement	Q2. Conversion from dm^3 to m^3		
	Correct	170	38.2
	Incorrect	275	61.8
	Q5. Conversion from m^3 to cm^3		
	Correct	153	34.4
	Incorrect	292	65.6
	Q7. Conversion from dm^3 to Liter		
	Correct	126	28.3
	Incorrect	319	71.7

4.5 Results Concerning Use of Materials in Measurement Instruction

The last research problem focused on the use of materials in measurement instruction and aimed not only to find out which materials were used by whom during measurement instruction but also to explore whether there is significant relationship between the students' performance on each test (CKT, PKT, and WPT) and use of materials. The analysis of the data obtained via the Student Questionnaire (SQ) indicated that while ruler (98.2%), unit cubes (65.4%), isometric paper (62.5%), dot paper (60.9%), and geometry stripes (54.9%) were more frequently used materials, cubes blocks (28.5%), square blocks (30.3%), volume blocks (37%), and pattern blocks (37.6%) were rarely-used materials during measurement instruction. Among ten materials, ruler was used more by students and unit cubes was used frequently by teachers. The rarely student-used material was cube blocks (10.5%) and ruler (4%) was rarely-used material for teachers. Table 4.24 displays the results of descriptive statistics concerning use of materials in measurement instruction in a detailed manner.

Table 4.24

Results Related to Use of Materials in Measurement Instruction

	Use of Materials											
	How often used						*Who used*					
Materials	Always		Sometimes		Never		Student		Teacher		As a Group	
	f	*%*	*f*	*%*	*f*	*%*	*f*	*%*	*f*	*%*	*f*	*%*
Ruler	145	32.6	292	65.6	8	1.8	279	62.7	18	4	36	8.1
Isometric Paper	19	4.3	259	58.2	167	37.5	194	43.6	33	7.4	36	8.1
Unit Cubes	32	7.2	259	58.2	154	34.6	60	13.5	133	30	41	9.2
Dot Paper	37	8.3	234	52.6	174	39.1	192	43.1	31	7	30	6.7
Pattern Blocks	19	4.3	148	33.3	278	62.5	48	10.8	86	19.3	28	6.3
Square Blocks	17	3.8	118	26.5	310	69.7	42	9.4	62	14	23	5.2
Tangram	25	5.6	144	32.4	276	62	51	11.5	56	12.6	25	5.6
Cubes Blocks	13	2.9	114	25.6	318	71.5	29	6.5	71	16	18	4
Volume Blocks	22	4.9	143	32.1	280	62.9	41	9.2	94	21.1	26	5.8
Geometry Stripes	31	7	213	47.9	201	45.2	44	10	109	24.5	37	8.3

Furthermore, in order to investigate whether there is significant relationship between the students' performance on each test (CKT, PKT, and WPT) and use of materials in learning measurement, point-biserial correlation that is considered as the most suitable type of correlation for quantifying the relationship between continuous variable and dichotomous variable (Field, 2009) was used. Before calculating the correlation, the responses related to use of materials in the SQ were re-coded to dichotomous format with 0 (never used) and 1 (used). As presented in Table 4.25, no significant relationship between the use of materials and students' overall performance on the PKT was observed. However, a significant but low relationship was observed between the use of ruler and the students' overall performance on the WPT (r_{pb} = .10, p < .05). Similarly, although the point-biserial correlation coefficients were low, the results indicated that there were significant relationships between the students' performances on the CKT and the use of square blocks (r_{pb} = .161, p < .05), of tangram (r_{pb} = .137, p < .05), of cube blocks (r_{pb} = .119, p < .05), of volume blocks (r_{pb} = .144, p < .05), and of geometry stripes (r_{pb} = .119, p < .05).

Table 4.25

Correlation Matrix for the CKT, PKT, and WPT

Overall Score	CKT	PKT	WPT
Ruler	.057	.088	.10*
Isometric Paper	.006	.019	.059
Unit Cubes	.011	.050	.080
Dot Paper	.023	.033	.022
Pattern Blocks	.039	.040	.035
Square Blocks	.161*	.040	.012
Tangram	.137*	.007	.025
Cube Blocks	.119*	.036	.021
Volume Blocks	.144*	.041	.035
Geometry Stripes	.119*	.008	.025

*p<.05

4.6 Summary of the Results

First of all, the findings obtained by the statistical analyses indicated that the 6th grade students participated to this study performed poorly in all tests, namely, in the Conceptual Knowledge, Procedural Knowledge, and the Word Problems Test. Considering both the students' overall performances and the performances on domains of measurement, the lowest mean scores were observed in the WPT, then CKT, and PKT respectively. Furthermore, the questions on length measurement had higher mean scores than area and volume measurement questions in all tests.

Additionally, the results evidenced a significant relationship among the tests with a strong and positive correlation. More specifically, when the students' performance on one of three tests increased, so their success on other tests also increased. Similarly, a significant relationship was also observed in three domains of measurement. That is to say, students' knowledge and skills in one domain of measurement (e.g. length measurement) positively correlated with other domain of measurement (e.g. area measurement).

Further, the MANOVA results indicated that gender did not affect 6th grade students' achievement on three tests in this study. That is, girls and boys had nearly same mean scores. Nonetheless, it was found that the overall performances of students on each test differed significantly according to previous mathematics achievement. Besides, the post-hoc analysis yielded a significant difference between the levels of previous mathematics achievement and the students' performances on the tests, especially between the low-achievers and high-achievers and between the average-achievers and high-achievers.

In addition, the analysis of the written responses indicated that 6th grade students made a wide range of common mistakes in each test. From counting the numbers on a ruler, rather than intervals, to believing that the amount of space covering the outside of a box equals to volume, the students exhibited very shallow knowledge and skills related to length, area, and volume measurement. Table 4.26 (p.174) summarizes the most common mistakes made by 6^{th} graders in each test according to domains of measurement.

The last research question of this study was related to use of materials in teaching and learning of measurement. Descriptive data analysis indicated that ruler, unit cubes, isometric paper, dot paper, and geometry stripes were the materials that were used frequently; and cubes blocks, square blocks, volume blocks, and pattern blocks were rarely-used materials during measurement instruction as reported by the students. Besides, while ruler was used more by students, unit cubes was used frequently by teachers. Additionally, rarely student-used material was found as cube blocks and ruler was found as a rarely teacher-used material. Among ten materials, only use of ruler and the students' performance on the WPT was significantly correlated, though the correlation value was quite low. In the same manner, the relatively low correlation coefficients found in this study between the students' performances on the CKT and the use of square, of tangram, of cube blocks, of volume blocks and of geometry stripes. However, none of the materials were significantly correlated with the students' performance on the PKT.

Table 4.26

Most Common Mistakes Made by 6th Graders in the Test according to the Domains of Measurement

Tests / Domains	*CKT*	*PKT*	*WPT*
Length Measurement (including perimeter)	Starting from 1	Using area formula	Using area formula
	Believing that perimeter is constant, when the shape is rearranged	Mistakes in four basic operations	Mistakes in four basic operations
	Believing that unless perimeter is known, it is impossible to find area (vice versa)	Adding only two side lengths for finding perimeter	Adding all sides and multiplying that number by 2
	Believing that if a shape has the largest area, so has the largest perimeter	Using units of area measurement	Using units of area measurement
	Counting the square units or dots for perimeter	Counting the numbers on the ruler	Believing that all rulers are 30 cm long
	Using units of area/volume measurement for perimeter	Incorrect alignment of a ruler	Counting the numbers on the ruler
Area Measurement	Believing that area is not constant, if a shape is rearranged	Using the perimeter formula	Area equals to perimeter plus length
	Counting the lines around a shape	Area equals to length plus width	Using the formula for perimeter
	Using units of length/volume measurement	Using units of length measurement	Mistakes in four basic operations
	Confusing volume with surface area	Mistakes in four basic operations	Area equals to width plus length
	Believing a shape has more than one surface areas	Surface area equals to length plus width plus height	Surface area equals to length plus width plus height
	Believing that surface area depends on volume	Surface area equals the multiplication of all dimensions	Surface area equals the multiplication of all dimensions
Volume Measurement	Counting the square units or faces of unit cubes or only visible unit cubes	Volume equals to length plus width plus height	Volume equals to length plus width plus height
	Double counting unit cubes	Mistakes in four basic operations	Volume equals to the multiplication of length with width
	Believing that there is a linear relationship between a volume of a shape and its dimensions	Volume equals to the multiplication of length with width	Mistakes in four basic operations

CHAPTER V

DISCUSSION

The final chapter is devoted to the discussion of the findings obtained from the statistical analysis and the implications for the practice and for further research. In the first part, the results were restated and discussed. The second part presents the implications under the headings of practice and further research.

5.1 Discussion

The present study aimed to investigate sixth grade students' conceptual and procedural knowledge and word problem solving skills in measurement, namely length, area, and volume, with respect to gender, previous mathematics achievement, and the use of materials.

More specifically, the main focuses of this study were twofold: determination of differences in students' performances in domains of measurement assessed by three different tests and the examination of differences and relationships between gender, previous mathematics achievement, and the use of materials. In the following sections, the conclusion drawn from the results of the study are discussed in line with the related literature.

5.1.1 Students' Performance on the Tests

The results presented in the previous chapter revealed that sixth grade students performed relatively poor in each test. The mean score of students' overall performance in the CKT was 19.6 out of 50, in the PKT was 8.3 out of 20, and in the WPT was 7.7 out of 20 and the overall success rate of the students in each test was found less than 50% (41.5% in the PKT; 39% in the CKT; 38.5% in the WPT). Based on this result, it can be concluded that the 6th grade students had quite limited knowledge about "what measurement means" and "how to measure" and consequently, had difficulties in solving word problems involving measurement.

This result is consistent with the previous studies claiming that students' mathematical competence is mostly build on both the knowledge of concepts and procedures in a mathematical domain and thus, with the help of knowing what/why and knowing how to do, students can make sense of mathematics and effectively use their repertoire of conceptual and procedural knowledge in problem solving situations (Baroody, et al., 2007; Hiebert & Lefevre, 1986; Gelman & Meck, 1986; Rittle-Johnson, et al., 2001; Silver, 1986).

With regard to domains of measurement, in each test the highest performance was observed in length measurement (M_{CKT} = 12.2, SD_{CKT} = 4.6; M_{PKT} = 4.7, SD_{PKT} = 1.7; M_{WPT} = 4.4, SD_{WPT} = 2) and the lowest performance (M_{CKT} = 2.7, SD_{CKT} = 2.5; M_{PKT} = 1.5, SD_{PKT} = 1.7; M_{WPT} = 1.5, SD_{WPT} = 1.7) was observed in volume measurement. The findings might be a consequence of the Turkish Elementary Mathematics Curriculum where length measurement starts to be taught in 1st grade, area measurement in 3rd grade, and volume measurement in 5th grade. As a result, students might have more opportunities to develop the concepts and skills involved in length measurement, than area and volume measurement (Tan-Sisman & Aksu, 2009).

Nevertheless, when compared to the total scores of the tests, the mean score of length, area, and volume measurement in each test was actually low. In this respect, it might be argued that neither six-year-study of length measurement nor four-year study of area measurement area as well as two-year-study of volume measurement at school is effective for students to gain underlying concepts and procedures of measurement.

5.1.2 Relationships among the Tests and the Domains of Measurement

In the present study, the significant positive correlation coefficients were obtained for the tests, namely CKT, PKT, and WPT, that clearly revealed a strong and positive interrelationship between understanding of the measurement concepts, carrying out operations with measurement, and solving word problems involving measurement. Therefore, it can be concluded that increases in one type of tests might lead to gains in the other tests and vice versa.

The evidence from research on mathematics education also indicated that being mathematically competent requires for the synthesis of conceptual and procedural knowledge and thus, absence of one type of knowledge most likely create trouble for students while making sense of mathematics (Hiebert & Carpenter, 1992; Kilpatrick, et al., 2001; Star, 2000).

In addition, Rittle-Johnson and her colleges (2001) study's produced the similar results with the present study. According to the results of their experimental study with fifth and sixth graders, the relationship between conceptual and procedural knowledge was bidirectional and conceptual knowledge had power to develop procedural knowledge and vice versa. Star's research study (2002) was also supported the positive relationship between knowledge of concepts and procedures in the case of equation solving. Furthermore, the results yielded a significant relationship, which was also positive and strong, both between and within students' performance on the tests in terms of three domains of measurement. In other words, when the students' performance on one domain of measurement (e.g. length measurement) increased in one of the tests, their performance on the same domain of measurement in the other tests increased, too.

Beside, the students' performance on the tasks involving one type of measurement domains (e.g. length measurement) in one of the tests (e.g. the CKT) was significantly correlated with the tasks related to the other domains of measurement (e.g. area/volume measurement) in the same test. Put in differently, the more students know about length measurement, the more they are successful in the other domains of measurement.

As mentioned previously, each of the domains of measurement has special principles that are composed of the concepts and procedures underlying and justifying measurement process. Without making sense of these principles unique to each domain of measurement, it is really difficult for students to learn to both do and understand measurement (Stephan & Clements, 2003; Lehrer, 2003; Kamii & Clark, 1997). In this respect, the findings of this study confirmed again the significant and positive relationship among the concepts, the procedures, and word-problem solving skills in each domain of measurement.

In addition to the key principles that are unique to measurement of length, area, and volume, there are common fundamental aspects of measurement, like iteration, unit structure, unit-attribute relations, and conservation of a spatial attribute (Curry, Mitchelmore, & Outhred, 2006; Lehrer, 2003). Further, meaningful understanding of one-dimensional measurement has been considered as a gatekeeper for the understanding of two- and three-dimensional measurement in several studies by many mathematics educators (Battista, 2003; Nührenbörger; 2001; Outhred & Mitchelmore, 2000; Stephan & Clements, 2003).

Therefore, the findings of this study indicated strong evidence that acquisition and coordination of the concepts and skills about length, area, and volume measurement were closely related to each other and either absence or partial understanding of these skills/concepts probably result in poor performance on the domains of measurement.

5.1.3 The Effect of Gender and Previous Mathematics Achievement on the Sixth Grade Students' Overall Performance on the Tests

In the mathematics education literature, gender, as a factor influencing students' mathematical competence, was studied over the years. Several reports and research conducted have pointed out that the gap between boys and girls in mathematical achievement has been declining (Barker, 1997; Knodel 1997).

According to the results of the present study, gender did not affect the 6^{th} grade students' performance on the tests. In other words, girls and boys had nearly the same mean scores in each test. This result differed from what Lubienski (2003) found. In the study he reported, measurement was the only content area in which the largest gender differences have been observed since 1990 in the previous NAEP exams. In line with the results of the Lubienski's study, Mullis and Stemler (2002) also found the superiority of boys over the girls in mathematics.

However, as claimed by several researchers (Leder, 1985; Peterson & Fennema, 1985; as cited in Alkhateeb, 2001), during the elementary school years mathematics achievement gap between boys and girls was not obvious and clear. Furthermore, most of the studies conducted in the Turkish context yielded no gender differences in mathematics (Aksu, 1997; Bulut, Gur, & Sriraman, 2010; lsiksal & Askar, 2005; Karaman, 2000; Kose, 2007; Ubuz, Ustun & Erbas, 2009). In this respect, the conclusion drawn from the present study's results might be that there is no significant difference between the performance of boys and of girls in measurement content area.

One of the more noteworthy findings to emerge from the present study is the significant effect of students' prior mathematics achievement on their performance on the tests. More specifically, the MANOVA results indicated that the overall performances of students on the CKT, PKT, and WPT significantly differed according to the students' previous mathematics achievement. As the students' prior mathematics achievement increased, their performance on the tests increased, too.

These results are consistent with Kabiri and Kiamanesh's (2004) findings. They also found the highest correlation between students' previous math achievement and their mathematics performance. Besides, the results of the Pajares's research (1996; Pajares & Kranzler 1995; Pajares & Miller, 1994) supported the view that students' prior achievement in mathematics is one of the strong predictors for their subsequent success in mathematics. Further, Aksu's research study (1997) on 6th grade Turkish students' performance on fractions also revealed the vital importance of prior experience in mathematics.

Additionally, Bragg and Outhred (2000), and Battista (2003) underlined that students' understanding of length measurement is crucial for understanding of rulers, scales, perimeter, area, and volume measurement. These studies which were consistent with the results of the current study confirmed the conclusion that previous mathematics achievement clearly affects students' future mathematics learning. Indeed, the results might also be interpreted as an indicator of the cumulative and sequential nature of mathematics.

Furthermore, the results of the post hoc comparisons were also indicated that whereas the differences between the low-achieving and high-achieving students as well as average-achieving and high-achieving students were statistically significant, there was no difference between low-achievers and average-achievers. Considering the vital role of previous mathematics achievement in the students' performance on the tests involving length, area, and volume measurement, it is not surprising to obtain such a finding in the present study, but non-significant difference between low-achievers and average-achievers might be due to the total number of students in each achievement level.

5.1.4 Students' Common Mistakes in the Tests

An investigation of the 6th grade students' common mistakes related to length, area, and volume measurement was the other major contribution of the current study. In each test, namely, CKT, PKT, and WPT, the students' written explanations for the questions were analyzed in a detailed manner and the common mistakes were tabulated. The results of this investigation was evidence for that the sixth grade students participated to the study had quite shallow knowledge and skills repertoire in three domains of measurement.

First of all, the sixth grade students' common mistakes with regard to length measurement were found as follows: (a) starting from 1 rather than 0 while engaging with a ruler; (b) counting either hash marks or numbers on a ruler instead of intervals; (c) focusing on end point while measuring with a ruler; (d) believing all rulers are 30 cm long; (e) mixing units of length with other units of measurement; and (f) treating centimeter as a different unit of measurement (i.e. not understanding the relationship between units (cm-m) of length measurement).

Similar difficulties experienced by both elementary and middle school students' were also reported in the mathematics education literature (Barrett et al., 2006; Boulton-Lewis et al., 1996; Bryant and Nunes 1994 (as cited in Nunes & Bryant, 1996); Ellis, Siegler, and Van Voorhis, 2001 (as cited in Lehrer, 2003); Heraud, 1989; Kamii, 1995; Schrage, 2000; Thompson & Van de Walle, 1985 (as cited in Schrage, 2000).

The students' mistakes found in this study clearly proved that the foundational concepts of length measurement were not comprehended by the students. Inadequate understanding of zero-point, unit iteration, the structure of a ruler, relation between number and measurement might be the possible reasons behind the errors committed by the students.

Regarding perimeter, a special linear dimension for a closed two-dimensional figure (Larsen, 2006, p.41), the analysis pointed out the following common mistakes as: (a) perimeter is constant, when the shape is rearranged; (b) unless perimeter is known, it is impossible to find area and vice versa; (c) if a shape has the largest area, so has the largest perimeter; (d) counting the square units or dots for perimeter; (e) using units of area/volume measurement for perimeter; (f) using the area formula for perimeter; and (e) perimeter equals to the total of two side lengths.

What research has found about student mistakes while learning the concept of perimeter measurement yielded the similar results with the present study. For instance, Kordaki and Portani's study (1998) showed that 6th grade students had difficulties in making connection between units of area and length measurement. Woodward and Bryd (1983) also found that most of 8th grade students believed that rectangles with the same perimeter occupy the same area. Likewise, Stone's 8th graders (1994) believed a shape with the same perimeter has the same area. Consistent with these findings, Emekli (2001) reported that majority of the 7th and 8th grade students confused the formula for perimeter with area. Tan-Sisman and Aksu (2009a) made a similar point with respect to the students' mistakes related to perimeter. They found that most of the 7th grade students confused the concept of area and perimeter, as well as the formulas for area and perimeter. Considering the previously documented mistakes, the findings of this study is not surprising and might be attributed to lack of attached-meaning to the concept of perimeter, so relying on only procedures (Moyer, 2001).

