INVESTIGATING THE RELATION BETWEEN MATHEMATICS VOCABULARY KNOWLEDGE AND MATHEMATICS ACHIEVEMENT AMONG EIGHT GRADE STUDENTS

by

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ABSTRACT

INVESTIGATING THE RELATION BETWEEN MATHEMATICS VOCABULARY KNOWLEDGE AND MATHEMATICS ACHIEVEMENT AMONG EIGHT GRADE STUDENTS

This study examines the relationship between mathematics vocabulary knowledge and achievement among 8th-grade students, with a particular focus on whether specific types of vocabulary (measurement, data, geometry, number, operation, algebra) have differential impacts on overall performance. Although not initially focused on low-achieving students, the analysis revealed the group was largely low-achieving, offering unique insights. Conducted in a state school in Istanbul, Turkey, during the 2023-2024 academic year, 108 students were assessed on cognitive and academic factors, including mathematics achievement, vocabulary knowledge, processing speed, working memory, reading comprehension, and non-verbal reasoning. Assessments included the Woodcock-Johnson III Achievement and Cognitive Subtests (Woodcock *et al.*, 2001) and the Wisconsin Card Sorting Test. Mathematics vocabulary was measured using a test developed by Ünal *et al.* (2021), and achievement was gauged using the High School Entrance Exam (LGS 2024) results. In the multiple linear regression analysis, where reading comprehension, processing speed, working memory, and non-verbal reasoning were treated as control variables, mathematics vocabulary significantly predicted mathematics achievement, accounting for 62% of the variance in the outcome ($R^2 = 0.62$). Notably, the addition of mathematics vocabulary to the model resulted in a 6% increase in the explained variance ($\Delta R^2 = 0.06$). Further analysis revealed that among the various types of mathematics vocabulary, only the vocabulary related to numbers, operations, and algebra was a significant predictor of mathematics achievement.

ÖZET

SEKİZİNCİ SINIF ÖĞRENCİLERİNİN MATEMATİK KELİME BİLGİSİ İLE MATEMATİK BAŞARISI ARASINDAKİ İLİŞKİNİN İNCELENMESİ

Bu çalışma, 8. sınıf öğrencileri arasında matematik kelime bilgisi ile matematik başarısı arasındaki ilişkiyi incelemekte ve belirli kelime bilgisi türlerinin (ölçme, veri, geometri, sayı, işlem, cebir) genel performans üzerindeki farklı etkileri olup olmadığını araştırmaktadır. Çalışma başlangıçta düşük başarı gösteren öğrencilere odaklanacak şekilde tasarlanmamış olmasına rağmen, analiz sonucunda katılımcı grubun büyük ölçüde bu demografik özellikte olduğu ortaya çıkmış ve bu durum benzersiz içgörüler sağlamıştır. 2023-2024 eğitim-öğretim yılında İstanbul, Türkiye'de bir devlet okulunda gerçekleştirilen bu çalışmada, 108 öğrenciye matematik başarısı, kelime bilgisi, işlem hızı, çalışma belleği, okuduğunu anlama ve sözel olmayan akıl yürütme gibi çeşitli bilişsel ve akademik değerlendirmeler yapılmıştır. Woodcock-Johnson III Başarı ve Bilişsel Alt Testler (Woodcock ve diğerleri, 2001) ve Wisconsin Kart Sıralama Testi kullanılmıştır. Matematik kelime bilgisi, Ünal ve arkadaşları (2021) tarafından geliştirilen bir test kullanılarak ölçülmüş ve başarı 2024 Lise Giriş Sınavı (LGS 2024) sonuçlarıyla değerlendirilmiştir. Okuduğunu anlama, işlem hızı, çalışma belleği ve sözel olmayan akıl yürütmenin kontrol değişkenleri olarak kullanıldığı çoklu doğrusal regresyon analizinde, matematik kelime bilgisinin matematik başarısını istatistiksel olarak önemli ölçüde yordadığı ve sonuçtaki varyansın %62'sini açıkladığı bulunmuştur ($R^2 = 0.62$). Özellikle, matematik kelime bilgisinin modele eklenmesi, açıklanan varyansta %6'lık bir artışa yol açmıştır ($\Delta R^2 = 0.06$). İlerleyen analizler, matematik kelime bilgisi türleri arasında sadece sayı, işlem ve cebirle ilgili grubun matematik başarısının önemli bir yordayıcısı olduğunu ortaya koymuştur.