Thirdly, the analysis of students' written responses to the area tasks indicated a wide range of mistakes given as follows: (a) area is not constant, under partitioning; (b) counting the lines around a shape for area; (c) point-counting for area; (d) confusing area with perimeter; (e) using the perimeter formula for area; (f) area equals to length + width; (g) area equals to perimeter + length; (h) using units of length/volume measurement; (i) surface area depends on volume; (j) using the volume formula for surface area; (k) surface area equals to length + width + height; (l) confusing surface area with volume; and (m) believing that a shape has more than one surface areas.

As stated previously, meaningful understanding of area measurement involves the organization and coordination of various concepts and skills. However, according to the results of this study, it is obvious that the 6^{th} graders neither comprehended the key concepts nor gained the skills of area measurement and thus, made different kinds of mistakes. There are also studies having parallel results with the results obtained from the analysis of students' errors in area measurement. The study conducted by Furinghetti and Paola (1999) revealed that linear relationship between area and perimeter was the common misunderstanding among 7^{th} graders. Besides, using formula for area and perimeter correctly without knowing what dimensions of a shape stands for becomes also evident in the Kidman and Cooper's study (1997) and the Zacharos' study (2006). Another research study carried out by Kamii and Kysh (2006) with 4^{th}, 6^{th}, 8^{th}, and 9^{th} grades. According to the results, a majority of the students in 4^{th} grade through 8^{th} grade did not consider a square as a unit of area measurement, and a few numbers of 8^{th} graders could not be able to conserve the area of a shape when it was rearranged. Similarly, Lehrer, and his colleagues (1998a-b) found that a majority of students from 1^{st} to 3^{rd} treated length measurement as a space-filling property and ignored two dimensional structure of area. In addition, students' poor understanding of surface area, even in a college-level, were also documented by different scholars as Cohen and Moreh, (1999); Gilbert, (1982), and Light, et al., (2007).

At this point, it can be concluded that the students of this study had serious difficulties in truly understanding and applying the concepts and skills involved in area measurement. More specifically, inadequate grasp of the spatial structure, of the multiplicative structure, inability to conserve area, and superficial understanding of length measurement resulted in the abovementioned mistakes made by the 6th grade students.

Concerning volume measurement, the last domain of measurement targeted in the current study, the students' common mistakes emerged from the tasks asked in the CKT, PKT, and WPT were found as follows: (a) counting the square units; (b) counting faces of unit cubes; (c) counting only visible unit cubes; (d) double counting unit cubes; (e) believing a linear relationship between a volume of a shape and its dimensions; (f) counting the faces of unit cubes given in the picture and doubling that number; (g) counting the faces of unit cubes given in the picture and multiplying that number with 3 because a prism has three dimensions; (h) volume equals to length + width + height; (i) volume equals to length x width; and (j) volume to length x width + height; (k) using units of length/area measurement.

Similar errors committed by students while engaging in volume measurement tasks were demonstrated in previous research as well. Campbell, Watson, and Collis's study (1992), for instance, produced evidence that counting the number of individual unit cubes was common strategy among elementary students, without paying attention to the invisible unit cubes. Putting emphasis on enumeration in 3D arrays, Battista and Clements's study (1996) also pointed that most of the 5th graders were lack of structuring array notion, consequently, could not be able to enumerate the cubes in a given solid correctly.

Additionally, Olkun (2003) also found in his study on the 4th, 5th, 6th and 7th grade students' performance and the strategies for finding the number of unit cubes in rectangular solids that even 7th graders were not ready to construct the meaning of volume formula. According to Saiz's study (2003), prospective teachers perceived volume as a number produced by multiplying the length, width and height of an object. In this respect, the findings of the current study clearly indicated that the students could not be able to make sense of the foundational principles behind volume measurement which requires more complex reasoning about the structure of space than measuring two or one dimensional regions. In particular, lack of spatial visualization and of meaningful enumeration of arrays of cubes as well as poor understanding in length and area measurement might be the reasons behind the several mistakes of the students in volume measurement.

5.1.5 Use of Materials in Measurement Instruction

Use of materials in teaching and learning of measurement was the last focus of this study. According to the results, among ten materials suitable for measurement instruction, ruler, unit cubes, isometric paper, and dot paper were frequently used materials; and cubes blocks, square blocks, volume blocks, and pattern blocks were rarely used materials during measurement instruction as reported by the students. Beside, the students stated that ruler was the only one that was used more by students, and unit cubes was used frequently by teachers. Additionally, cube blocks were the rarely-used material by students, whereas ruler was the rarely-used material by teachers.

With regard to the relationship between the use of materials and the students' performance on the tests, the relatively low correlation coefficients found between the students' performances on the CKT and the use of square blocks, of tangram, of cube blocks, of volume blocks and of geometry stripes. Similarly, among ten materials, the use of only one material, ruler, was correlated significantly with the students' performance on the WPT was significantly correlated, though the correlation coefficient value was quite low. Nonetheless, none of the materials were significantly correlated with the students' performance on the PKT.

In general, using materials to teach mathematics has been advocated by most of the mathematics educators. Parham's meta-analysis study (1983) indicated that manipulatives as a part of mathematics instruction were beneficial for students' success. Another study done by Cramer, Post, and delMas (2002) also revealed that the use of materials had great impact on students' learning. Although the studies examining the use of materials in three domains of measurement together are non-existent in the mathematics education literature, to our knowledge, the commonly-held belief in the domain of measurement is that the use of materials has a unique place in students' understanding of the related concepts and skills. The NCTM's Principles and Standards for School Mathematics document (2000), the importance of use of materials is expressed as "Measurement lends itself especially well to the use of concrete materials" (p.44). Nonetheless, as stated by Clements (1999), students' performances might be increased through the use of materials, yet the benefits may depend on grade level, topic, ability level, etc.

Considering the results of the present study, the use of materials in measurement instruction was quite seldom, and the relationship between the students' performance on the tests and the use of materials either relatively low or non-significant. The reasons behind seldom use of materials in measurement instruction might be due to the availability of instructional materials at schools and teachers' individual teaching preferences. For the low or non-significant relationship between the students' performance on the tests and the use of materials, it is probably due to the rare use of materials in measurement instruction that reported in the previous chapter. In this respect, it can be stated that the findings of this study neither produced significant relationship between the use of materials and the students' performance nor supported the view that concrete materials helps students scaffold their learning.

5.2 Implications of the Study

Based on the findings of the study, the implications for the practice and for the further research are presented in the following sections.

5.2.1 Implications for Practice

Measurement, among mathematical strands, has a vital role in almost all mathematics curricula, as well as in science and in our life. In order to make sense of how to measure and what measurement means, namely being competent in measurement, it is obvious that students should fully comprehend the concepts and skills involved in the domain. This study is an attempt to investigate sixth grade students' conceptual knowledge, procedural knowledge and word-problem solving skills in length, area, and volume measurement with regard to gender, previous mathematics achievement, and the use of materials.

In general, the results of the study clearly indicated that the 6^{th} graders neither comprehended the key concepts nor gained the skills of measurement and thus, made a wide range of mistakes. It was also found that not only there was strong and positive relationship between students' performance among three tests but also between students' performance on one domain of measurement and the other domains.

In addition, according to the results, students' previous mathematics achievement had great impact on their performance on the measurement tasks posed in three tests. Another major finding to emerge from the study is rarely use of material in teaching and learning measurement.

Taken together, these results proved superficial and inadequate understanding and skills of the sixth graders in length, area, and volume measurement which is obviously not the intended and desired learning outcome of the mathematics curriculum. As declared by Schmidt, et al., (2002; as cited in Hook, 2004) "Specifically the curriculum itself -what is taught- makes a huge difference" in students' achievement (p.1). In this respect, the findings might be considered as the evidences calling for the curricular and instructional changes in measurement strand.

First and foremost, the foundational concepts and skills of length, area, and volume measurement should be included explicitly in the content in a spiral manner. Especially, zero-point, unit iteration, the structure of a ruler, relation between number and measurement, relationship between the attribute being measured and a unit of measurement being used, the understanding that perimeter might be changed under partitioning, the difference between perimeter and area and between their formulas, the spatial structure of, the multiplicative structure of, conservation of area, spatial visualization, meaningful enumeration of arrays of cubes, the difference between surface area and volume and between their formulas should become integral part of measurement strand.

Secondly, in the mathematics curriculum guide (2009) it is stated that more emphasis is put on the development of students' conceptual knowledge and problem solving skills along with procedural fluency. However, the findings of the current study indicated that the 6^{th} graders' performance on the Procedural Knowledge test was higher than both Conceptual Knowledge and Word Problem test in each domains of measurement. Therefore, it might be suggested that instead of putting early emphasis on activities tied to a formula, beginning from students' naïve ideas (e.g. building arrays of units) to gradually continuing with more sophisticated ideas (e.g. how the length and width produce an area, as a result of multiplication) may help students to differentiate and/or relate the concepts in meaningful ways.

Thirdly, the findings also revealed that most of the 6^{th} graders did not pay attention to what the problem text is talking about and the necessary mathematical operations executed. As a consequence, they tried to reach answer through meaningless calculation attempts (e.g. Area = Perimeter + Length; Height = Length + Volume). Taking the students' mistakes in the WPT as evidence for the difficulties with comprehending the problem situation, it might be suggested that while teaching measurement, students should be engaged in both word problems and numeric format problems which are vital for promoting mathematical understanding in terms of connecting different meanings, interpretations, and relationships with mathematics operations (Van de Walle, 2006).

Additionally, the most of the mistakes made by the sixth graders in the tests seems to be connected with each other. The mistake, for instance, "counting the lines around a shape while finding its area" in the CKT seemed to be linked to the error "confusing area formula with perimeter formula" both in PKT and WPT. Indeed, the main reason behind these parallel errors probably lies in the inadequate grasp of the concept of perimeter and area. Similarly, poor understanding of the relation between attribute being measured and the units of measurement might result in such mistakes as "believing cm is not suitable unit to measure in meters", "using units of length/volume measurement for reporting the area of a shape", and "trying to compare the length of two different objects measured by using different-sized units (wooden stripe vs. metal stripe). In this respect, designing both hands-on and minds-on-experience-based activities (e.g. constructing a ruler, measuring with a broken ruler, etc.) that highlights the links between measurement concepts and skills may provide more meaningful learning opportunities for students.

Besides, the present study proved again the importance of previously grasped concepts and skills in students' subsequent attainment in measurement. According to the findings, for example, the students missed some of the tasks in the test due to the mistakes in four basic operations, namely, addition, subtraction, multiplication and division.

Focusing on the study of measurement in particular, Bragg and Outhred, (2000) stated that having an understanding of length measurement probably results in success in area and volume measurement which was also confirmed in the current study.

Moreover, unless we know well what students understand and think about measurement, we fail to design effective measurement instruction (Stephan & Mendiola, 2003; Curry, & Outhred, 2005). Providing teachers with research-based explicit knowledge about student's thinking in a specific content domain positively affects teachers' instruction and students' achievement (Carpenter, et al., 1989). At this point, a close examination of the students' written responses indicated that the most of the mistakes made by the sixth graders in the tests were related to each other. The mistake, for instance, "counting the lines around a shape while finding its area" in the CKT was related to the error "confusing area formula with perimeter formula" both in PKT and WPT. In this respect, the common mistakes identified in the test related to length, area, and volume measurement should be considered as valuable input for moving the barriers in front of students' learning in measurement. Besides, this kind of research-based information might be used in the mathematics curriculum guide to inform teachers about the students' difficulties in measurement.

Further, previous studies put emphasis on the use of tools, materials or manipulatives in students' understandings of the mathematical ideas (Bohan & Shawaker, 1994; Sowell, 1989; Thompson, 1992), yet the results of this study revealed that the use of materials while teaching and learning measurement was seldom, and possibly due to infrequent -use, either relatively low or non-significant relationship was observed between the students' performance on the tests and the use of materials.

Besides, one of the interesting findings to emerge from this study is that although the 6^{th} graders reported that ruler was most frequently used material in measurement instruction, a majority of them understand neither how a ruler works nor what means the numerals on a ruler. Considering the fact that ruler as a standard tool for measurement is introduced to students in the second grade and that the grade level of the students participated is sixth grade, four-year instruction seems to be ineffective. Tan-Sisman and Aksu (2009b), in their study on the length measurement topic in the elementary mathematics curriculum (1^{st} - 5^{th} grade) also concluded that the learning and teaching activities for facilitating students' understanding of measuring processes built into rulers seems to be superficial and inadequate. In the light of these findings, the time and the content devoted to the underpinnings of a ruler should be increased and different activities in a variety of contexts (e.g. working on a broken ruler) should be embedded in the curriculum.

5.2.2 Implications for Further Research

Based on the findings emerged from the study, recommendations for future research are as following:

- The present study was conducted with 6^{th} grade students (n = 445) attending public primary schools located in four different main districts of Ankara. A further study can be replicated with a larger sample for generalization to a bigger population.

- It is also essential to design a study with different grade levels, maybe a cross-sectional study, in order to get a wider and more detailed picture about the extent to which students' knowledge and skills are developed and improved in the domains of measurement.

- It would be interesting to assess the effectiveness of the instruction that is designed to eliminate the students' mistakes identified in the present study.

- In the current study, measurement instruction that the students were received at school was not assessed. Thus, there is a need for conducting a qualitative study to examine teaching and learning activities of measurement (e.g. the questions that are posed to students in the context of measurement; how a teacher encourages students to think about different possibilities about measurement) in a detailed manner.

- A qualitative research might be conducted to better understand students' limited understanding and skills in length, area, and volume measurement. In this respect, the three tests used in this study would be adapted as an interview tasks and asked to students.

- Further research studies can be carried out to examine the relationship between students' reading comprehension skills and their performance on the tests used in the current study.

- As it is particularly important for prospective elementary school teachers to have a good grasp of what measurement means and how to measure, it is recommended that further research be undertaken with a sample of prospective elementary school teachers to shed light on their strengths and weakness in measurement strand.

- More information on the use of materials in measurement instruction would help to establish a greater degree of accuracy on its contribution to students' learning in measurement.

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APPENDICES

APPENDIX A

STUDENT QUESTIONNAIRE

A. KİŞİSEL BİLGİLER

Bu bölümdeki sorular sizinle ilgili kişisel bilgileri elde etmeye yönelik olarak hazırlanmıştır. Lütfen her soruyu dikkatlice okuyunuz ve size göre en uygun olan seçeneğin yanına (X) işareti koyarak belirtiniz.

(1) Cinsiyetiniz:	( ) Kız ( ) Erkek
(2) Doğum yılınız:	( )1994 ( )1995 ( )1996 ( )1997
(3) Beşinci sınıftaki matematik dersi karne notunuz:	( ) 5 ( ) 4 ( ) 3 ( ) 2 ( ) 1
(4) Dershaneye gidiyor musunuz?	( ) Evet ( ) Hayır
(5) Okulda verilen matematik dersi kursuna gidiyor musunuz?	( ) Evet ( ) Hayır ( ) Okulda kurs verilmiyor.
(6) Matematik dersi ile ilgili özel ders alıyor musunuz?	( ) Evet ( ) Hayır
(7) Anne ve babanızın tamamladığı en son eğitim düzeyi nedir? Aşağıda belirtiniz.	
a) Annemin tamamladığı en son eğitim düzeyi	**b) Babamın tamamladığı en son eğitim düzeyi**
( ) Okuma-yazma bilmiyor	( ) Okuma-yazma bilmiyor
( ) Okuma-yazma biliyor ama okula gitmedi	( ) Okuma-yazma biliyor ama okula gitmedi
( ) İlkokulu bitirdi	( ) İlkokulu bitirdi
( ) Ortaokulu bitirdi	( ) Ortaokulu bitirdi
( ) Liseyi bitirdi	( ) Liseyi bitirdi
( ) Üniversiteyi bitirdi	( ) Üniversiteyi bitirdi
( ) Yüksek lisans ya da doktora yaptı	( ) Yüksek lisans ya da doktora yaptı
( ) Bilmiyorum	( ) Bilmiyorum

B. MATEMATİK DERSİ ÖLÇME KONUSUNDA KULLANILAN ARAÇ-GEREÇLERIN KULLANIM SIKLIĞI

Aşağıda verilen araç-gereçlerden hangilerinin matematik derslerinizde ***ÖLÇME konusu işlenirken*** ne sıklıkta kullanıldığını uygun olan seçeneğin yanına (X) işareti koyarak belirtiniz.

ÖLÇME *konusu işlenirken* kullanılan araç-gereçler	**Ne sıklıkta kullanıldı?** ***Sadece tek bir seçenek işaretleyiniz***
Cetvel	( ) Her zaman ( ) Bazen ( ) Hiçbir zaman
İzometrik Kağıt	( ) Her zaman ( ) Bazen ( ) Hiçbir zaman
Birim Küpler	( ) Her zaman ( ) Bazen ( ) Hiçbir zaman
Noktalı Kağıt	( ) Her zaman ( ) Bazen ( ) Hiçbir zaman
Örüntü Blokları	( ) Her zaman ( ) Bazen ( ) Hiçbir zaman
Çok Kareliler Takımı	( ) Her zaman ( ) Bazen ( ) Hiçbir zaman
Tangram	( ) Her zaman ( ) Bazen ( ) Hiçbir zaman
Çok Küplüler Takımı	( ) Her zaman ( ) Bazen ( ) Hiçbir zaman
Hacimler Takımı	( ) Her zaman ( ) Bazen ( ) Hiçbir zaman
Geometri Şeritleri	( ) Her zaman ( ) Bazen ( ) Hiçbir zaman
Diğer *araç-gereçler*:	( ) Her zaman ( ) Bazen ( ) Hiçbir zaman

C. MATEMATİK DERSİ ÖLÇME KONUSUNDA KULLANILAN ARAÇ-GEREÇLER

Aşağıda verilen araç-gereçlerden hangilerinin matematik derslerinizde ***ÖLÇME konusu işlenirken*** kim tarafından kullanıldığını uygun olan seçeneğin yanına (X) işareti koyarak belirtiniz.

ÖLÇME *konusu işlenirken* kullanılan araç-gereçler	**Kim Kullandı?** ***Birden fazla seçenek işaretleyebilirsiniz***
Cetvel	( ) Bireysel olarak kullandım. ( ) Öğretmenim kullandı. ( ) Grup olarak kullandık. ( ) Kimse kullanmadı.
İzometrik Kağıt	( ) Bireysel olarak kullandım. ( ) Öğretmenim kullandı. ( ) Grup olarak kullandık. ( ) Kimse kullanmadı.
Birim Küpler	( ) Bireysel olarak kullandım. ( ) Öğretmenim kullandı. ( ) Grup olarak kullandık. ( ) Kimse kullanmadı.
Noktalı Kağıt	( ) Bireysel olarak kullandım. ( ) Öğretmenim kullandı. ( ) Grup olarak kullandık. ( ) Kimse kullanmadı.
Örüntü Blokları	( ) Bireysel olarak kullandım. ( ) Öğretmenim kullandı. ( ) Grup olarak kullandık. ( ) Kimse kullanmadı.
Çok Kareliler Takımı	( ) Bireysel olarak kullandım. ( ) Öğretmenim kullandı. ( ) Grup olarak kullandık. ( ) Kimse kullanmadı.
Tangram	( ) Bireysel olarak kullandım. ( ) Öğretmenim kullandı. ( ) Grup olarak kullandık. ( ) Kimse kullanmadı.
Çok Küplüler Takımı	( ) Bireysel olarak kullandım. ( ) Öğretmenim kullandı. ( ) Grup olarak kullandık. ( ) Kimse kullanmadı.
Hacimler Takımı	( ) Bireysel olarak kullandım. ( ) Öğretmenim kullandı. ( ) Grup olarak kullandık. ( ) Kimse kullanmadı.
Geometri Şeritleri	( ) Bireysel olarak kullandım. ( ) Öğretmenim kullandı. ( ) Grup olarak kullandık. ( ) Kimse kullanmadı.
Diğer *araç-gereçler*:	( ) Bireysel olarak kullandım. ( ) Öğretmenim kullandı. ( ) Grup olarak kullandık. ( ) Kimse kullanmadı.

APPENDIX B

THE LEARNING OBJECTIVES OF LENGTH, AREA, AND VOLUME MEASUREMENT FOR 1st – 5th GRADES

Ö L Ç M E Ö Ğ R E N M E A L A N I			
SINIF	**ALT ÖĞRENME ALANLARI**	**KAZANIMLARI**	**TOPLAM**
1.SINIF	Uzunlukları Ölçme	**1.** Nesneleri uzunlukları yönünden karşılaştırarak ilişkilerini belirtir. **2.** Bir nesnenin uzunluklarına göre sıralanmış nesne topluluğu içindeki yerini belirler. **3.** Standart olmayan birimlerle uzunlukları ölçer. **4.** Standart olmayan uzunluk ölçme birimleri ile ilgili problemleri çözer ve kurar.	**4**
2.SINIF	Uzunlukları Ölçme	**1.** Standart olmayan farklı uzunluk ölçme birimlerini birlikte kullanarak bir uzunluğu ölçer. **2.** Standart uzunluk ölçme araçlarını belirterek gerekliliğini açıklar. **3.** Uzunlukları metre ve santimetre birimleriyle ölçer. **4.** Uzunlukları metre ve santimetre birimleriyle tahmin eder ve tahminini ölçme sonucuyla karşılaştırır. **5.** Metre ve santimetre birimleriyle ilgili problemleri çözer ve kurar. **6.** Standart olan veya olmayan uzunluk ölçme birimleriyle sayı doğrusu modelleri oluşturur.	**6**
3.SINIF	Uzunlukları Ölçme	**1.** Metre ve santimetre arasındaki ilişkiyi açıklar. **2.** Metre ve santimetre arasında ondalık kesir yazımını gerektirmeyen dönüşümler yapar. **3.** Nesnelerin uzunluklarını tahmin eder ve tahminini ölçme sonucuyla karşılaştırır. **4.** Cetvel kullanarak belirli bir uzunluğu ölçer ve ölçüsü verilen bir uzunluğu çizer. **5.** Metre ve santimetre birimlerinin kullanıldığı problemleri çözer ve kurar.	**5**
	Çevre	**1.** Nesnelerin çevrelerini belirler. **2.** Düzlemsel şekillerin çevre uzunluğunu hesaplar. **3.** Düzlemsel şekillerin çevre uzunlukları ile ilgili problemleri çözer ve kurar.	**3**
	Alan	**1.** Cisimlerin bir yüzünün alanını standart olmayan birimlerle ölçer.	**1**

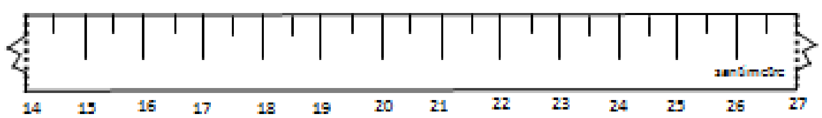
4.SINIF	Uzunlukları Ölçme	**1.** Atatürk'ün önderliğinde ölçme birimlerine getirilen yeniliklerin gerekliliğini nedenleriyle açıklar. **2.** Standart uzunluk ölçme birimlerinden kilometre ve milimetrenin kullanım alanlarını belirtir. **3.** Milimetre-santimetre, santimetre-metre ve metre-kilometre arasındaki ilişkileri açıklar. **4.** Belirli uzunlukları farklı uzunluk ölçme birimleriyle ifade eder. **5.** Bir uzunluğu en uygun uzunluk ölçme birimiyle tahmin eder ve tahminini ölçme yaparak kontrol eder. **6.** Uzunluk ölçme birimlerinin kullanıldığı problemleri çözer ve kurar.	**6**
	Çevre	**1.** Düzlemsel şekillerin çevre uzunluklarını belirler. **2.** Kare ve dikdörtgenin çevre uzunlukları ile kenar uzunlukları arasındaki ilişkiyi belirler. **3.** Aynı çevre uzunluğuna sahip farklı geometrik şekiller oluşturur. **4.** Düzlemsel şekillerin çevre uzunluklarını hesaplamayla ilgili problemleri çözer ve kurar.	**4**
	Alan	**1.** Bir alanı, standart olmayan alan ölçme birimleriyle tahmin eder ve birimleri sayarak tahminini kontrol eder. **2.** Düzlemsel bölgelerin alanlarının, bu alanı kaplayan birim karelerin sayısı olduğunu belirler. **3.** Karesel ve dikdörtgensel bölgelerin alanlarını birim kareleri kullanarak hesaplar.	**3**
5.SINIF	Uzunlukları Ölçme	**1.** Metre-kilometre, metre-santimetre-milimetre birimlerini birbirine dönüştürür. **2.** Milimetre, santimetre, metre ve kilometre birimleri arasındaki dönüşümleri içeren problemleri çözer ve kurar.	**2**
	Çevre	**1.** Üçgen, kare, dikdörtgen, eşkenar dörtgen, paralelkenar ve yamuğun çevre uzunluklarını belirler. **2.** Bir çemberin uzunluğu ile çapı arasındaki ilişkiyi ölçme yaparak belirler. **3.** Çapı veya yarıçapı verilen bir çemberin uzunluğunu belirler. **4.** Düzlemsel şekillerin çevre uzunlukları ile ilgili problemleri çözer ve kurar.	**4**
	Alan	**1.** Standart alan ölçme birimlerinin gerekliliğini açıklar, $1cm^2$ lik ve $1\ m^2$ lik birimleri kullanarak ölçmeler yapar. **2.** Belirlenen bir alanı cm^2 ve m^2 birimleriyle tahmin eder ve tahminini ölçme yaparak kontrol eder. **3.** Dikdörtgensel ve karesel bölgelerin alanlarını santimetrekare ve metrekare birimleriyle hesaplar. **4.** Paralelkenarsal bölgenin alanını bulur. **5.** Üçgensel bölgenin alanını bulur.	**5**
	Hacmi Ölçme	**1.** Bir geometrik cismin hacmini standart olmayan bir birimle ölçer. **2.** Aynı sayıdaki birimküpleri kullanarak farklı yapılar oluşturur.	**2**

APPENDIX C
CONCEPTUAL KNOWLEDGE TEST

Uzunluk, Alan ve Hacim Ölçüleri
KAVRAMSAL BİLGİ TESTİ

- ✓ Uzunluk, Alan ve Hacim Ölçüleri Kavramsal Bilgi Testi, toplam 16 sorudan oluşmaktadır.
- ✓ Testi cevaplama süresi 40 dakikadır.
- ✓ Her soruyu dikkatlice okuduktan sonra, cevabınızı noktalı yerlere **açık ve net** bir şekilde yazınız.
- ✓ Hiçbir soruyu boş **bırakmayınız**.
- ✓ Test sayfalarındaki boş yerleri, soruların çözümü için kullanabilirsiniz.
- ✓ Cevaplamaya istediğiniz sorudan başlayabilirsiniz.

Soru 1



a) Ceren'in matematik dersinde kırılan cetvelinden kalan parça yukarıda verilmiştir. Cetveli dikkatlice inceledikten sonra, aşağıdaki soruları yanıtlayınız.

➔ Kırık cetvelin başlangıç ve bitiş yerleri noktalı çizgilerle işaretlenmiştir. Bu **işaretlenmiş bölümün uzunluğu** kaç santimetredir? .... cm

➔ Kırık cetvelin uzunluğunu **nasıl** bulduğunuzu **açıklayınız**.

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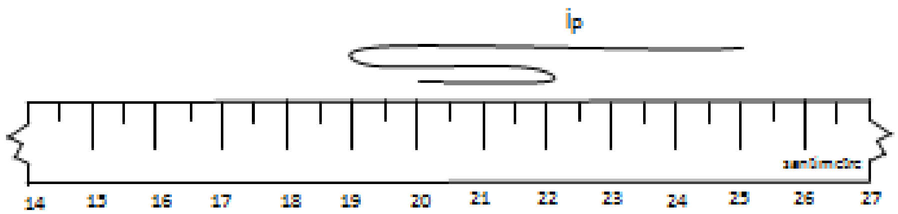
....

b) Yaklaşık 2 metre uzunluğunda bir kumaşın uzunluğunu ölçmeniz istendiğini düşünün. Sizce, bu kumaş Ceren'in kırık cetveli kullanılarak ölçülebilir mi? Aşağıdaki seçeneklerden size göre doğru olanı (X) ile işaretleyip, **gerekli açıklamayı noktalı yerlere yazınız**.

☐ **A) Evet**, Ceren'in kırık cetvelini kullanarak bu kumaşın uzunluğu ölçülebilir.	☐ **B) Hayır**, Ceren'in kırık cetvelini kullanarak bu kumaşın uzunluğunu ölçmek mümkün değildir.
Neden ölçülebilir? Açıklayınız. .... **Nasıl ölçülebilir? Açıklayınız.**	**Neden ölçülemez? Açıklayınız.** ....

c) Aşağıdaki şekilde verildiği gibi, Ceren'in kırık cetvelinin üstüne bir ip parçası yerleştirilmiştir. Bu ip parçasının uzunluğu kaç santimetredir?



➔ İp parçasının uzunluğu : ……………………………… cm

➔ Ip parçasının uzunluğunu nasıl bulduğunuzu **<u>açıklayınız</u>**.

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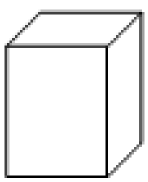
<u>Soru 2</u>



Yan tarafta verilen kare prizma şeklindeki kutu, paket kağıdı yapıştırılarak kaplanacaktır. Kutuyu tamamen kaplamada kullanılacak kağıt miktarını bulmak için aşağıdaki bilgilerden hangisini bilmeniz gerekir?

➔ Aşağıda verilen seçeneklerden **<u>size göre doğru olan tek bir seçeneği (X) ile işaretleyip, cevabınızı nedenleriyle açıklayınız.</u>**

☐ Kutunun ayrıt uzunlukları toplamı. Çünkü……………………………………………………
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☐ Kutunun yüzey alanı. Çünkü…………………………………………………………………
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☐ Kutunun hacmi. Çünkü………………………………………………………………………
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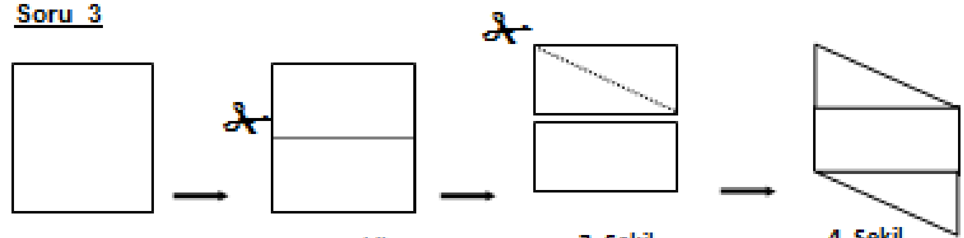
Soru 3



1. Şekil 2. Şekil 3. Şekil 4. Şekil

➔ 1. şekilde verilen kare bir kağıt ortadan ikiye katlandıktan sonra makasla iki eş parçaya kesiliyor (2. Şekil). Daha sonra, bu parçalardan bir tanesi, 3. şekilde gösterildiği gibi ortadan ikiye tekrar kesiliyor. Oluşan tüm parçalar biraraya getirilerek 4. şekil oluşturuluyor.

➔ Aşağıda verilen yorumları dikkatlice okuduktan sonra, **size göre doğru olan tek bir seçeneği (X) ile işaretleyip, nedenleriyle açıklayınız.**

Yorum I: 1. şeklin çevre uzunluğu, 4.şeklin çevre uzunluğundan daha büyüktür.
☐ **Bu yoruma katılıyorum, çünkü** ……………………………………………………………………………
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Yorum II: 1. ve 4. şekillerinin çevre uzunlukları birbirine eşittir.
☐ **Bu yoruma katılıyorum, çünkü** ……………………………………………………………………………
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Yorum III: 4. şeklin çevre uzunluğu, 1. şeklin çevre uzunluğundan daha büyüktür.
☐ **Bu yoruma katılıyorum, çünkü** ……………………………………………………………………………
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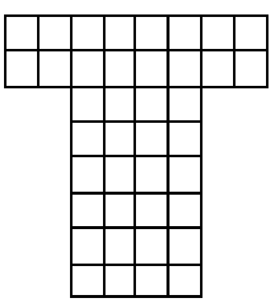
Soru 4



Şekilde açık hali verilen dikdörtgenler prizmasının **hacmini bulunuz** ve **nasıl bulduğunuzu açıklayınız**. **Uyarı:** Küçük karelerin her birinin kenar uzunluğu 1 birimdir.

➔ Dikdörtgenler prizmasının hacmi: ………………..

➔ Açıklama:……………………………………………………………………………
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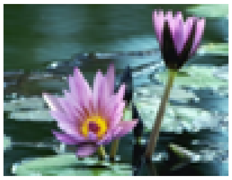
Soru 5



Yandaki resme uygun bir çerçeve yapmak için resmin alanını mı yoksa çevresini mi bulmak gerekir? Aşağıda verilen seçeneklerden **size göre doğru olan tek bir seçeneği (X) ile işaretleyip, nedenleriyle açıklayınız**.

☐ Resmin **çevre uzunluğunu** bulmak gerekir. Çünkü…………………………………………… …………………………………………………… …………………………………………………… …………………………………………………… …………………………………………………… …………………………………………………… …………………………………………………… …………………………………………………… …………………………………………………… ……………………………………………………	☐ Resmin **alanını** bulmak gerekir. Çünkü …………………………………………… …………………………………………………… …………………………………………………… …………………………………………………… …………………………………………………… …………………………………………………… …………………………………………………… …………………………………………………… …………………………………………………… ……………………………………………………

Soru 6

Bir dikdörtgenler prizmasının hacmi 3 kat artırıldığında, bu prizmanın tüm boyutları da 3 kat artar mı?

➔ Aşağıda verilen seçeneklerden **size göre doğru olan tek bir seçeneği (X) ile işaretleyip, nedenleriyle açıklayınız.**

☐ **Tüm boyutları da 3 kat artar.** **Çünkü**, ……………………………… ……………………………………… ……………………………………… ……………………………………… ……………………………………… ……………………………………… ……………………………………… ……………………………………… ……………………………………… ……………………………………… ……………………………………… ……………………………………… ……………………………………… ……………………………………… ……………………………………… ……………………………………… ……………………………………… ……………………………………… ………………………………………	☐ **Boyutlarında hiçbir değişiklik olmaz, aynı kalır. Çünkü**,………… ……………………………………… ……………………………………… ……………………………………… ……………………………………… ……………………………………… ……………………………………… ……………………………………… ……………………………………… ……………………………………… ……………………………………… ……………………………………… ……………………………………… ……………………………………… ……………………………………… ……………………………………… ……………………………………… ……………………………………… ………………………………………	☐ **Tüm boyutları 3 kat artmaz.** **Çünkü**, ……………………………… ……………………………………… ……………………………………… ……………………………………… ……………………………………… ……………………………………… ……………………………………… ……………………………………… ……………………………………… ……………………………………… ……………………………………… ……………………………………… ……………………………………… ……………………………………… ……………………………………… ……………………………………… ……………………………………… ……………………………………… ………………………………………

Soru 7

A ve B iplerinin uzunluğu tahta sopa ile; C ve D iplerinin uzunluğu ise metal bir çubuk yardımıyla ölçülmüştür ve her ipe ait ölçüm sonuçları aşağıdaki tabloda verilmiştir.

Ipler	**Olçüm Sonuçları**
A ipi	11 tahta sopa
B ipi	9 tahta sopa
C ipi	11 metal çubuk
D ipi	14 metal çubuk

➔ Tabloyu dikkatlice inceledikten sonra, aşağıda verilen her seçenek için size göre doğru olduğunu düşündüğünüz cevabı (X) ile işaretleyiniz.

a) A ve C iplerinin uzunluğu birbirine eşittir.

☐ Doğru ☐ Yanlış ☐ Iplerin uzunlukları hakkında yorum yapamayız.

b) D ipinin uzunluğu, C ipinin uzunluğundan daha uzundur.

☐ Doğru ☐ Yanlış ☐ Iplerin uzunlukları hakkında yorum yapamayız.

c) B ipinin uzunluğu, A ipinin uzunluğundan daha kısadır.

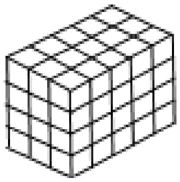
☐ Doğru ☐ Yanlış ☐ Iplerin uzunlukları hakkında yorum yapamayız.

Soru 8

A sütununda farklı ölçümler, B sütununda ise çeşitli ölçme birimleri verilmiştir. A sütununda her bir ölçümün yanındaki boşluğa, B sütunundan seçtiğiniz, ölçüme **en uygun** olan ölçme birimini gösteren harfi yazınız. **B sütununda yer alan ölçme birimlerini bir defa veya birden fazla kullanabilir, ya da hiç kullanmayabilirsiniz.**

A Sütunu: Olçümler	**B Sütunu: Olçme birimleri**
______ 1. Iki şehir arasındaki uzaklık	A. Kilometre
______ 2. Futbol sahasının alanı	B. Kilometrekare
______ 3. Avuç içinizin alanı	C. Metre
______ 4. Yüzme havuzundaki su miktarı	D. Metrekare
______ 5. Sınıf tahtanızın çevre uzunluğu	E. Metreküp
______ 6. Demir 1 YTL'nın kalınlığı	F. Santimetre
______ 7. Sınıf tahtanızın alanı	G. Santimetrekare
______ 8. Kibrit kutusunun hacmi	H. Santimetreküp
	I. Milimetre
	I. Milimetrekare
	K. Milimetreküp

Soru 9



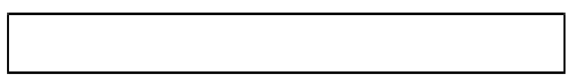
Şekilde verilen prizma birim küpler kullanılarak oluşturulmuştur. Prizmayı oluşturmak için **kullanılan birim küp sayısını bulunuz** ve bu sayıyı **nasıl bulduğunuzu açıklayınız?**

➔ Prizmayı oluşturmak için kullanılan toplam birim küp sayısı: ....

➔ Açıklama:...
....
....
....
....
....

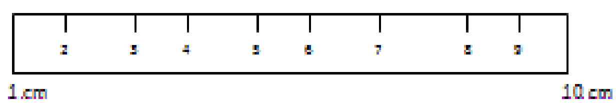
Soru 10

Sizden matematik derslerinizde kullanmak için, 10 santimetrelik bir cetvel hazırlamanız istendiğini ve aşağıda verilen kağıttan yapılmış boş cetvelin verildiğini düşünün.