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LIST OF ACRONYMS/ABBREVIATIONS

GV	General Vocabulary
LGS	High School Entrance Exam
MoNE	Ministry of National Education
MVT	Mathematics Vocabulary Test
NVR	Non-verbal Reasoning
PS	Processing Speed
WCST	Wisconsin Card Sorting Test
WJ-III	Woodcock-Johnson III Achievement and Cognitive Tests
WM	Working Memory

1. INTRODUCTION

Mathematics learning has an enormous impact on one's lifelong achievement, as many high-paying and demanding careers require a strong foundation in mathematics (National Council of Teachers of Mathematics, 2000). Duncan *et al.* (2007) conducted a study examining six longitudinal data sets in which they concluded that early math skills were powerful predictors of later learning, controlling cognitive ability. Numerous studies have shown how crucial early math skills are in shaping long-term educational attainment, employment prospects, and overall socio-economic well-being (Claessens and Engel, 2013). In pursuing their goals, each person strives for a specific level of academic achievement upon completing their education. In this context, the mastery of mathematics is imperative to this academic accomplishment. Hence, examining the factors contributing to fundamental mathematics skills is essential. When solving mathematics problems, there is a complicated process that depends on both cognitive abilities (like processing speed and working memory) as well as domain-specific skills (including number sense and arithmetic competencies) (Peng and Lin, 2019). Understanding the interaction between these cognitive abilities and domain-specific skills can provide valuable insights into how to support the development of mathematical proficiency in students. By identifying and targeting areas of weakness in either cognitive abilities or domain-specific skills, educators can tailor their instruction to meet individual students' needs better. Taking a comprehensive approach to understanding the factors contributing to mathematical proficiency can help teachers in assisting students to build a strong foundation in mathematics. This foundation will serve them well in their academic and professional careers. Ultimately, a deeper understanding of these factors can lead to more effective teaching strategies and improved student outcomes in mathematics.

The existing body of research in this field has primarily centered on early number development and its impact on elementary school students, with a substantial focus on their mathematics achievement. Mathematics vocabulary skills have been a specific

area of focus in recent years (Forsyth and Powell, 2017; Peng and Lin, 2019; Ünal *et al.*, 2021). Mathematics vocabulary refers to understanding of specific mathematical terms such as "fraction" and "subtract", as well as phrases like "area of a triangle", and the use of symbols (e.g., $<$, $>$, $-$) to represent mathematical expressions (Monroe and Orme, 2002). Studies have shown that mathematics vocabulary knowledge can predict students' mathematics achievement (Forsyth and Powell, 2017; Powell *et al.*, 2017; Ünal *et al.*, 2021). Although the majority of research on this subject has concentrated on early number development and the elementary school level (Geary and Moore, 2016; Powell, Driver, Roberts, and Fall, 2017; Lin *et al.*, 2021), studies conducted at the middle school level have also demonstrated a positive correlation between the two variables (Ünal *et al.*, 2021). Research findings consistently indicate a positive correlation between mathematics vocabulary and mathematics achievement in elementary and middle school students. These results imply that a robust mathematics vocabulary could significantly impact students' overall mathematical proficiency. Nonetheless, there is a noticeable gap in research specifically targeting middle school students, especially in diverse educational settings.

In Turkey, high-stakes exams such as the high school entrance exam have been pivotal in determining students' academic futures for nearly 30 years, with their forms evolving over time (Caner and Bayhan, 2020). Despite changes in the types of exams and curriculum, performance on these exams has consistently shaped educational trajectories, making the development of strong mathematical skills especially critical. This is particularly important for low-achieving students, who may struggle more with mathematics and are at greater risk of underperforming in these assessments. The introduction of the High School Entrance Exam (LGS) in the 2017-2018 academic year marked the latest iteration of these exams, becoming the primary determinant for high school placement. The LGS, like its predecessors, plays a crucial role in determining educational outcomes in Turkey, building on a decades-long tradition of high-stakes exams that shape students' academic futures (Poyraz and Ergün, 2023). As with previous changes, this shift brought corresponding adjustments in instructional practices and curricular focus, with educators increasingly focusing on strategies that align with

the higher cognitive demands of the LGS exam (Bozkurt *et al.*, 2023). The prominence of the LGS in the current educational landscape underscores its significance, highlighting the pressing need for research that specifically addresses the challenges and needs of low-achieving students in relation to mathematics vocabulary and achievement—a gap that remains inadequately explored.