Sınıf arkadaşlarınızdan biri olan Melih cetvelini aşağıda gösterilen şekilde yapmıştır. Bu şekle göre Melih, cetvelini doğru bir şekilde oluşturmuş mudur?

Melih'in cetveli



➔ Aşağıdaki seçeneklerden **size göre doğru olan tek bir seçeneği (X) ile işaretleyip, nedenleriyle açıklayınız.**

☐ **A) Evet**, Melih cetveli doğru şekilde oluşturmuştur.	☐ **B) Hayır**, Melih cetveli doğru şekilde oluşturamamıştır.
Nedenleriyle açıklayınız.	Nedenleriyle açıklayınız. ....

Soru 11

➔ Yukarıdaki şekilde verildiği gibi, bir çiftçinin değişik şekillere sahip 4 farklı bahçesi vardır. Çiftçi, bu bahçelerin etrafını çevirmek için, sahip olduğu teli 4 eşit parçaya ayırıyor ve her bahçe için eşit miktarda tel parçası kullanıyor. Hiçbir tel parçası eklenmemiş veya artmamış olduğuna göre aşağıdakilerden hangisi **doğrudur?**

A) En büyük çevre uzunluğu D bahçesine aittir.

B) Tüm bahçelerin çevre uzunlukları birbirine eşittir.

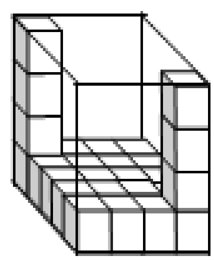
C) B bahçesi, en kısa çevre uzunluğuna sahip bahçedir.

D) C bahçesinin çevre uzunluğu, A bahçesinin çevre uzunluğundan daha büyüktür.

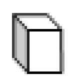
➔ **Işaretlediğiniz seçeneğe nasıl karar vediğinizi açıklayınız.**

………
………
………
………

Soru 12



Dikdörtgenler prizması şeklindeki kutu



Birim küp

☞ Yukarıda verilen dikdörtgenler prizması şeklindeki kutu, bir kenarının uzunluğu 1 birim olan birim küpler ile doldurulacaktır. Buna göre, aşağıdaki soruları cevaplayınız.

a) Bir kısmı doldurulmuş olarak verilen kutuyu, tamamen doldurmak için kaç tane birim küpe ihtiyaç vardır?

➔ **Ihtiyaç duyulan birim küp sayısı:** ....

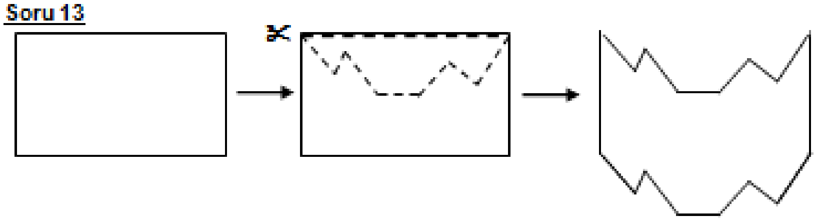
b) Kutu, birim küplerle tamamen doldurulduğunda hacmi kaç birim küptür?

➔ **Kutunun hacmi:** .... birim küp

c) Kutunun hacmini **nasıl bulduğunuzu açıklayınız**.

………
………

Soru 13



Şekil A Şekil B Şekil C

➔ Jale, şekil A'da verilen dikdörtgen şeklindeki bir kağıdı, şekil B'de gösterildiği gibi kesmiştir. Daha sonra, kestiği parçayı dikdörtgenin alt kısmına kaydırarak şekil C'yi oluşturmuştur. Sizce, yeni oluşan **C şeklinin alanı için** ne söylenebilir? Aşağıdaki seçeneklerden **size göre doğru olan tek bir seçeneği (X) ile işaretleyip, nedenleriyle açıklayınız.**

☐ C şeklinin alanı, A şeklinden daha **büyüktür**. Çünkü, ………………	☐ C şeklinin alanı, A şeklinden daha **küçüktür**. Çünkü, ………………	☐ C ve A şekillerinin alanları birbirine **eşittir**. Çünkü,………………
……………………………………………………	……………………………………………………	……………………………………………………

Soru 14

Bir küpün hacmi yarısına indirildiğinde, yüzey alanı da yarıya iner mi? Aşağıda verilen seçeneklerden **size göre doğru olan tek bir seçeneği (X) ile işaretleyip, nedenleriyle açıklayınız.**

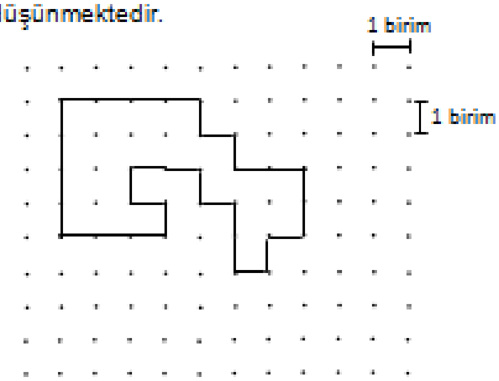
☐ **Evet, yüzey alanı da yarıya iner. Çünkü**……………………………………………………………
………

☐ **Yüzey alanında hiçbir değişiklik olmaz, aynı kalır. Çünkü**……………………………………
………

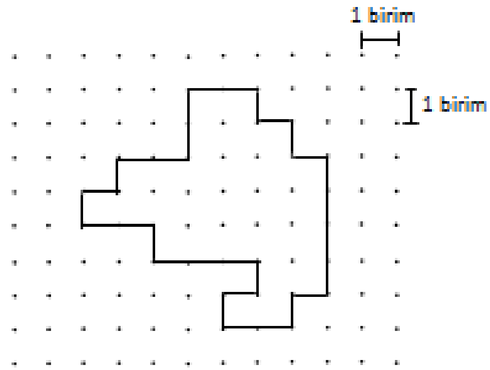
☐ **Hayır, yüzey alanı da yarıya inmez. Çünkü**…………………………………………………………
………

Soru 15

Burcu, aşağıda verildiği gibi iki noktanın birbirine uzaklığı 1 birim olan noktalı kağıtlara, iki tane şekil çizmiştir ve çizdiği bu **iki şeklin alanlarının ve çevrelerinin birbirine eşit olduğunu** düşünmektedir.



Burcu'nun çizdiği **1. şekil**



Burcu'nun çizdiği **2. şekil**

➔ **Verilenlere göre aşağıdaki soruları cevaplayınız.**

a) Sizce Burcu'nun çizmiş olduğu **iki şeklin ALANI birbirine eşit midir?** Aşağıda verilen seçeneklerden size göre doğru olan tek bir seçeneği (X) ile işaretleyip, **nedenleriyle açıklayınız**.

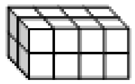
☐ **Evet**, iki şeklin **ALANI** birbirine **eşittir**. Çünkü	☐ **Hayır**, iki şeklin **ALANI** birbirine **eşit değildir**. Çünkü ....

b) Sizce Burcu'nun çizmiş olduğu **iki şeklin ÇEVRE UZUNLUKLARI birbirine eşit midir?** Aşağıda verilen seçeneklerden **size göre doğru olanı (X) ile işaretleyip**, **nedenleriyle açıklayınız**.

☐ **Evet**, iki şeklin **ÇEVRE UZUNLUKLARI** birbirine **eşittir**. Çünkü	☐ **Hayır**, iki şeklin **ÇEVRE UZUNLUKLARI** birbirine **eşit değildir**. Çünkü ....

Soru 16

Aşağıda verilen dikdörtgenler prizması şeklindeki kutu, birim küpler kullanılarak oluşturulmuştur. Birim küplerden her birinin kenar uzunluğu 1 birimdir. Aşağıdaki soruları bu şekilleri dikkate alarak cevaplayınız.

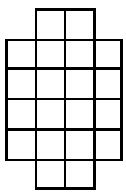


Kutu

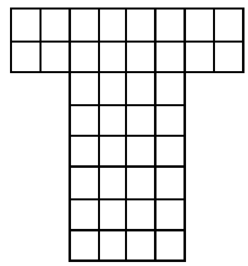
a) Dikdörtgenler prizması şeklindeki bu kutunun, ayrıtlarından kesilip, açıldığını düşünün. Buna göre, aşağıdaki şekillerden hangisi bu kutunun açık halidir?

Uyarı: Küçük karelerin her birinin kenar uzunluğu 1 birimdir.

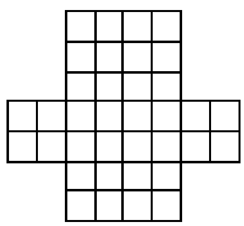
I)



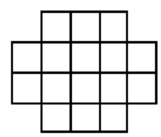
II)



III)



IV)



➔ İşaretlediğiniz seçeneğe **nasıl karar vediğinizi açıklayınız**.

……

……

……

……

b) Bir önceki soruda işaretlediğiniz kutunun açık halini gösteren şekildeki küçük karelerin toplam sayısını bulduğunuzu düşünün. Bu sayı, kutu hakkında hangi bilgiyi size verir? Aşağıda verilen seçeneklerden **size göre doğru olanı (X) ile işaretleyip**, **nedenleriyle açıklayınız**.

☐ Kutunun **hacmi** hakkında bilgi verir. Çünkü ……………… ……………………………………………………………… ……………………………………………………………… ……………………………………………………………… ……………………………………………………………… ……………………………………………………………… ……………………………………………………………… ………………………………………………………………	☐ Kutunun **yüzey alanı** hakkında bilgi verir. Çünkü ……… ……………………………………………………………… ……………………………………………………………… ……………………………………………………………… ……………………………………………………………… ……………………………………………………………… ……………………………………………………………… ………………………………………………………………

APPDENDIX D
PROCEDURAL KNOWLEDGE TEST

Uzunluk, Alan ve Hacim Ölçüleri
İŞLEM TESTİ

- ✓ Uzunluk, Alan ve Hacim Ölçüleri İşlem Testi, toplam 20 sorudan oluşmaktadır.
- ✓ Testi cevaplama süresi 40 dakikadır.
- ✓ Her soruyu dikkatlice okuduktan sonra, sorunun çözümü için yaptığınız işlemi ya da işlemleri ilgili sorunun altındaki boş bırakılan alana **açık ve net** bir şekilde yazınız.
- ✓ Hiçbir soruyu boş **bırakmayınız**.
- ✓ Test sayfalarındaki boş yerleri, soruların çözümü için kullanabilirsiniz.
- ✓ Cevaplamaya istediğiniz sorudan başlayabilirsiniz.

SORULAR

Aşağıda verilen ölçüleri istenilen birimlere çeviriniz.

1.Soru: 16 mm = _______________ cm

2.Soru: 250 dm^3 = _______________ cm^3

3.Soru: 492 km^2 = _______________ m^2

4.Soru: 0,305 km = _______________ m

5.Soru: 3 m^3 = _______________ cm^3

6.Soru: 7552 m^2 = _______________ km^2

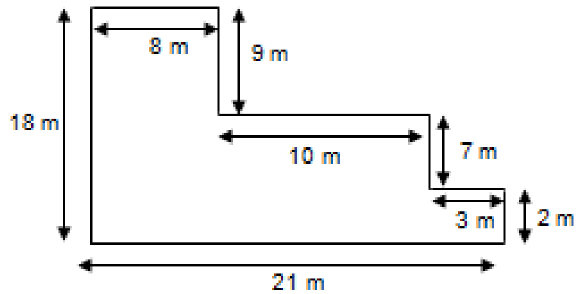
7.Soru: 450 dm^3 = _______________ litre

8.Soru: 1000 cm = _______________ m

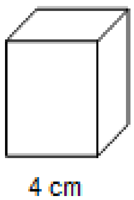
9.Soru: 2000 m^2 = _______________ cm^2

10.Soru:

Yanda tarafta verilen şeklin çevresini bulunuz.



11.Soru:



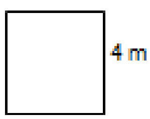
Şekilde verilen kare prizmanın;

Kenar uzunluğu: 4 cm

Yüzey alanı: 144 cm^2 ise,

Yüksekliği: _________?

12.Soru:



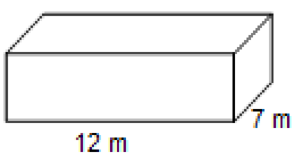
Şekilde verilen karenin;

Kenar uzunluğu: 4 m ise,

Çevre uzunluğu: _________?

---

13. Soru



Şekilde verilen dikdörtgenler prizmasının;

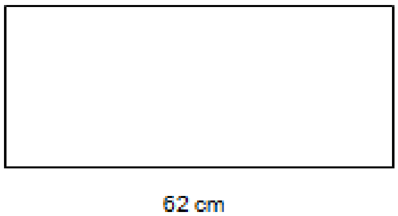
Hacmi: 168 m^3

Uzunluğu: 12 m

Eni: 7 m ise,

Yüksekliği: . _________?

14.Soru:



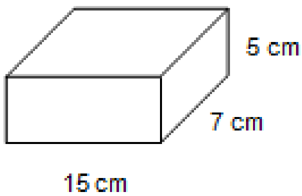
Şekilde verilen dikdörtgenin;

Çevresi: 224 cm

Uzun kenarı: 62 cm ise,

Alanı: _________?

15.Soru:



Şekilde verilen dikdörtgenler prizmasının;

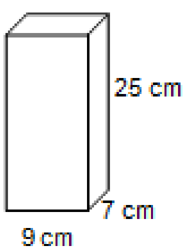
Uzunluğu: 15 cm

Eni: 7 cm

Yüksekliği: 5 cm ise,

Yüzey alanı: _________?

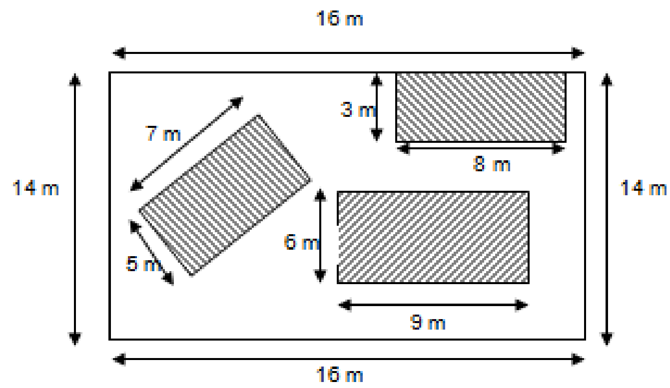
16.Soru



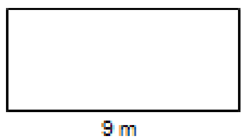
Şekilde verilen dikdörtgenler prizmasının;
Uzunluğu: 9 cm
Eni: 7 cm
Yüksekliği: 25 cm ise,
Hacmi: _________?

17.Soru:

Yanda verilen şekildeki **taralı olmayan** alan kaç m²'dir?

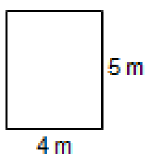


18.Soru:



Şekilde verilen dikdörtgenin;
Çevresi: 30 m
Uzun kenarı: 9 m ise,
Kısa kenarı: _________?

19.Soru:



Şekilde verilen dikdörtgenin;
Uzun kenarı: 5 m
Kısa kenarı: 4 m ise,
Alanı: _________?

20.Soru:

Yukarıda gösterilen şekildeki B ve C noktaları arasındaki uzunluğu **CETVEL** kullanarak ölçünüz. Bulduğunuz sonucu noktalı yere yazınız.

➔ B ve C noktaları arasındaki uzunluk: ....

APPENDIX E
WORD PROBLEM TEST

Uzunluk, Alan ve Hacim Ölçüleri
SÖZEL PROBLEM TESTİ

- ✓ Uzunluk, Alan ve Hacim Olçüleri Problem Testi, toplam 20 sorudan oluşmaktadır.
- ✓ Testi cevaplama süresi 40 dakikadır.
- ✓ Her problemi dikkatlice okuduktan sonra, problemin çözüm basamaklarını ve sonucu **açık ve net** bir şekilde ilgili sorunun altındaki boş bırakılan alana yazınız.
- ✓ Hiçbir soruyu boş **bırakmayınız**.
- ✓ Test sayfalarındaki boş yerleri, problemlerin çözümü için kullanabilirsiniz.
- ✓ Cevaplamaya istediğiniz sorudan başlayabilirsiniz.

SORULAR

1. Soru: 16 **mm** uzunluğunda olan bir toplu iğnenin uzunluğu **cm** cinsinden ne kadardır?

2. Soru: Bir su deposu 250 **dm³** su kapasitesine sahiptir. Bu deponun aldığı su miktarı, **cm³** cinsinden ne kadardır?

3. Soru: Yalova ilinin yüzölçümü 492 **km²** dir. Bu ilin sahip olduğu yüzölçümü **m²** cinsinden ne kadardır?

4. Soru: Bir gökdelen için en düşük yükseklik 0,305 **km** olarak kabul edilmektedir. Bu yükseklik **m** cinsinden ne kadardır?

5. Soru: Bir akaryakıt tankının kapasitesi 3 **m³**'tür. Bu tankın kapasitesi **cm³** cinsinden ne kadardır?

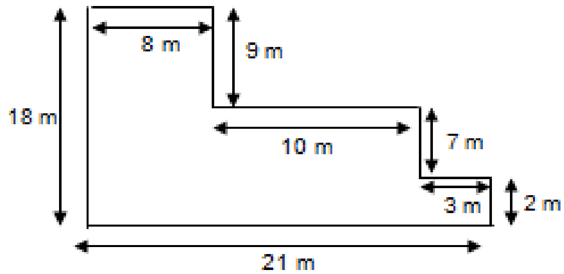
6. Soru: Volkan'nın okulunun bahçesi 7552 **m²** lik bir alanı kaplamaktadır. Bahçenin alanını **km²** cinsinden ne kadardır?

7. Soru: Tamamen doldurulduğunda 450 **dm³** su alabilen bir havuzun, aldığı su miktarı **litre** cinsinden ne kadardır?

8. Soru: 1000 **cm** kaç **m** vardır?

9. Soru: Ceren'in dedesinin tarlasının alanı 2000 **m²** dir. Bu tarlanın alanı kaç **cm²**'dir?

➔Yeni bir ev aldığınızı ve bu evin bahçesinin yanda verilen şekildeki gibi olduğunu düşünün ve *aşağıdaki soruları* bu şekle *göre cevaplayınız*.



10.Soru:

Bahçenin tamamını metal tel ile çevirmek istiyorsunuz. Toplam kaç metre metal tele ihtiyacınız olur?

11.Soru:

Bahçenizin bir kısmına domates yetiştirmek için dikdörtgen şeklinde ayrı bir bölüm yaptığınızı ve bu bölümü telle çevirmek için toplam 30 metre tel kullandığınızı düşünün. Dikdörtgen şeklindeki domates bahçesinin uzun kenarı 9 metre olduğuna göre, kısa kenarı kaç metredir?

12.Soru:

Bahçenize köpeğiniz için de bir yer yapmak istiyorsunuz. Köpeğiniz için ayırdığınız yer, kare şeklinde ve bir kenarının uzunluğu 4 metre olduğuna göre, burayı tahta çitle çevirmek için gerekli olan çit kaç metredir?

13.Soru

Tamamen dolduğunda 168 m^3'lük su kapasitesi olan dikdörtgenler prizması şeklindeki bir havuzun uzunluğu 12 m, eni 7 m olduğuna göre, havuzun derinliği kaç m'dir?

14.Soru:

Dilan ve babası yeni doğan kedi yavruları için, evlerinin bahçesine dikdörtgen şeklinde bir barınak yaptılar ve tabanını halı ile kapladılar. Barınağın etrafını çevirmek için 224 cm koruyucu tel kullandılar. Barınağın bir kenarının uzunluğu 62 cm olduğuna göre, barınağın tabanını tamamen kaplamak için kaç cm^2 halı kullandılar?

15.Soru:

Burçin, görsel sanatlar dersinde annesine ahşap (tahta) mücevher kutusu yaptı. Kutunun dışını yeşil renkli el işi kağıdıyla kapladı. Kutu 15 cm uzunluğunda, 7 cm genişliğinde ve 5 cm yüksekliğinde olduğuna göre, kutunun dışının tamamen kaplanması için ne kadar el işi kağıdı kullanılmıştır?

16.Soru:

Yüksekliği 25 cm, eni 7 cm ve uzunluğu 9 cm olan bir süt kutusunu tamamen süt ile doldurmak için, ne kadar süte ihtiyaç vardır?

17.Soru

Genişliği 16 metre, uzunluğu 14 metre olan dikdörtgen biçimindeki bir araziye 3 farklı çeşitte çim ekilecektir. Aşağıdaki tabloda 3 farklı çim ve bunların yetişmesi için gerekli dikdörtgen şeklindeki alanların boyutları verilmiştir. Buna göre 3 farklı çim tohumu ekildikten sonra, arazide kalan alan (çim *ekilmemiş* alan) ne kadardır?

Çim çeşitleri	Çimin yetişmesi için gerekli dikdörtgen şeklindeki alanların boyutları
A	7 m genişlik – 5 m uzunluk
B	8 m genişlik – 3 m uzunluk
C	9 m genişlik - 6 m uzunluk

18.Soru:

Matematik dersinde kullanmak için taban ayrıtlarından bir tanesinin uzunluğu 4 cm olan kare prizma şeklinde bir kutu tasarladığınızı düşünün. Bu kutuyu yapmak için 144 cm^2 karton kullandığınıza göre, kutunun yüksekliği kaç cm'dir?

19.Soru

Efe'nin dikdörtgen şeklindeki odasının zemini halı ile kaplanacaktır. Odanın uzunluğu 5 metre, eni 4 metre olduğuna göre, Efe'nin odasının zeminini tamamen kaplamak için kaç m^2 halı alınması gerekir?

20.Soru

Ceren'in cetveli matematik dersinde kırılmıştır. Cetvelin şu anki başlangıç noktası 14 santimetre, bitiş noktası ise 27 santimetre olduğuna göre, cetvelin şimdiki uzunluğu kaç santimetredir?

APPENDIX F

CONSENT LETTER OF THE INSTITUTION

T.C.
ANKARA VALİLİĞİ
Milli Eğitim Müdürlüğü

BÖLÜM : Strateji Geliştirme
SAYI : B B.08.4.MEM.4.06.00.04-312/3643 — 14.01.2008
KONU : Gülçin TAN ŞİŞMAN

VALİLİK MAKAMINA

İLGİ : a) M.E.B. Bağlı Okul ve Kurumlarda Yapılacak Araştırma ve Araştırma Desteğine Yönelik İzin ve Uygulama Yönergesi.
b) Orta Doğu Teknik Üniversitesi Öğrenci İşleri Dairesi Başkanlığı'nın 25.12.2007 tarih 018512 sayılı yazısı.

Orta Doğu Teknik Üniversitesi Eğitim Bilimleri Anabilim Dalı Doktora Programı öğrencilerinden Gülçin TAN ŞİŞMAN'ın **"6.Sınıf Öğrencilerinin Uzunluk ,Alan ve Hacim Ölçüleri Konusundaki Kavramsal Bilgi, İşlemsel Bilgi ve Sözel Problemlerdeki Başarıları"** konulu tezi ile ilgili anket çalışmalarının, İlimiz okullarında uygulama isteği ilgi (a) yönerge doğrultusunda Müdürlüğümüz Değerlendirme Komisyonu tarafından incelenmiş olup, ekte adı geçen okullarda gönüllülük esasına dayalı olarak (Uzunluk ,Alan ve Hacim Ölçüleri Kavramsal Bilgi Testi 10 sayfa,16 soru,Uzunluk,Alan ve Hacim Ölçüleri İşlemsel Bilgi Testi 5 sayfa, 13 soru, Uzunluk, Alan ve Hacim Ölçüleri Sözel Problem Testi 6 sayfa,13 soru, Kavramsal Bilgi Testi Öğrenci Görüşme Sorularından oluşan) anket uygulama isteği Müdürlüğümüzce uygun görülmüştür.

Makamlarınızca da uygun görüldüğü takdirde Olurlarınıza arz ederim.

Murat Bey BALTA
Milli Eğitim Müdürü

OLUR
11/01/2008

Mehmet KURDOĞLU
Vali a.
Vali Yardımcısı

Ekler:
1-Okul Listesi (1 sayfa)
2- Uzunluk Bil.Testi (10 sayfa)
3- İşlemsel Bil.Testi (5 sayfa)
4- Problem Testi.(6 sayfa)
5-Öğrenci Görüşme Soruları

.../.../2008 Bil.İşl. : R.SOLMAZ
10/01/2008 Şef : K.SARI
10/01/2008 Md.Yrd. : G.UYSAL

APPENDIX G

TURKISH SUMMARY

ALTINCI SINIF ÖĞRENCİLERİNİN UZUNLUK, ALAN VE HACİM ÖLÇÜLERİ KONUSUNDAKİ KAVRAMSAL VE İŞLEMSEL BİLGİLERİ VE SÖZEL PROBLEMLERİ ÇÖZME BECERİLERİ

GİRİŞ

Günümüzde, matematik alanındaki yetkinlik ve matematik okur-yazarlığı, bilgi toplumunun ihtiyaç duyduğu insan modelinin yetiştirilmesinde en önemli unsurlardan biri olarak kabul edilmektedir. Matematiksel yetkinliğe sahip toplumlar için, öğrencilerin kavram ve becerileri anlamlı öğrenmesine ve bunlar arasında bağ kurmalarına fırsat veren matematik öğretimi üzerine odaklanmak gerekmektedir. Kavramsal temellere dayanan matematiksel bilgi ve beceriler, öğrencilerin akıl yürütme ve ilişkilendirme yaparak farklı durum ve ortamlarda karşılarına çıkabilecek problemlerin çözümüne başarıyla ulaşabilmelerini sağlamaktır.

Van De Walle (1989), matematik öğretiminin kalıcı ve anlamlı olması için öğrencilerin matematiksel kavram ve işlemleri anlamaları ve aynı zamanda bu kavram ve işlemler arasındaki bağı kurmaları gerektiğini vurgulamıştır. Skemp (1978) matematiksel anlamayı iki farklı bilgi formuna ayırarak incelemiştir: Enstrumental anlama (Instrumental understanding) ve ilişkilendirerek anlama (Relational understanding). Enstrumental anlamayı "kuralları muhakemesiz olarak bilme" (p.9) olarak, ilişkilendirerek anlamayı ise "neden ve nasıl yapılacağını bilme" (p.9) şeklinde tanımlamıştır. Enstrumental anlamanın kolayca kavranabilen, ortama bağlı, öğrencinin doğru cevaba kısa sürede ulaşmasını sağlayan, somut ve anında sonuç veren tamamen mekanik bilgilerden oluştuğunu belirtirken, ilişkilendirerek anlamayı kolayca hatırlanabilen, ortama bağlı olmayan, ilişkiler üzerine kurulmuş kavramlar bilgisi olarak tanımlamıştır. Skemp'in yaptığı bu ayrım ile matematiğin nasıl öğretilmesi gerektiği, hangi bilginin daha gerekli ve önemli olduğu, bu iki farklı bilgi türü arasında nasıl bir denge kurulması gerektiği gibi konularda uzun yıllar süren tartışmaların önü açılmıştır.

Özellikle Hiebert'in kitabının (1986) yayınlanmasından sonra, matematiksel bilginin sınıflandırılması kavramsal bilgi (conceptual knowledge) ve işlemsel bilgi (procedural knowledge) terimleri kullanılarak yapılmaya başlanmıştır. Hiebert ve Lefevre (1986), kavramsal bilgiyi 'birbirine bağlı bilgiler ağı' (p.3), işlemsel bilgiyi ise matematiksel sembol ve algoritimlerden oluşan 'işlemin nasıl tamamlanacağının basamak basamak tarif edildiği' (p.6) bilgi olarak tanımlamışlardır. Diğer bir değişle, kavramsal bilgi, diğer matematiksel fikir ve kavramlarla bağlantılı ya da iç içe geçmiş ilişkileri anlamayı kapsarken, işlemsel bilgi matematiksel kurallara ve işlemlere ilişkin matematiği betimlemede kullanılan sembolleri kapsamaktadır (Aksu, 1997). İşlemler ve kavramlar arasındaki bağın kurulmasıyla, öğrenci işlemlerin sadece nasıl yapıldığını değil aynı zamanda niçin yapıldığını da açıklayabilir ve böylece anlamlı öğrenmenin gerçekleşmesi kolaylaşır. Matematik eğitimi alanında yapılan çalışmaların bir çoğu, sağlam temellere dayanan bir matematik öğretiminin en gerekli parçalarından olan kavramsal ve işlemsel bilgi arasında pozitif bir korelasyon olduğunu ve bu nedenle, iki bilgi türü arasındaki ilişkiler ön plana çıkartılarak öğretilmesi gerektiğini vurgulamışlardır (Hiebert & Lefevre, 1986; Rittle-Johnson & Siegler, 1998).

Matematik öğretiminin amaçlarından birisi; kişiye günlük hayatta kullanabileceği bilgileri kazandırmak ve bu bilgileri gerektiği durumlarda kullanabilmelerini sağlamaktır. İlköğretim matematik programının öğrenme alanlarından biri olan "ölçme", öğrencilerin günlük hayatta sıklıkla karşılaştığı konulardan birisidir. Ölçme alanın içerdiği konuların öğretimi, öğrencilere hem matematiğin günlük hayatta kullanımını göstermede ve bu sayede matematiğin hayatımızdaki öneminin kavratılmasında hem de birçok matematiksel kavram ve becerinin geliştirilmesinde önemli bir yer tutmaktadır. Fakat işlemlerin sağlam kavramsal temellere dayandırılmaması, matematiksel kavramların anlamlarının gözardı edilmesi, formüllerin ve kuralların ezberletme yoluna gidilmesi günlük hayatımızda sürekli karşımıza çıkan ölçme konusunun öğretiminde problemlere yol açmaktadır (Aksu, 1997; Baki, 1998; Baykul 1999; Hiebert,1986; Thompson ve diğ., 1994).

Varolan bilgi birikiminin hızla değiştiği ve geliştiği günümüz dünyasında problem çözme becerisi oldukça önem kazanmaktadır. Matematik konu alanı gözönüne alındığında, öğrencilerin kavramsal ve işlemsel bilgilerinin gelişmesinin odağında problem çözme yeralmaktadır. Matematik programlarının ayrılmaz parçası olan sözel problemler ise öğrencilerin varolan bilgi ve beceri birikimlerini uygulama fırsatı yakaladıkları ve yeni kavram ve becerilerin oluşmasına ortam hazırlayan bir araç olarak kabul edilmektedir (Verschaffel, Greer, & De Corte, 2000). Matematiksel sözel problemler üzerine yapılan çalışmaların genellikle toplama ve çıkarmadan oluşan aritmetik konuları üzerine yoğunlaştıkları görülmüştür.

Matematik kendi içinde anlam bütünlüğü olan ilişki ve örüntüler ağından oluşan kümülatif bir disiplindir. Anlamlı bir matematik öğretimi, yeni kavram ya da becerinin varolanların üzerine kurularak ve onlarla ilişkilendirilerek öğrenilmesini gerektirir. Bu bağlamda, öğrencilerin önceden öğrendiği kavram ve becerilerin ileride öğrenecekleri üzerindeki olumlu etkisi oldukça açıktır. Alan yazında yapılan çalışmalarda da, matematik bilgi dağarcığı ilişki ve örüntüler üzerine yapılandırılmış bir öğrencinin, hem bu bilgileri hafızasına kodlaması ve gerekli koşullarda hatırlama ve uygulamaya sokma sürecinin kolaylaştığından hem de daha üst düzeyde bir öğrenmenin gerçekleştiğinden bahsedilmiştir.

Ölçme konusunda yapılan çalışmalardan çıkan ortak sonuçlardan biri de, uzunluk ölçülerine ait kavram ve becerilerin, alan ve hacim ölçülerini anlayabilmek için gerekli ön öğrenmeyi oluşturduğu yönündedir. Bu nedenlerle, öğrencilerin önceden öğrendiği kavramlar ve beceriler, ileride öğrenecekleri yeni bilgilerin kavranmasında önemli etkenlerden birisidir.

Matematik öğretimin daha anlamlı ve kalıcı olması için önerilen diğer bir yolda öğretimin materyal kullanımıyla zenginleştirilmesidir. Yapılan araştırmalar, matematik derslerinde materyal kullanımını destekleyen sonuçlar ortaya koymuştur (Bohan & Shawaker, 1994; Sowell, 1989). Clements'in yaptığı bir araştırmada (1999), matematik derslerinde materyal kullanılan öğrencilerin genel anlamda materyal kullanılmayan sınıftaki öğrencilere göre daha başarılı oldukları görülmüştür. Ayrıca, cetvel, ataç, birim küpler, birim kareler, gibi materyallerin kullanımı hemen hemen her matematik programının ölçme konu alanına özgü ayrılmaz parçalarındandır.

Diğer bir yandan, matematik eğitiminde cinsiyet değişkenin öğrenci başarısında önemli bir faktör olduğu uzun yıllardır ileri sürülen ve tartışılan bir konudur. Leder, (1985), Peterson ve Fennema (1985; aktaran Alkhateeb, 2001), cinsiyete bağlı matematik başarısında gözlenen farklılığın ilköğretim süresinde çok açık ve net olmadığı, fakat ilerleyen yıllarda kızların matematik başarısında erkeklerin gerisinde kaldıklarını ifade etmişlerdir.

Son yıllarda bu alanda yapılan çalışmaların farklı sonuçlara ulaşıldığı görülmektedir. Örneğin, PISA-2003'ten elde edilen veriler (Guiso ve diğ., 2008), matematik başarısında erkeklerin kızlara göre daha yüksek puanlara sahip olduğunu gösterirken, Aksu (1997), Hyde ve Linn (2006) tarafından yapılan araştırmaların sonuçları matematik başarısında cinsiyete göre anlamlı bir fark olmadığını göstermiştir. Ölçme konusuna yönelik yapılan bu çalışmada cinsiyetin de bir değişken olarak ele alınmasının alan yazını açısından önemli olduğu düşünülmektedir.

Çalışmanın Amacı

Bu çalışmanın amacı, devlet ilköğretim okullarının 6. sınıflarında öğrenim gören öğrencilerin uzunluk, alan ve hacim ölçme konularındaki kavramsal ve işlemsel bilgilerini ve sözel problemleri çözme becerilerini cinsiyet, önceki döneme ait matematik dersi başarısı (5.sınıf) ve materyal kullamı değişkenlerine göre araştırmaktır. Bu doğrultuda aşağıdaki alt problemlere cevap aranmıştır:

1. Altıncı sınıf öğrencilerinin Kavramsal Bilgi Testi, İşlemsel Bilgi Testi ve Sözel Problem Testindeki genel başarı düzeyleri nasıldır?
    - 1.1. Altıncı sınıf öğrencilerinin Kavramsal Bilgi Testi, İşlemsel Bilgi Testi ve Sözel Problem Testindeki uzunluk ölçmeye ait başarı düzeyleri nasıldır?
    - 1.2. Altıncı sınıf öğrencilerinin Kavramsal Bilgi Testi, İşlemsel Bilgi Testi ve Sözel Problem Testindeki alan ölçmeye ait başarı düzeyleri nasıldır?
    - 1.3. Altıncı sınıf öğrencilerinin Kavramsal Bilgi Testi, İşlemsel Bilgi Testi ve Sözel Problem Testindeki hacim ölçmeye ait başarı düzeyleri nasıldır?
2. Altıncı sınıf öğrencilerinin Kavramsal Bilgi Testi, İşlemsel Bilgi Testi ve Sözel Problem Testindeki genel başarı düzeyleri arasında anlamlı bir ilişki var mıdır?
    - 2.1. Altıncı sınıf öğrencilerinin Kavramsal Bilgi Testi, İşlemsel Bilgi Testi ve Sözel Problem Testindeki uzunluk ölçmeye ait başarı düzeyleri arasında anlamlı bir ilişki var mıdır?
    - 2.2. Altıncı sınıf öğrencilerinin Kavramsal Bilgi Testi, İşlemsel Bilgi Testi ve Sözel Problem Testindeki alan ölçmeye ait başarı düzeyleri arasında anlamlı bir ilişki var mıdır?
    - 2.3. Altıncı sınıf öğrencilerinin Kavramsal Bilgi Testi, İşlemsel Bilgi Testi ve Sözel Problem Testindeki hacim ölçmeye ait başarı düzeyleri arasında anlamlı bir ilişki var mıdır?
    - 2.4. Altıncı sınıf öğrencilerinin Kavramsal Bilgi Testi, İşlemsel Bilgi Testi ve Sözel Problem Testindeki her bir ölçme alanına (uzunluk, alan, hacim) ait başarı düzeyleri arasında arasında anlamlı bir ilişki var mıdır?

3. Altıncı sınıf öğrencilerinin Kavramsal Bilgi Testi, İşlemsel Bilgi Testi ve Sözel Problem Testindeki genel başarı düzeyleri cinsiyet faktörü açısından anlamlı bir fark göstermekte midir?
4. Altıncı sınıf öğrencilerinin Kavramsal Bilgi Testi, İşlemsel Bilgi Testi ve Sözel Problem Testindeki genel başarı düzeyleri önceki döneme ait matematik dersi başarısına (5. sınıf) göre anlamlı bir fark göstermekte midir?
5. Altıncı sınıf öğrencilerinin Kavramsal Bilgi Testi, İşlemsel Bilgi Testi ve Sözel Problem Testinde uzunluk, alan ve hacim ölçme konularına ilişkin ortak hataları nelerdir ?
6. Ölçme konusunun öğretiminde sıklıkla kullanılan materyaller nelerdir?
    6.1. Ölçme konusunun öğretiminde materyal kullanımı kim tarafından yapılmaktadır?
    6.2. Altıncı sınıf öğrencilerinin Kavramsal Bilgi Testi, İşlemsel Bilgi Testi ve Sözel Problem Testindeki genel başarı düzeyleri ile ölçme konusunun öğretiminde kullanılan materyaller arasında anlamlı bir ilişki var mıdır?

Çalışmanın Önemi

Matematiğin, günlük ve profesyonel yaşamda yansımalarının en somut olarak gözlemlendiği alanlardan biri olan ölçme konusunun kalıcı ve anlamlı olarak öğrenilmesinin önemi oldukça açıktır. Bu bağlamda, öğrencilerin uzunluk, alan ve hacim ölçme konularındaki kavramsal ve işlemsel bilgilerini ve sözel problemleri çözme becerilerini araştırmayı amaçlayan bu çalışmanın bulguları, bir çok açıdan değer taşımaktadır.