To address these gaps, the current study focuses on eighth-grade Turkish students, with an emphasis on understanding the relationship between different types of mathematics vocabulary (measurement, geometry, and numerical operations) and mathematics achievement. This study also controls for variables such as general vocabulary, reading comprehension, and essential cognitive skills to provide a more nuanced understanding of the factors influencing mathematics achievement at this crucial educational stage. By focusing on these factors, this research aims to identify strategies that can support all students, particularly those who are low-achieving, in developing the mathematical skills necessary for success in both their academic careers and in high-stakes exam environments like the high school entrance exam.

1.1. The Significance of the Study

This study investigates the differential relationship between mathematics vocabulary and mathematics achievement among eighth-grade students while also examining the impact of general vocabulary, reading comprehension, and cognitive skills.

Understanding the factors that influence mathematical achievement is particularly crucial in the context of Turkey's educational system, where high-stakes exams like the LGS play a pivotal role in determining students' academic futures. Since its introduction in the 2017-2018 academic year, the LGS has become the primary determinant for high school placement, making strong mathematical skills essential for student success. This underscores the importance of examining the specific components of mathematical proficiency, such as mathematics vocabulary, which may have a significant impact on students' performance in these critical exams.

Although recent studies have explored the relationship between mathematics vocabulary and achievement (Forsyth and Powell, 2017; Peng *et al.*, 2016; Peng and Lin, 2019; Peng *et al.*, 2020; Powell *et al.*, 2017; Ünal *et al.*, 2021), there remains a noticeable gap in research focused on older students, such as eighth graders. For instance, Ünal *et al.* (2020) compared eighth-grade students in the US and Turkey concerning mathematics vocabulary knowledge and achievement but did not account for specific types of mathematics vocabulary or cognitive abilities, instead using only general vocabulary as a control factor.

In contrast, Peng and Lin (2019) studied fourth-grade Chinese students, considering the effects of different types of mathematics vocabulary and cognitive skills on mathematics achievement. Their findings suggested that various types of vocabulary are linked to different forms of mathematical achievement, highlighting the need for a more nuanced understanding of this relationship.

Building on these insights, the current study focuses on eighth-grade students in Turkey, examining how different types of mathematics vocabulary relate to their mathematics skills. By controlling for general vocabulary, reading comprehension, and cognitive abilities such as processing speed, working memory, and non-verbal reasoning, this study aims to provide a comprehensive understanding of how mathematics vocabulary influences student performance at this critical educational stage. Given the high stakes associated with the LGS exam, the findings of this research could have significant implications for educational practices and policies aimed at enhancing students' readiness for this pivotal assessment.

1.2. The Purpose of the Study

The study aims to investigate the differential relationship between types of mathematics vocabulary knowledge and mathematics achievement controlling general language skills (general vocabulary and reading comprehension) and cognitive skills (processing speed, working memory, and non-verbal reasoning) by examining eight-grade

students. Scholars reported that mathematics vocabulary knowledge is related to mathematics achievement controlling for general vocabulary (Pen and Lin, 2019; Ünal *et al.*, 2021). Also, Pen and Lin (2019) reported that different kinds of mathematics outcomes varied according to the different types of mathematics vocabulary knowledge of fourth-grade students. They concluded that mathematical vocabulary might not be a unified construct and that different types of mathematical terms could impact specific mathematical abilities, such as problem-solving, but not computational skills. Therefore, evaluating different subtypes of mathematics vocabulary may differentiate the relation between mathematics vocabulary and overall mathematics achievement. Even though Ünal *et al.* (2021) conducted a study on Turkish participants, the literature seems to lack explanations for types of mathematical vocabulary and their effect on achievement. Thus, the purpose of this study is to investigate the relationship between eighth-grade students' mathematics vocabulary knowledge and their types and mathematics achievement. This investigation controls for the aforementioned language skills and cognitive abilities.

1.3. The Research Questions

The current study is designed to investigate two key research questions.

(i) To what extent does mathematics vocabulary knowledge predict mathematics achievement when controlling for language skills (general vocabulary and reading comprehension) and essential cognitive skills (processing speed, working memory, and non-verbal reasoning)?

(ii) Is there a differential relationship between types of mathematics vocabulary knowledge – specifically, the vocabulary associated with measurement and data, geometry, and numerical operations and algebra – and mathematics achievement when controlling for language skills (general vocabulary and reading comprehension) and essential cognitive skills (processing speed, working memory, and non-verbal reasoning)?