Matematik eğitimi alanında yapılan çalışmaların ortak konu alanı sayılar, dört işlem, kesirler ve geometri olarak karşımıza çıkmaktadır. Ölçme, matematik programlarının ayrılmaz bir parçası olmasına rağmen, diğer konu alanlarına göre arka planda kalmaktadır.

Ayrıca, Türkiye'de ölçme konusundaki araştırmalar oldukça nadir olup, yapılan bu çalışmanın bir benzerine rastlanmamıştır. Bu bağlamda, uzunluk, alan ve hacim ölçüleri konularında öğrencilerin hem kavramsal ve işlem bilgilerinin hem de sözel problemleri çözme becerilerinin bir bütün olarak incelenmesi ile hem sınırlı olan literatüre katkıda bulunulacağına hem de bu alanda yapılacak olan diğer çalışmalara öncülük edeceğine inanılmaktadır.

Diğer yandan, elde edilen bulguların ışında, ölçme konusunda öğrenci eksikliklerinin ve olası nedenlerinin belirlenmesi ve bunların giderilmesine yönelik önerilecek farklı yaklaşımlar ile ilköğretim matematik programına, öğretime ve öğretmenlere geribildirimler sağlanmasında yardımcı olacağı düşünülmektedir.

LİTERATÜR TARAMASI

Matematik Eğitimde Kavramsal ve İşlemsel Bilgi

Matematik eğitimde, kavramsal ve işlemsel bilgi öğrencinin hem matematiği anlamasında hem de matematiksel işlemlerde yetkinlik kazanmasındaki en temel öğeler arasında görülmektedir (Hiebert & Carpenter, 1992; Rittle-Johnson & Alibali, 1999). Matematikte başarılı olmanın kaynağında, öğrenilen bir kavramın ya da işlemin içselleştirmesi ve bunlar arasında anlamlı bağların kurulması yer almaktadır. Bu bağlamda, sadece kavramın anlamını bilmek ya da işlemi doğru olarak sonuçlandırmak, matematiğin kalıcı ve anlamlı olarak öğrenildiğini göstermez, bu nedenle kavramlar ve işlemler arasındaki bağın mutlaka kurulması gerekmektedir.

İşlemsel bilgi, öğrencilerin matematiksel hesaplamaları ve işlemleri etkin ve doğru olarak tamamlamasına yardımcı olur. Ayrıca, daha önceden alıştırma ve ezber yoluyla mekanikleşmiş işlem bilgisi, öğrencinin daha hızlı ve kolay şekilde verilen matematiksel hesaplamayı tamamlamasını sağlar (Hiebert & Carpenter,1992). İşlemleri doğru olarak yapma becerisi mutlaka o işlemin ardındaki kavramsal temelleri bilmeyi gerektirmesede, aralarındaki ilişkinin farkına varılmasıyla kazanılmış matematiksel bilginin kalıcı ve anlamlı öğrenmeyi en üst seviyelere taşıyacağı birçok eğitimci tarafından vurgulanan bir gerçektir (Baroody, 2003; Hiebert & Lefevre, 1986; Star, 2005). Diğer bir yandan, kavramsal temeller üzerine kurulmuş işlemsel bilgi, öğrencinin sembolleri, formülleri ve/ya kuralları anlamlandırmasına, daha da önemlisi, rutin olmayan bir problemin çözüme ulaştırılmasında en uygun işlem ya da formülü seçip uygulamasına yardımcı olur. İlgili alan yazını incelendiğinde, kavramsal ve işlemsel bilgi arasındaki ilişkiye yönelik farklı argümanlara rastlanmıştır. Örneğin, İnaktivasyon görüşünü (Inactivation view) benimseyen bazı araştırmacılar Nesher (1986), Resnick ve Omanson (1987) bu iki matematiksel bilgi arasında hiçbir ilişkinin olmadığını ileri sürerken, Rittle-Johnson, ve diğerleri (2001) tarafından önerilen Tekrarlı/Ötelemeli Model'de (Iterative model) kavramsal ve işlemsel bilgi arasında çift yönlü ve nedensel bir ilişkiden söz edilmektedir.

Uzunluk, Alan ve Hacim Ölçme

Matematik programlarının en temel konu alanlarından biri olan ölçme bir çokluğun miktarının belirlenmesi ihtiyacından doğmuştur (Kilpatrick, ve diğ., 2001). Ölçme 'bir nitelikte, birim kabul edilen bir miktardan kaç tane olduğunun saptanması işidir' (Baykul, 1999) ve bu süreçte, öğrencilerin sonuca ulaşabilmesi birden çok karar vermesi gerekir. Öncelikle belirlenmesi gereken bir nesnenin hangi niteliğinin ölçüleceğine karar verilmesi gerekir. Daha sonra, nasıl ya da hangi yolla bu özelliğin ölçülmesi belirlenmelidir. Son olarak, ölçülen niteliğin aynı nitelikten birim kabul edilen miktar ile karşılaştırılarak ölçüm sonucunun yorumlanması gerekmektedir (Van de Walle, 2007; Wilson & Rowland, 1992).

Lehrer'e göre (2003; s.181), ölçme sürecini anlamak ve ölçme işini doğru olarak yapabilmek için gerekli temeller şunlardır: birim ve ölçülecek nitelik arasındaki ilişki, öteleme, kaplama/yanyana koyma, eşit/özdeş birim kullanma, standartlaşma, orantılılık, toplanırlık ve başlangıç noktası. Bunlara ek olarak, korunum, geçişlilik, karşılaştırma, ölçülecek niteliğe uygun araç seçme gibi beceri ve/ya kavramlarında kazanılmış olması gerekmektedir (Barrett, ve diğ., 2003; Grant & Kline, 2003; Stephan & Clements, 2003). Literatürde ölçme konusuna ait genel temellere ek olarak, uzunluk, alan ve hacim ölçmeye ait özel kavram ve beceriler de tanımlanmıştır. Uzunluk ölçmenin anlamlı olarak öğrenilebilmesi için kazanılması gereken temeller korunum, geçişlilik, orantılılık, yığılarak/birikerek ilerleme, birim öteleme ve sayı ve ölçme arasındaki ilişki olarak nitelendirilmiştir. Stephan ve Clements (2003) alan ölçme için temel teşkil eden kazanımları, eşit bölüm/bölmelere ayırma, birim öteleme, korunum ve dizi yapısı (satır/sütun) olarak belirtmiştir. Ben-Haim, Lappan, ve Houang (1985) ve Battista'ya (2003) göre, hacim ölçmenin anlamlı olarak öğrenilmesi için temel oluşturan kavramlar uzamsal görselleştirme, korunum ve dizilerin anlamlı sıralanması olarak tanımlanmıştır.

Alan yazınında yapılan çalışmalarda, öğrencilerin ölçme konusuna ait kavram ve becerilerin öğrenilmesi sürecinde ciddi güçlükler yaşadıklarını ve bu güçlüklerin özellikle uzunluk, alan ve hacim ölçme boyutunda karşılaşıldığını ortaya koyulmuştur. Bu güçlüklerin ardında yatan en önemli etkenin ise ölçme konusuna ait kavramsal bilginin tam olarak öğretilmeden işlemsel bilgiyi ön plana çıkaran bir öğretime yoğunlaşılması olarak tanımlanmıştır.

Geçmiş araştırmalardan elde edilen bulgularda uzunluk ölçme ile ilgili öğrenci hataları, cetvel ile ölçüm yaparken sıfır yerine bir sayısını başlangıç olarak kabul etme, cetvel ve ölçülecek uzunluğu doğru olarak ayarlayamama, cetvel üzerindeki sayıları sayma, uzunluk ölçü birimlerini diğer ölçü birimleri ile karıştırma, alan ve çevre kavramlarını birbiriyle karıştırma vb. olarak gözlemlenmiştir. Alan ölçme konusunda öğrencilerin öğrenmekte zorluk çektiği kavram ve beceriler; alan korunumu, uzunluk ölçü birimleri ile alan kavramı arasındaki ilişki, alan kavramının iki boyutlu yapıya sahip olması, alan ve çevre kavramları ve bunlara ait formülleri birbiri ile karıştırma olarak bulunmuştur.

Üç boyutluluk, uzamsal yapılandırma, görselleştirme gibi özelliklerin koordinasyonunu gerektiren hacim ölçme, alan yazınında öğrenme zorluklarının en çok karşılaşıldığı diğer bir konu alanı olarak karşımıza çıkmaktadır. Hacim ölçmeyi öğrenirken ne gibi zorluklarla karşılaştıklarına ilişkin yapılan önceki araştırmalarda, öğrencilerin hacim kavramının üç boyutluluk özelliğini tam olarak kavrayamadıkları, birim küplerden oluşan prizmalar içerisindeki birim küpleri bulurken sadece görünen küpleri ya da küp yüzeylerini sayarak hacim olarak adlandırmaları, dolayısıyla yüzey alanı ve hacim kavramları arasındaki farkı anlayamamaları ve bu iki kavrama ait formülleri karıştırmaları olarak belirtilmiştir. Alan yazınındaki bu bulgular ışığında, her alt boyuta ait kavram ve becerilere ve bunlar arasındaki ilişkiye odaklı öğrenme yaşantıları sunulması ölçme konusunun tam ve anlamlı öğrenilmesi için en gerekli koşullardan biri olduğu sonucuna ulaşılabilir. Ayrıca, uzunluk ölçmenin diğer alt boyutların (örn. Alan ve/ya hacim ölçme) öğrenilmesinde oldukça önem taşıdığı, bu nedenle alan ve hacim ölçme konularının öğretiminde uzunluk ölçmeye ait kavram ve beceriler ile ilişkiler kurarak ilerlenmesi gerektiği literatürde vurgulanan diğer bir ayrıntıdır.

Matematik Eğitiminde Sözel Problemler

Her matematik programının ayrılmaz bir parçası olan sözel problemlere ilişkin matematik eğitimi alan yazınında birçok çalışmaya rastlanmıştır. Elde edilen bulgular, iyi yapılandırılmış bir sözel problemin, sadece işlemleri yapabilme becerisi kazandırmanın çok daha ötesinde olduğunu, öğrencilerin sahip olduğu matematiksel bilgi dağarcığı doğrultusunda farklı problem durumlarına göre uygun stratejileri seçip, uygulamaya koyup doğru sonuca ulaşabilmelerine olanak sağladığını ortaya koymuştur (Verschaffel et al., 2000). Diğer bir değişle, öğrencilerin hem matematiksel kavram bilgisi hem de işlem bilgisinin gelişmesinde ve daha kalıcı olmasında sözel problemler bir köprü görevi üstlenir (Silver, 1986). Yapılan çalışmalarda sözel problemlerin farklı özellikleri ile öğrenci başarısı arasındaki ilişkiler incelenmiştir. Örneğin, sözel problemlerde kullanılan semantik yapının daha açık ve anlaşılabilir olması, öğrencilerin problemleri başarıyla çözmesini etkileyen faktörlerdendir (Reusser & Stebler, 1997). Diğer bir yandan, farklı yaş gruplarıyla yapılan araştırmalardan elde edilen bulgular öğrencilerin sözel problemde verilen bilgilerle ne istendiğine dikkat etmeden işlemler yaptıklarını, hatta çözümü olmayan absurd problemleri bile çözmeye çalıştıklarını göstermiştir (Radatz, 1983, 1984; aktaran Verschaffel et al., 2000; Moreau & Coquin-Viennot, 2003). Bunlara ek olarak, ilköğretimden üniversiteye farklı gruplarla yapılan çalışmalarda, öğrencilerin sayısal ya da denklem formatında verilen sorulardaki başarılarıyla sözel problemleri çözme başarıları arasında büyük farklar gözlemlenmiştir. Diğer bir değişle, öğrenciler sayısal formatta hazırlanmış sorularda daha yüksek başarı göstermişlerdir. Bu sonuçlardan hareketle, öğrencilerin matematikle ilgili kavram ve becerilerinin gelişimine katkıda bulunan sözel problemlerde başarılı olabilmek için problemin anlaşılması, verilen bilgilerin varolan matematiksel bilgi dağarcığı sayesinde yorumlanıp, istenen sonuca ulaşmada kullanılması gereken işlemlerin doğru olarak yapılması gerekir.

Matematik Eğitiminde Cinsiyet Farkı, Geçmiş Döneme ait Matematik Yaşantısı ve Materyal Kullanımının Öğrenci Başarısına Etkileri

Matematik eğitimiyle ilgili yapılan çalışmalarda, öğrencilerin başarısını etkileyen birçok faktör olduğu bulunmuştur. Bu faktörler arasından cinsiyet farkı, geçmiş matematik yaşantısı ve materyal kullanımı yapılan bu araştırmanın değişkenleri arasında yeralmaktadır.

Literatürde oldukça fazla çalışılan konulardan biri olan matematik başarısındaki cinsiyet farkı araştırmaları genellikle erkeklerin daha başarılı olduğunu destekler niteliktedir (örn. Hyde, Fennema & Lamon 1990; Reis & Park 2001). Fakat, son on yılda varolan bu başarı farkının gün geçtikçe kapandığını gösteren sonuçlar elde edilmiştir (Ercikan, McCreith, & Lapointe, 2005; Ding, Song,& Richardson, 2007). Fennema ve Sherman (1978), Singh Kaeley (1995) ve Ding, ve arkadaşları (2007), erkekler ve kızlar arasındaki cinsiyet farkı hakkında kesin bir genellemede bulunmanın neredeyse imkansız olduğunu, çünkü matematik başarısında cinsiyet farkının, tutumlar, inanışlar, beceriler, öğretim programı, öğretmen, aile desteği, sözel beceri gibi faktörlerle etkileşim içerisinde olabileceğini belirtmişlerdir. Diğer bir yandan, yapılan çalışmaların ortak sonuçları gözönüne alındığında kızların genelde sayılarla işlem yapma, matematiksel sembolik ilişkileri kullanma, algısal hıza yönelik sorularda; erkeklerin ise problem çözme, uzamsal görselleştirme, geometri gibi konularda daha başarılı oldukları söylenebilir (Battista, 1990; Ben-Haim, et al., 1985, Fennema & Carpenter, 1981; Lummis & Stevenson, 1990, Xu & Farrel, 1992, aktaran Singh Kaeley, 1995). Türkiye'de yapılan çalışmaların hemen hemen hepsi, matematik başarısında cinsiyetin etkili bir faktör olmadığı yönündedir (Aksu, 1997; Bulut, Gur, & Sriraman, 2010).

Alan yazında, matematiğin kümülatif ve sarmal yapısıyla parallel olarak, öğrencilerin geçmişte öğrendikleri kavram ve becerilerinin onlara gelecekteki öğrenmelerde temel teşkil edeceği birçok matematik eğitimci tarafından belirtilmiştir. Yapılan çalışmalar, öğrencinin sahip olduğu matematiksel bilgisinin ileriki zamanda öğrenecekleri üzerinde pozitif bir ilişki olduğunu kanıtlamıştır (Cooper ve Sweller, 1987; aktaran Chinnappan, 2003). Kabiri ve Kiamanesh (2004) kaygı, tutum, kendine güven gibi faktörlerin öğrencilerin matematik başarısına olan etkisini araştırdıkları çalışmalarında, en yüksek ilişkinin geçmiş matematik öğrenmeleri olduğu sonucunu bulmuşlardır. Aynı şekilde, Pajares'in yaptığı çalışmalarda da (1996; Pajares & Kranzler 1995; Pajares & Miller, 1994) geçmiş matematik bilgisi öğrencinin gelecekteki başarısı hakkında en güçlü yordayıcılardan biri olarak karşımıza çıkmaktadır.

Yapılan bu çalışmanın değişkenlerinden sonuncusu olan materyal kullanımı konusunda literatürde oldukça fazla araştırma vardır. Bu araştırmaların çoğunluğu, matematik derslerinde materyal kullanımı ile öğrenci başarısı arasında pozitif bir ilişki olduğunu ortaya koymuştur. Kesirler, geometri, sayılar gibi konuların öğretiminde materyal kullanımı üzerine yapılan çalışmalarda, materyal kullanımı ile desteklenmiş öğrenme ortamlarında öğretim gören öğrencilerin, materyalsiz sınıflardakilere göre daha başarılı oldukları bulunmuştur (Clements, 1999; Cramer, Post, & delMas, 2002).

YÖNTEM

Bu çalışmayla, ilköğretim 6. sınıf öğrencilerinin uzunluk, alan ve hacim ölçme konularındaki kavramsal ve işlemsel bilgilerini ve sözel problemleri çözme becerilerini araştırmak amaçlanmıştır.

Araştırma Grubu

Araştırma, Ankara ilinin 4 farklı merkez ilçesinde yer alan 6 devlet ilköğretim okulunda öğrenim gören 6. sınıf öğrencileriyle gerçekleştirilmiştir. Araştırma grubu, amaçlı örneklem yöntemiyle, Ankara ilinde yer alan okulların 2006 yılına ait Ortaöğretim Kurumları Öğrenci Seçme Sınavı (OKS) Matematik puan ortalaması temel alınarak oluşturulmuştur. 2006 OKS'ye katılan devlet ilköğretim okullarının matematik puanları en yüksekten ($\overline{X}$ = 9.30), en düşüğe ($\overline{X}$ = -3) doğru sıralanmıştır. Bu sıralama kendi içinde yüksek ($\overline{X}$ = 9.30- 5.20 arası okullar), orta ($\overline{X}$ = 5.19 - 1.10 arası okullar) ve düşük ($\overline{X}$ = 1.09 - (-3) arası okullar) olmak üzere gruplanmıştır. Okul mevcudu (1000-2000) ve okulun bulunduğu ilçe dikkate alınarak, her düzeyde başarı gösteren okullar arasından 2 tane okul olmak üzere toplamda 6 okul seçilmiştir ve bu okullarda öğrenim gören 6. sınıf öğrencileri (N = 445) çalışmaya dahil edilmiştir. Araştırma grubunu oluşturan okullara ilişkin bilgiler Tablo 1'de sunulmuştur.

Tablo 1

Araştırma Grubunu Oluşturan Okullara ait Bilgiler

Başarı seviyesi	Seçilen Okullar	OKS 2006 Matematik puan ortalaması	Merkez İlçeler	Okul Mevcudu	Katılan 6.sınıf öğrenci sayısı
Yüksek	X School	7.27	Cankaya	1077	81
	Y School	6.65	Cankaya	1099	81
Orta	Z School	4.51	Yenimahalle	1073	83
	F School	3.31	Kecioren	1056	67
Düşük	L School	0.59	Kecioren	1010	50
	K School	-0.58	Altindag	1000	83

Çalışmaya katılan 445 altıncı sınıf öğrencisinden, 203'ü (% 45.6) erkek, 242'si (% 54.4) kızdır. Öğrencilerin yaşları on bir ile on dört arasında değişmektedir ve 87%'lik kısmı on iki yaşındadır. Geçmiş matematik başarıları, yani beşinci sınıf matematik dersi karne notları incelendiğinde, 18'i düşük, 159'u orta ve 268'i yüksek seviyede başarılıdırlar.

Veri Toplama Araçları

Çalışmada veri toplamak amacıyla 4 farklı araç kullanılmıştır. Bunlardan ilki, araştırmacı tarafından geliştirilen Öğrenci Anketidir (ÖA). Bu anketin amacı hem ölçüler konusunun öğretiminde materyal kullanımı hakkında veri toplamak hem de yaş, cinsiyet, beşinci sınıf matematik dersi karne notu gibi öğrencilerin kişisel bilgilerine ulaşmaktır.

Çalışmada kullanılan diğer bir veri toplama araçları ise Kavramsal Bilgi Testi (KBT), İşlemsel Bilgi Testi (İBT) ve Sözel Problem Testidir (SPT). Her test için hazırlanan sorularda, ilgili literatürde vurgulanan ölçme konusuna ait kavram ve beceriler, öğrenci hataları ve matematik programının 7.sınıfa kadar olan uzunluk, alan ve hacim ölçme konularının içerdiği kavram ve beceriler temel alınmıştır. Testlerin kapsamını belirlemede öncelikle ilköğretim matematik programı, birinci sınıftan, sekizinci sınıfa kadar olan kazanımlar uzunluk, alan ve hacim ölçme konuları açısından incelenmiştir. Öğrencilerin uzunluk ölçme ile ilk kez tanıştıkları sınıf seviyesinin birinci sınıf, alan ölçme ile üçüncü sınıf ve hacim ölçme ile beşinci sınıf olduğu gözlemlenmiştir. Birinci sınıftan altıncı sınıfa kadar olan uzunluk, alan ve hacim ölçme konularına ait kazanımlar bu konuların temelindeki bilgi ve becerilerden oluştuğu, yedinci ve sekinci sınıflarda ise daha özel ve detaylı hale geldiği görülmüştür. Çalışmanın temel amacı öğrencilerin uzunluk, alan ve hacim ölçme konularına ait temel kavram ve becerilerini farklı boyutlardan incelemek olduğundan, yedinci ve sekinzinci sınıf konuları testlerin kapsamına dahil edilmemiştir.

Öğrencilerin uzunluk, alan ve hacim ölçme konuları hakkında kavramsal bilgilerini ölçmeyi amaçlayan KBT'nde toplam 16 soru yeralmaktadır, sadece 2 soru haricinde tüm sorular araştırmacı tarafından geliştirilmiştir. Toplam 20 sorudan oluşan, öğrencilerin uzunluk, alan ve hacim ölçme konusundaki işlem becerisini ölçmeyi amaçlayan İBT araştırmacı tarafından geliştirilmiştir. Sadece hesaplama yapmayı gerektiren sorulardan oluşmaktadır. Öğrencilerin uzunluk, alan ve hacim ölçmeye ilişkin sözel problemleri çözme becerilerinin ölçüldüğü test olan SPT'de toplam 20 sözel problem yeralmaktadır. Araştırmacı tarafından geliştirilen bu testteki problemler, İBT'ndeki soruların sözel problem haline getirilmiş şekilleridir.

Testin kapsam geçerliliğinin sağlanması için uzman görüşlerinden, ilgili literatürden, ve ilköğretim matematik programı 1.- 6. sınıf uzunluk, alan ve hacim ölçme ile ilgili kazanımlardan yararlanılmıştır. Geliştirilen testler, 3 matematik öğretmeni ve 5 alan uzmanına verilerek, hem kapsam hem de görünüş geçerliliği açısından değerlendirme yapmaları istenmiştir.

Araştırma grubu seçiminde kullanılan temel kriterler (OKS-2006 Matematik puan ortalaması ve okul mevcudu) doğrultusunda Ankara ili merkez ilçe okulları arasından seçilen bir ilköğretim okulunun tüm 7. sınıflarında öğrenim gören 134 öğrencinin katılımıyla tüm veri toplama araçlarının pilot uygulaması yapılmıştır. Elde edilen verilerle, testlerin güvenirliği Kuder-Richardson-21 formülü kullanılarak hesaplanmış ve güvenilirlik katsayısı KBT için .87, İBT için .88 ve SPT için .89 olarak bulunmuştur. Tablo 2'de veri toplama araçlarına ilişkin detaylı bilgi verilmiştir.

Tablo 2

Veri Toplama Araçları

	KBT	İBT	SPT	ÖA
Toplam soru sayısı	16	20	20	27
Toplam alt soru sayısı	50	-	-	-
Soru türü	Açık uçlu, eşleştirme, çoktan seçmeli, kısa cevaplı	Açık uçlu	Açık uçlu,	Kişisel bilgi Likert tipi
Test Süresi	40-45 dak.	35-40 dak.	40-45 dak.	10 dak.
Toplam puan	50	20	20	-

Milli Eğitim Bakanlığı ve ODTÜ Etik Kurulu'ndan gerekli izinler alındıktan ve seçilen okullarda uzunluk, alan ve hacim ölçme konularının öğretiminin bitmesinin ardından, asıl uygulama Mayıs-Haziran 2008 tarihlerinde araştırmacı tarafından yapılmıştır. Veri toplama araçlarının aynı anda uygulanması hem öğrencileri yoracağından hem de alınacak sonuçları olumsuz yönde etkileyebileceğinden, farklı günlerde uygulanmıştır.

Testlerin puanlandırılmasında, 3 alan uzmanının görüşleri dahilinde hazırlanan cevap anahtarı kullanılmıştır. Veriler, her doğru cevap '1' ve her yanlış cevap '0' şeklinde olmak üzere PASW programına aktarılmıştır. Elde edilen veriler betimsel ve yordamsal istatistik (Çoklu Varyans Analizi-MANOVA) yöntemleri kullanılarak analiz edilmiştir. Öğrencilerin testlerde yaptıkları hataları değerlendirmek amacıyla, araştırmacı tarafından literatürde bulunan hatalar dahilinde hazırlanan bir yönerge kullanılmıştır. Bu yönerge doğrultusunda, her bir test sorusu tek tek incelenip, kategorize edilmiştir. Son olarak, ilköğretim 6.sınıf öğrencilerinin uzunluk, alan ve hacim ölçme konularındaki kavramsal ve işlemsel bilgileri ve sözel problemleri çözme becerilerinin incelendiği bu çalışma, örneklemi ve veri toplama araçlarından elde edilen bulgular ile sınırlıdır.

BULGULAR

Toplam 445 altıncı sınıf öğrencisinin katılımıyla gerçekleşen ve dört farklı veri toplama aracı yoluyla toplanan verilere ait istatistiksel çözümlemeler araştırma soruları doğrultusunda verilmiştir.

Altıncı Sınıf Öğrencilerinin Kavramsal Bilgi Testi, İşlemsel Bilgi Testi ve Sözel Problem Testlerindeki Performansları

Çalışmanın başında saptanan ilk araştırma sorusu öğrencilerin her testteki genel başarı düzeyini belirlemeyi amaçlamaktadır. Betimsel analiz sonuçlarına göre, öğrencilerin testlerden aldıkları ortalama puanlar oldukça düşüktür ($\overline{X}_{KBT}$ = 19.6, SD_{KBT} = 9.2; $\overline{X}_{İBT}$ = 8.3 $SD_{İBT}$ = 4.7; $\overline{X}_{SPT}$ = 7.7, SD_{SPT} = 4.8). Bulgular, başarı oranının SPT'de %38.5 (7.7/20 = .38.5) ; KBT'de %39 (19.6/50 = .39) ve PKT'de ise %41.5 olduğunu göstermiştir.

Ölçmenin alt boyutlarındaki öğrenci performansına ait analiz sonuçlarında en yüksek başarı uzunluk ölçülerinde ($\overline{X}_{KBT}$ = 12.2, SD_{KBT} = 4.6; $\overline{X}_{İBT}$ = 4.7, $SD_{İBT}$ = 1.7; $\overline{X}_{SPT}$ = 4.4, SD_{SPT} = 2); en düşük başarı ise hacim ölçmede ($\overline{X}_{KBT}$ = 2.7, SD_{KBT} = 2.5; $\overline{X}_{İBT}$ = 1.5, $SD_{İBT}$ = 1.7; $\overline{X}_{SPT}$ = 1.5, SD_{SPT} = 1.7) gözlemlenmiştir.

Altıncı Sınıf Öğrencilerinin Kavramsal Bilgi Testi, İşlemsel Bilgi Testi ve Sözel Problem Testlerindeki Performansları Arasındaki İlişki

Öğrencilerin her üç testte gösterdiği performanslar arasında anlamlı bir ilişki olup olmadığı ikili korelasyon (bivariate correlation) analizi kullanılarak test edilmiştir. Elde edilen Pearson korelasyon katsayısı değerlerine göre, testler arasında istatiksel olarak anlamlı ve pozitif bir ilişki vardır ($r_{İBT - SPT}$ =.84, p < 0.5; $r_{KBT - SPT}$ =.73, p < 0.5; $r_{KBT - İBT}$ =. 70, p < 0.5).

Öğrencilerin KBT, İBT ve SPT'ndeki uzunluk, alan ve hacim ölçmeye ait performansları arasındaki ilişkinin tesbit edilmesi için ikili korelasyon analizi kullanılmıştır. Bulgular, öğrencilerin her bir ölçme alanına ait her bir testte gösterdikleri performans arasında anlamlı ve pozitif bir ilişki olduğunu göstermiştir. Uzunluk ölçme alanında öğrencilerin İBT ve SPT'ndeki performansları arasındaki ilişki r = .71, p < 0.5; SPT ve KBT arasındaki ilişki r = .59, p < 0.5; İBT ve SPT arasındaki ilişki ise r = .56, p < 0.5 olarak bulunmuştur. Alan ölçme boyutunda öğrencilerin İBT ve SPT'ndeki performansları arasındaki ilişki r = .75, p < 0.5; SPT ve KBT arasındaki ilişki r = .54, p < 0.5; İBT ve SPT arasındaki ilişki ise r = .82, p < 0.5 olarak bulunmuştur. Hacim ölçmede ise öğrencilerin İBT ve SPT'ndeki performansları arasındaki ilişki r = .82, p < 0.5; SPT ve KBT arasındaki ilişki r = .61, p < 0.5; İBT ve SPT arasındaki ilişki ise r = .61, p < 0.5 olarak bulunmuştur.

İkili korelasyon analizinden elde edilen diğer bir sonuç ise, altıncı sınıf öğrencilerinin KBT, İBT ve SPT'ndeki her bir ölçme alanına (uzunluk, alan, hacim) ait performansları arasında istatiksel olarak anlamlı bir ilişkinin olmasıdır. Öğrencilerin KBT'nde uzunluk ve alan ölçme performansları arasındaki ilişki r = .62, p < 0.5; uzunluk ve hacim ölçme performansları arasındaki ilişki r = .64, p < 0.5; alan ve hacim ölçme arasındaki ilişki r = .61, p < 0.5 olarak bulunmuştur. İBT'nde öğrencilerin uzunluk ve alan ölçme performansları arasındaki ilişki r = .64, p < 0.5; uzunluk ve hacim ölçme performansları arasındaki ilişki r = .56, p < 0.5; alan ve hacim ölçme arasındaki ilişki $r = .73$, $p < 0.5$ olarak bulunmuştur. SPT'nde ise öğrencilerin uzunluk ve alan ölçme performansları arasındaki ilişki $r = .60$, $p < 0.5$; uzunluk ve hacim ölçme performansları arasındaki ilişki $r = .59$, $p < 0.5$; alan ve hacim ölçme arasındaki ilişki $r = .77$, $p < 0.5$ olarak bulunmuştur. Cohen'e göre (1988), analiz sonucunda bulunan Pearson korelasyon katsayısı değerlerinin tümü oldukça güçlü ve pozitiftir.

Altıncı Sınıf Öğrencilerinin Kavramsal Bilgi Testi, İşlemsel Bilgi Testi ve Sözel Problem Testlerindeki Genel Performanslarında Cinsiyet ve Önceki Döneme ait Matematik Dersi Başarı Notunun Etkisi

Öğrencilerin testlerdeki performanslarında cinsiyet ve önceki döneme ait matematik dersi başarı notunun (ÖDMB) etkisi Çoklu Varyans Analizi (MANOVA) kullanılarak test edilmiştir. Değişkenlere ait alt boyutların farklı sayılarda olması nedeniyle (unequal sample size in cells), Wilk's Lamda yerine Pillai's Trace test sonuçları kullanılmıştır (Field, 2009; French, & Poulsen, 2008; Tabachnick & Fidell, 2007).

Öğrencilerin testlerdeki performansları cinsiyet değişkeninden etkilenmemektedir. Yani erkek ve kız öğrencilerin testlerden aldıkları puanlar arasında anlamlı bir fark yoktur (Pillai's Trace =.008, F (3,437) = 1.22, $p > .05$). Ancak, öğrenci performansları önceki döneme ait matematik dersi başarı notuna göre anlamlı olarak farklılık göstermektedir (Pillai's Trace=.104, F (6,876) = 8, $p < .05$, kısmi $\eta^2 = .052$). Anlamlı bulunan çoklu varyans analiz sonuçları doğrultusunda, tekli varyans (univariate) analiz sonuçları da incelenmiştir. Elde edilen bulgular, öğrenci performansının her bir test için önceki döneme ait matematik dersi başarı notuna göre anlamlı olarak değiştiğini göstermiştir (F_{KBT} (2,439) = 14.46, $p <.017$, kısmi $\eta^2 = .062$; $F_{İBT}$ (2,439) = 22.1, $p <.017$, kısmi $\eta^2 = .091$; F_{SPT} (2,439) = 21.9, $p <.017$, kısmi $\eta^2 = .091$). Çoklu ve tekli varyans analiz sonuçları Tablo 3'te verilmiştir.

Tablo 3

Çoklu ve Tekli Varyans Analiz Sonuçları

	MANOVA	ANOVA		
		KBT	İBT	SPT
Cinsiyet	V= .01, F(3, 437)	F(1,439)=.87	F(1,439)=.63	F(1,439)=.009
ÖDMB	V= .10, F(6, 876)*	F(2,439)=14.46**	F(2,439)=22.10**	F(2,439)=21.90**

Not. ÖDMB:Önceki döneme ait matematik dersi başarı notu.

F değerleri Pillai's Trace test sonuçlarıdır.

*p<.05, **p<.017 (Bonferroni uyarlaması)

Ayrıca, Post hoc Scheffe's test sonuçlarına göre, öğrencilerin testlerdeki performansları önceki döneme ait matematik dersi başarı notu düzeylerine göre anlamlı olarak farklılık göstermektedir. Tablo 4'te de görüldüğü gibi, hem düşük ve yüksek başarılı, hem de orta ve yüksek başarılı öğrencilerin testlerdeki performansları arasında anlamlı bir fark gözlemlenmiştir.

Tablo 4

Post hoc Scheffe's Test Sonuçları

	Altıncı Sınıf Öğrencileri						
	Düşük (1)		Orta (2)		Yüksek (3)		
	M	*SD*	*M*	*SD*	*M*	*SD*	*Post hoc*
KBT	11.9	5.1	15.4	7.6	20.5	9.2	3>1, 3>2
İBT	4.5	3.5	5.2	3.9	9	4.6	3>1, 3>2
SPT	2.9	2.9	4.8	4	8.3	4.8	3>1, 3>2

Altıncı Sınıf Öğrencilerinin Kavramsal Bilgi Testi, İşlemsel Bilgi Testi ve Sözel Problem Testlerindeki Uzunluk, Alan ve Hacim Ölçme Konularındaki Ortak Hataları

Çalışmaya katılan öğrencilerin testlerdeki sorulara verdikleri yazılı cevaplar incelendiğinde, yapılan hataların oldukça geniş bir boyuta yayıldığı görülmüştür. Diğer bir değişle, öğrencilerin bu ölçme alanlarına ait kavram ve becerileri tam olarak içselleştiremediklerinin göstergesi olan kırık cetvelin uzunluğunu bulurken, cetvel üzerindeki sayılar arasındaki boşlukları saymak yerine sadece sayma, bir cismin dışını kaplayan kağıt miktarının o cismin hacmine eşit olduğu yargısı gibi birçok hata ile karşılmıştır.

Uzunluk ölçmede alanında belirlenen öğrenci hataları şöyle özetlenebilir: cetvel ile yapılan ölçümlerde 1 sayısından başlamak, metre birimi kullanılarak verilen bir nesnenin santimetre birimli bir cetvel ile ölçülemeyeceği kanısı, parçalara ayırılıp, aynı parçalar kullanılarak yeniden oluşturulan bir şeklin çevresinin değişmeyeceği yargısı, noktalı kağıda çizilmiş bir şeklin çevresini bulmak için birim kareleri sayma, çevre yerine alan formülü kullanma, dikdörtgen şeklindeki bir şeklin çevre formülünü (a+b) şeklinde kullanma, tüm cetvellerin uzunluğunun 30 cm olduğu kanısı, alan ölçü birimlerini kullanma. Diğer bir yandan, alan ölçme sorularına verilen yazılı cevaplardan ortaya çıkan bazı hatalar şöyledir: alan formülü yerine çevre formülü kullanma, bir şeklin alanının parçalara ayrılıp tekrar birleştirilmesi sonucunda alanın değiştiği kanısı, uzunluk ya da hacim ölçü birimlerini alan için kullanma, bir şeklin birden fazla yüzey alanına sahip olduğu yargısı, yüzey alanı için hacim formülü kullanma, yüzey alanının hacme bağlı olarak değiştiği kanısı, yüzey alanı için (a + b + c) formülünü kullanma. Hacim ölçmede ortaya çıkan öğrenci hataları arasında birim küplerden oluşturulmuş bir şeklin hacmini bulmak için sadece görünen küpleri ya da küp yüzlerini sayma, bir cismin boyutları ile hacmi arasında doğrusal bir orantının olduğu kanısı, hacim için (a + b + c) formülünü kullanma yeralmaktadır.

Ölçüler Konusunun Öğretiminde Materyal Kullanımı

Öğrenci anketi yoluyla toplanan verilerin betimsel analizi sonucunda elde edilen bulgular, ölçüler konusunun öğretiminde sıklıkla kullanılan materyallerin cetvel (%98.2), birim küpler (%65.4), izometrik kağıt (%62.5), noktalı kağıt (%60.9) ve geometri şeritleri (54.9) olduğunu gösterirken, çok küplüler takımı (%28.5), çok kareliler takımı (%30.3), hacimler takımı (%37) ve örüntü bloklarının (%37.6) nadir olarak kullanılan materyaller olduğunu göstermiştir. Ayrıca, cetvel öğrencilerin; birim küpler ise öğretmenlerin ölçme derslerinde sıklıkla kullandığı materyallerdir. Bu sonuçlara ek olarak, öğrencilerin en nadir olarak kullandığı materyal çok küplüler takımı (%10.5), öğretmenlerin en az kullandığı materyal ise cetvel (%4) olarak bulunmuştur.

Yapılan bu çalışmanın diğer bir araştırma sorusu olan öğrencilerinin testlerdeki genel başarı düzeyleri ile ölçme konusunun öğretiminde kullanılan materyaller arasında anlamlı bir ilişki olup olmadığı iki serili korelasyon (Point-biserial correlation) kullanılarak test edilmiştir.

Analiz sonuçları, öğrencilerin KBT'ndeki performansıyla çok kareliler takımının (r_{pb} = .161, $p < .05$), tangramın (r_{pb} = .137, $p < .05$), çok küplüler takımının (r_{pb} = .119, $p < .05$), hacimler takımının (r_{pb} = .144, $p < .05$), ve geometri şeritlerinin (r_{pb} = .119, $p < .05$) kullanımı arasında düşük fakat anlamlı bir ilişki olduğunu göstermiştir. SPT'ndeki öğrenci başarısı ile anlamlı ilişkisi olan tek materyal cetvel olarak bulunmuştur. Fakat, ankette verilen 10 değişik materyalden hiçbirinin kullanımı ve öğrencilerin İBT'ndeki performansı arasında anlamlı bir ilişki bulunamamıştır.