2. LITERATURE REVIEW

The study of mathematics and its various elements has been a significant focus in academic research. There is a strong emphasis on early mastery of mathematics as it plays a crucial role in shaping future job opportunities (Shapka *et al.*, 2006). Therefore, it is essential to understand the various factors that influence mathematics achievement to develop effective teaching methods. This study specifically delves into the domain-specific knowledge of mathematics learning. Numerous studies have investigated the relationship between mathematics vocabulary knowledge, cognitive components, and actual mathematics achievement. This literature review will explore four primary areas that contribute to mathematics achievement: general vocabulary and reading comprehension, general cognitive abilities (processing speed, working memory, and non-verbal reasoning), mathematics vocabulary, and the role of high-stakes exams like the LGS in shaping mathematics education in Turkey. By examining these areas, this review aims to provide a comprehensive understanding of the factors that underpin mathematics achievement, particularly in the context of the Turkish educational system.

2.1. General Vocabulary and Reading Comprehension

Language is fundamental in the development of mathematics, as it is a means for students to acquire early numeracy skills and to develop formal mathematical knowledge (Negen and Sarnecka, 2012; Vukovic and Lesaux, 2013; Purpura and Reid, 2016). General vocabulary, which encompasses words used in everyday communication, strongly correlates with overall performance in mathematics (Powell *et al.*, 2017). Peng *et al.* (2020) found that having a strong general vocabulary, as part of language skills, activates mathematical knowledge, as well as working memory and reasoning abilities. Therefore, the effect of general vocabulary on mathematics achievement should be considered while examining the impact of mathematics vocabulary on achievement. Hence, general vocabulary is employed as one of the components of the analysis.

In addition to general vocabulary, reading comprehension plays a crucial role in mathematics achievement, particularly in problem-solving contexts (Grimm, 2008). Students who struggle with reading comprehension may find it challenging to interpret and solve word problems, a common component of mathematics assessments. Reading comprehension, making meaning from the text rather than isolated words and sentences, is associated with how a given passage is understood (Woolley, 2011). As the first step of problem-solving is understanding the given facts, students with low comprehension would have difficulty solving mathematics questions. Ünal *et al.* (2022) conducted a meta-analytic study on the correlation between reading and mathematics achievement, concluding that the relationship is primarily driven by domain-general cognitive processes. These processes refer to cognitive skills, such as working memory and executive function, that are not specific to any single domain but rather support a range of learning activities, including both reading and mathematics. Fuchs *et al.* (2015) also discovered that solving a word problem in mathematics requires working memory and language comprehension to work together as it would in text comprehension. Therefore, reading comprehension is a crucial component to be evaluated while examining the relation between mathematics vocabulary and mathematics achievement.

Understanding the role of general vocabulary and reading comprehension in mathematics achievement can be further enriched by considering Vygotsky's (1986) perspective on language development. According to Vygotsky, the development of cognitive systems and learning is deeply intertwined with language acquisition. This connection is particularly relevant when examining academic achievement, as language serves as a foundation for complex cognitive processes involved in mathematics. Therefore, assessing language ability-specifically vocabulary knowledge and reading comprehension-can provide valuable insights into the complex relationship between mathematics vocabulary and mathematics achievement.

2.2. General Abilities

Cognitive skills have been a significant focus for researchers examining learning and academic performance, particularly in mathematics. The development of new knowledge relies on the cognitive system's ability to process encountered information, with working memory playing a vital role in this process (Geary and Moore, 2015). Numerous scholars have demonstrated that cognitive skills predict mathematical competencies across various age groups (Raghubar *et al.*, 2010; Peng *et al.*, 2016; Ünal *et al.*, 2023). Moreover, specific cognitive abilities, such as processing speed, working memory, and non-verbal reasoning, have been identified as key predictors of mathematical achievement (Floyd *et al.*, 2003). This section will explore these cognitive abilities and their relationship with mathematical performance.

2.2.1. Processing Speed

Processing speed is a cognitive function that refers to the rate at which an individual can perform mental tasks, including perceiving stimuli, recognizing shapes, and distinguishing between letters or words (Case, 1985). Effective processing speed involves the coordination of attention, evaluation, and action, enabling individuals to efficiently process information and respond to tasks. In the context of education, particularly mathematics, processing speed has been consistently linked to mathematical achievement, with numerous studies highlighting its importance.