TARTIŞMA

Bu çalışmayla 6. sınıf öğrencilerinin uzunluk, alan ve hacim ölçme konularındaki kavramsal ve işlemsel bilgiler ve sözel problemleri çözme becerileri farklı değişkenler açısından sınanmıştır.

Elde edilen bulgular ışığında, öğrencilerin testlerden aldıkları puanlar oldukça düşüktür. 50 puan üzerinden değerlendirilen KBT'nde, öğrencilerin aritmetik ortalaması 19.5, 20 puan üzerinden değerlendirilen İBT'nin aritmetik ortalaması 8.3 ve 20 puan üzerinden değerlendirilen SPT'nin aritmetik ortalaması 7.7 olarak bulunmuştur. Bu sonuçtan hareketle, çalışmaya katılan 6. sınıf öğrencilerinin ölçmenin ne anlama geldiğini ve nasıl ölçme yapılacağı hakkında sahip olduğu bilgilerin oldukça yetersiz olduğu görülmüştür. Sahip olunan bu yüzeysel bilgilerden dolayı da ölçmeyle ilgili sözel problemlerin çözümünde zorluklar yaşadıkları tespit edilmiştir. Alan yazında yer alan bir çok araştırma (Baroody, et al., 2007; Hiebert & Lefevre, 1986; Gelman & Meck, 1986; Rittle-Johnson, et al., 2001; Silver, 1986) matematiksel yetkinliğin temelinde kavramsal ve işlemsel bilginin olduğu ve bu bilgiler arasındaki ilişkinin kurulmasıyla neyin, nasıl yapılacağının nedenleriyle öğrenmesini sağlar ve böylece, anlamlı ilişkilerle birbirine bağlanan işlemsel ve kavramsal bilginin farklı problem çözme durumlarında etkin bir şekilde kullanabileceği vurgulanmıştır.

Çalışmadan elde edilen diğer bir sonuç ise, en yüksek performansın uzunluk ölçme alanında, en düşük performansın ise hacim ölçme alanında olmasıdır. Bu sonuç İlköğretim Matematik Programının yapısından kaynaklanabilir. Programda, uzunluk ölçme 1. sınıftan, alan ölçme 3. sınıftan ve hacim ölçme 5. sınıftan itibaren öğretilmeye başlanmaktadır. Doğal olarak, uzunluk ölçmeye ait kavram ve beceriler, alan ve hacim ölçmeye göre daha geniş bir zaman diliminde öğrencilere sunulmaktadır (Tan-Sisman & Aksu, 2009). Fakat, testlerin toplam puanları ve öğrenci başarısına ait aritmetik ortalamalar karşılaştırıldığında, öğrencilerin performanslarının çok düşük olduğu açıkça görülmektedir. Bu bağlamda, altıncı sınıfa kadar olan uzunluk, alan ve hacim ölçme öğretiminin öğrencilerin bu konu alanlarına ait kavram ve becerileri kazanmasında yetersiz olduğu söylenebilir.

Araştırmanın sonuçlarından ortaya çıkan diğer önemli bir nokta ise, öğrencilerin her üç testte gösterdiği performanslar arasında anlamlı ve pozitif bir ilişkinin saptanmadır. Diğer bir değişle, öğrencinin KBT'nde aldığu puan artıkça İBT ve SPT'lerinden aldıkları puanlarda artmaktadır. Ayrıca, öğrencilerin hem her testten aldığı her bir ölçme alanına ait puanlar arasında (örneğin, öğrencinin KBT, İBT ve SPT'nden aldığı alan ölçme puanlarından biri arttıkça diğerleri de artmaktadır) hem de bir testten aldığı her ölçme alanına ait puanlar arasında (örneğin, öğrencinin İBT'nden aldığı uzunluk, alan ve hacim ölçme puanlarından biri arttıkça diğerleri de artmaktadır) güçlü ve pozitif bir ilişki vardır. Elde edilen bu sonuçlar, alan yazında rapor edilen bir çok çalışmanın bulgularıyla paralellik göstermektedir (Battista, 2003; Curry, Mitchelmore, & Outhred, 2006; Hiebert & Carpenter, 1992; Kilpatrick, et al., 2001; Lehrer, 2003; Nührenbörger; 2001; Outhred & Mitchelmore, 2000; Star, 2000; Stephan & Clements, 2003;).

Matematik başarısında cinsiyet faktörü uzun yıllardan beri araştırmalara dahil edilmiş değişkenler arasında yer almaktadır. Alan yazında, son 10 yılda rapor edilen sonuçlar erkek ve kızlar arasındaki cinsiyete bağlı farkın giderek kapandığını destekler niteliktedir. Özellikle ilköğretim sürecinde cinsiyet faktörünün matematik başarısına olan etkisinin açık ve net olmadığı, ortaöğretim ya da üniversite eğitimi sürecinde bu farkın daha belirginleştiği bir çok matematik eğitimcisi tarafından rapor edilmiştir (Leder, 1985; Peterson & Fennema, 1985; as cited in Alkhateeb, 2001). Türkiye'de yapılan çalışmaların hemen hemen hepsi, matematik başarısında cinsiyetin etkili bir faktör olmadığı yönündedir (Aksu, 1997; Bulut, Gur, & Sriraman, 2010). Bu çalışmada ise, çoklu varyans analizi sonuçlarında, öğrencilerin testlerdeki performanslarının cinsiyet değişkeninden etkilenmediği, yani erkek ve kız öğrencilerin testlerden aldıkları puanlar arasında anlamlı bir farkın olmadığı görülmüştür. Bu bağlamda, cinsiyete dair bulunan sonuçların diğer çalışmaların bulgularıyla paralellik taşıdığı söylenebilir. Çoklu varyans analizi sonuçlarında ortaya çıkan diğer bir bulgu, öğrencilerin önceki döneme ait matematik dersi başarı notunun, onların KBT, İBT ve SPT'lerinde gösterdikleri performansları anlamlı ölçüde farklılaştırdığını göstermiştir. Bu sonuç, matematiğin sarmal ve kümülatif yapısının bir kanıtı olarak yorumlanabilir. Elde edilen bu anlamlı fark aynı zamanda uzunluk, alan ve hacim ölçme konularının sadece birbiriyle değil, diğer konularla olan sıkı ilişkisinin de bir göstergesi olarak algınalabilir. İlgili literatür incelendiğinde, hem Türkiye'de hem de yurt dışında yapılan çalışmalarda da öğrencilerin geçmişte öğrendikleri bilgi ve becerilerinin yeni öğrenecekleri konulara temel oluşturduğunu destekleyen sonuçlar bulunmuştur (Aksu, 1997; Bragg & Outhred, 2000; Battista, 2003; Kabiri & Kiamanesh, 2004; Pajares & Kranzler 1995; Pajares & Miller, 1994).

Öğrencilerin KBT, İBT ve SPT'lerindeki sorulara verdikleri yazılı açıklamalar incelendiğinde, uzunluk, alan ve hacim konularında oldukça kısıtlı ve yüzeysel bilgi ve becerilere sahip oldukları görülmüştür. Uzunluk ölçüleri alanında tespit edilen öğrenci hataları (a) cetvel ile ölçüm yaparken 0 yerine 1 sayısından başlama; (b) cetvel üzerindeki sayıları ya da çentikleri sayıp, buldukları sayıyı ölçülen nesnenin uzunluğu olarak rapor etme; (c) kırık cetvelin uzunluğunu, cetvelin en sonundaki sayı olarak raporlama; (d) tüm cetvellerin 30 cm uzunluğunda olduğu yargısı; (e) uzunluk ölçü birimleri ile diğer birimleri birlik kullanma; ve (f) uzunluk ölçü birimlerinden olan santimetreyi farklı bir ölçü birimi olarak zannetme şeklinde sıralanabilir. Alan yazında ilk ve ortaöğretim öğrencileriyle yapılan çalışmalarda da benzer bulgulara rastlanmıştır (Barrett et al., 2006; Boulton-Lewis et al., 1996; Bryant and Nunes 1994 (as cited in Nunes & Bryant, 1996); Ellis, Siegler, and Van Voorhis, 2001 (as cited in Lehrer, 2003); Heraud, 1989; Kamii, 1995; Schrage, 2000; Thompson & Van de Walle, 1985 (as cited in Schrage, 2000). Saptanan bu hatalar 6. sınıf öğrencilerinin temel kavram becerileri tam olarak içselleştiremediklerini açıkça göstermektedir. Öğrencilerin uzunluk ölçme sorularında yaptıkları hataların ardında yatan temel nedenler sıfır-nokta (zero-point) özelliğinin kavranamaması, birim öteleme kavramının anlaşılamaması, cetvelin yapısının (örn:üzerindeki sayı ve çentiklerin ne ifade ettiği) kavranamaması ve ölçme ile sayılar arasındaki ilişkinin kurulamaması olarak gösterilebilir.

Çevre ile ilgili bulunan öğrenci hataları (a) aynı parçalar kullanılarak oluşturulan yeni şeklin çevre uzunluğunun değişmeyeceği yargısı; (b) bir şeklin çevre uzunluğu bilinmeden, alanının hesaplanamayacağı yargısı; (c) çevre uzunluğu ile alanın doğru orantılı olduğu yargısı; (d) çevre uzunluğunu bulurken birim kareleri sayma; (e) çevre uzunluğu için alan ya da hacim ölçü birimlerini kullanma; (f) çevre hesaplamada alan formülü kullanma ve (g) dikdörtgenin çevre uzunluğunu bulurken (a + b) formülünü kullanma olarak özetlenebilir. Literatürde farklı öğrenci gruplarıyla yapılan çalışmalarda da bu araştırmada bulunan hatalardan söz edilmektedir. (Emekli, 2001; Kordaki & Portani, 1998; Moyer, 2001; Stone, 1994; Tan-Sisman & Aksu, 2009a; Woodward & Bryd, 1983).

Bunlara ek olarak, öğrencilerin KBT, İBT ve SPT'lerinde alan ölçme ile yaptıkları hatalar (a) aynı parçalar kullanılarak oluşturulan yeni şeklin alanı değişir yargısı; (b) noktalı kağıda çizilmiş bir şeklin alanını bulmak için etrafını çevreleyen çizgileri sayma; (c) noktalı kağıda çizilmiş bir şeklin alanını bulmak için şeklin içindeki noktaları sayma; (d) alan ve çevre kavramını birbiriyle karıştırma; (e) alan hesaplamada çevre formülünü kullanma; (f) alan hesaplarken (a + b) formülünü kullanma; (g) alan hesaplarken (çevre + uzunluk) formülünü kullanma; (h) uzunluk/hacim ölçü birimlerini kullanma; (i) yüzey alanının hacimle doğru orantılı olduğuna inanma; (j) yüzey alanı hesaplamada hacim formülü kullanma; (k) yüzey alanı için (a + b + c) formülü kullanma; (l) yüzey alanı kavramıyla hacim kavramını birbirine karıştırma; ve (m) bir şeklin birden fazla yüzey alanına sahip olduğu yargısına sahip olma olarak tespit edilmiştir. Bahsedilen bu bulgular, literatürdeki çalışmaların sonuçlarıyla paralellik göstermektedir (Chappell & Thompson, 1999; Emekli, 2001; Furinghetti & Paola, 1999; Hirstein, Lamb, & Osborne, 1978; Woodward & Byrd, 1983; Moreira & Contente, 1997; Kidman & Cooper, 1997;

Moyer, 2001). Bu hatalar, öğrencilerin alan ölçmeye ait kavram ve becerilerden yoksun olduğunu açıkça ortaya koymuştur. Daha açık olarak ifade edilirse, altıncı sınıf öğrencilerinin uzamsal yapı, çarpmayla ilgili (multiplicative) yapı, alan korunumu ve uzunluk ölçme konularındaki eksik ve yüzeysel kavrama düzeyleri saptanan hataların ardında yatan en temel nedenlerdendir.

Hacim ölçmeye ilişkin bulunan öğrenci hataları ise (a) hacmi belirlerken birim kareleri sayma; (b) birim küplerden oluşan bir prizmanın hacmini bulurken birim küplerin yüzlerini ya da sadece görünen birim küpleri sayma; (c) birim küpleri çift sayma; (d) bir cismin boyutları ve hacmi arasında doğrusal bir orantı olduğu yargısı; (e) birim küplerden oluşan bir prizmanın hacmini bulurken görünen birim küpleri sayıp 3 ile çarpma (3 boyutlu olduğu için); (f) hacim hesaplamada (a + b + c) , (a x b) ya da (a x b + c) formülünü kullanma; (g) volume equals to length x width; and (h) volume to length x width + height; (h) uzunluk/alan ölçü birimlerini kullanmadır. Campbell, Watson, ve Collis (1992), Battista ve Clements (1996), Olkun (2003) ve Saiz'in (2003) yaptığı çalışmalarda da öğrencilerin bu çalışmada bulunan hatalara benzer hatalar yaptıkları belirtilmiştir. Diğer ölçme alanlarında bulunan hatalarda da belirtildiği gibi, hacim ölçme alanındaki hataların temelinde de yetersiz ve yüzeysel olarak öğrenilen temel bilgi ve beceriler yer almaktadır. Daha ayrıntılı olarak ele alındığında, öğrencilerin hacim ölçme sorularında yaptıkların hataların uzamsal görselleştirme, dizilerin/katların üç boyutlu olarak anlamlı sıralanması ve uzunluk ve alan ölçme konularında yetersizlikler nedeniyle oluştuğu söylenebilir.

Bu çalışmada yer verilen temel konulardan birisi de ölçme dersinde materyal kullanımıdır. Alan yazında yapılan çalışmalar genellikle matematik derslerinde materyal kullanımını destekleyen ve öğrenci başarısıyla pozitif bir ilişki olduğunu ortaya koymuştur. Fakat, betimsel analiz sonuçları, ölçme derslerinde materyal kullanımının oldukça düşük olduğu göstermiştir. Nadir materyal kullanımının sebepleri arasında okulun materyal açısından yetersiz olması ya da matematik öğretmeninin öğretim ile ilgili kişisel tercihleri olarak gösterilebilir. Diğer bir yandan, materyal kullanımı ve öğrencilerin testlerdeki başarısı arasındaki ilişki incelendiğinde, ya çok düşük düzeyde ya da anlamlı olmayan bir ilişki bulunmuştur. Bu bulgunun nedeni ise betimsel analizde elde edilen düşük seviyede materyal kullanımı olabilir.

Sonuç olarak, çalışmaya katılan 6. sınıf öğrencilerinin uzunluk, alan ve hacim ölçme konularını hem anlamada hem de işlemlerde etkin biçimde kullanmada ciddi güçlükler yaşadıkları görülmektedir. Uzunluk ölçmenin ilköğretim 1.sınıftan, alan ölçmenin 3. sınıftan ve hacim ölçmenin 5. sınıftan itibaren öğretimine başlanıldığı göz önüne alındığında, 6.sınıf öğrencilerinin bu konulara ait temel kavram ve becerileri henüz tam olarak kavrayamamış olmaları dikkat çekicidir.

ÖNERİLER

Bu araştırmada elde edilen sonuçların ışığında hem uygulamaya hem de ileride bu alanda yapılacak araştırmalara yönelik önerilerden bazıları aşağıda verilmiştir:

Uygulamayla İlgili Öneriler

- İlköğretim Matematik Programında, uzunluk, alan ve hacim ölçme konularının temelini oluşturan kavram ve becerilere daha açık ve net bir şekilde yer verilmelidir.
- Öncelikle ölçme konusuna ait temel kavramların kazanılmasına ağırlık veren, kavramsal bilgilerden hareketle işlemsel bilgilerin kazandırılması ve bu bilgilerin her ikisininde kullanımını gerektirecek sözel problem çözme durumları ile desteklenen öğrenme ortamları oluşturulması anlamlı öğrenme açısından daha yararlı olacaktır.
- Ölçme konularının öğretiminde hem sayısal formatta hem de sözel problem formatında hazırlanmış birbirine paralel soru örneklerine yer verilmelidir.
- Öğrencilerin akıl yürütebilecekleri, kavramların anlamlarını ve işlemlerle olan ilişkisini sorgulayabilecekleri (Örneğin; Hacimleri eşit olan iki şeklin, yüzey

alanları da eşit midir?), kesme, katlama, yeniden düzenlemeyi içeren etkinlik temelli bir öğretim ortamı tespit edilen hataların giderilmesinde yararlı olabilir.

- Hem ölçme konusunda önceden öğrenilen bilgi ve becerilerin (örn. uzunluk ölçme konusu alan ve hacim ölçme konularının öğretimindeki önemi) hem de ölçme konusunun öğretimine yardımcı olacak diğer konulara (örn. dört işlem) ait bilgi ve becerilerin ileri de öğretilecek konulara olan etkisi her zaman göz önünde bulundurulmalıdır.
- Çalışmada belirlenen hataların İlköğretim Matematik Programının uzunluk, alan ve hacim ölçme konularıyla ilgili açıklamalar kısmına dahil edilmesi, öğrenci hatalarının öğretmen tarafından önceden bilinip, bunların ortaya çıkmaması ya da giderilmesi yönünde etkili bir öğretimin tasarlanması açısından oldukça önem taşımaktadır.

İleride Yapılacak Araştırmalarla İlgili Öneriler

- Toplam 445 altıncı sınıf öğrencisiyle yapılan bu araştırma, daha geniş bir örneklem kullanılarak ve farklı sınıf düzeylerinde tekrarlanmalıdır.
- Ölçme alanlarının sınıf ortamında nasıl öğretildiği, öğrencilere nasıl bir öğrenme ortamı sunulduğu gibi konularda detaylı bilgi edinebilmek için nitel çalışmalara ihtiyaç duyulmaktadır.
- Bu çalışmada belirlenen hataların giderilmesi için tasarlanacak öğretimin etkililiğinin sınandığı araştırmalar planlanmalıdır.
- Öğretmen adaylarının uzunluk, alan ve hacim ölçme konularıyla ilgili kavram ve becerilere ne düzeyde hakim olduklarını ortaya çıkarmayı amaçlayan araştırmalar yapılmalıdır.
- Öğrencilerin yaptıkları hataların nedenlerini ortaya çıkarmayı amaçlayan nitel araştırmalara ihtiyaç duyulmaktadır.
- Ölçme konusunun öğretiminde materyal kullanımının etkisini inceleyen araştırmalar planlanmalıdır.

APPENDIX H

CURRICULUM VITAE

PERSONAL INFORMATION

Surname, Name: Tan-Şişman, Gülçin
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EDUCATION

Degree	**Institution**	**Year of Graduation**
PhD on MS	Middle East Technical University, Educational Sciences	2010
BS	Gazi Üniversity, Elementary School Education	2002
High School	Anıttepe High School, Ankara	1997

WORK EXPERIENCE

Year	**Place**	**Enrollment**
2002- 2010	Middle East Technical University, Educational Sciences	Research Assistant
2006-2007	Michigan State University, College of Education, U.S.A	Visiting Scholar

FOREIGN LANGUAGE
Advanced English

SELECTED PUBLICATIONS

Erdoğan, M., Kurşun, E., Tan-Şişman, G., Saltan, F., Gök, A. & Yıldız, İ. (2010). A qualitative study on classroom management and classroom discipline problems, reasons, and solutions: A case of information technologies class. *Educational Sciences: Theory & Practice*, *10*(2), 857-891.

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