Research consistently demonstrates that processing speed (PS) is not only essential for executing basic arithmetic operations but also plays a critical role in more complex mathematical tasks. Bull and Johnston (1997) identified PS as a significant predictor of mathematical ability in 7-year-olds with arithmetic difficulties, even after accounting for reading skills. Their findings suggest that students with faster PS are better equipped to perform fundamental calculations, such as counting and recalling procedural steps from long-term memory, which are vital for mathematical success. Moreover, Geary (1993) further emphasized the role of PS in mathematical proficiency,

highlighting that a decline in this cognitive ability can severely impair a student's capacity to solve problems efficiently within standard timeframes. This decline can lead to compounding difficulties in mathematics, particularly for students who already struggle with arithmetic. These students might encounter increased frustration and diminished performance as their slower processing speed worsens their existing challenges, making it progressively harder for them to keep up with more advanced mathematical concepts.

The relationship between processing speed and mathematics achievement is further complicated by its interaction with other cognitive functions, particularly working memory. Berg (2007) explored this dynamic, finding that faster processing speed not only supports quick retrieval and storage of information but also enhances the effective use of working memory during mathematical tasks. This interplay suggests that students who can process information quickly are better able to manage and manipulate multiple pieces of numerical data in real-time, allowing them to solve more complex mathematical problems with greater ease.

Moreover, these findings align with the broader understanding that processing speed is integral to the development of mathematical skills across various educational levels. Studies indicate that processing speed supports the transition from basic arithmetic to more advanced mathematical reasoning by enabling students to keep pace with increasingly complex tasks. For instance, students with faster processing speed are better equipped to handle the cognitive load of multi-step problems, where maintaining and processing multiple pieces of information simultaneously is crucial.

Collectively, the research underscores the critical role of processing speed in mathematical success. Faster processing speed not only enhances the ability to perform fundamental calculations but also supports the cognitive processes required for advanced problem-solving. As such, when examining factors that contribute to mathematics achievement, it is essential to consider processing speed in conjunction with other cognitive abilities like working memory. This holistic approach allows for a more accurate assessment of the underlying factors that influence mathematical performance, par-

ticularly when investigating the impact of mathematics vocabulary on mathematics achievement.

2.2.2. Working Memory

Working memory (WM) is a critical cognitive system that temporarily stores and processes information necessary for complex tasks, including language comprehension, learning, and reasoning (Baddeley, 1992). It enables individuals to maintain and manipulate information over short periods while engaging in other cognitive activities, making it essential for a wide range of cognitive tasks (Hitch, 1978; Baddeley, 1992).

The relationship between working memory and mathematics abilities has been well-documented in the literature. Studies have shown that working memory plays a central role in arithmetic operations, such as addition, subtraction, and multiplication, by allowing individuals to retain and manipulate numbers during calculations (Healy and Nairne, 1985; Holmes and Adams, 2006). This is particularly important in tasks that require mental computation, where the ability to hold and process numerical information in working memory is crucial for accurate performance. Moreover, working memory is not only essential for basic arithmetic but also significantly contributes to problem-solving in mathematics. It facilitates the retention of relevant information and the integration of new data, which is necessary for solving word problems and other complex mathematical tasks (Lee *et al.*, 2004). This dual role of working memory in both basic operations and higher-order problem-solving highlights its importance in overall mathematical achievement.

Numerous studies have investigated the impact of working memory deficits on mathematical performance, particularly among students with learning difficulties. Passolunghi and Siegel (2004) highlighted that deficits in the central executive component of working memory, which is crucial for the active manipulation and processing of information, are strongly linked to mathematical difficulties. These deficits can impair a student's ability to manage and integrate multiple pieces of information, which

is essential for performing complex calculations and solving mathematical problems. Building on this, Swanson (2016) conducted a study with elementary students who were struggling in mathematics and found that those with higher working memory capacities consistently outperformed their peers with lower working memory capacities. This study reinforces the notion that working memory capacity is a critical limiting factor in mathematical achievement, affecting both specific skills, such as arithmetic, and broader cognitive abilities.

The implications of these findings are significant for understanding the challenges faced by students with poor working memory. Such students often struggle to process and retain mathematical concepts, leading to difficulties in problem-solving and comprehension. This underscores the importance of addressing WM deficits in educational interventions aimed at improving mathematical performance, particularly for students who struggle with mathematics.

Given the crucial role of working memory in mathematical achievement, it is essential to consider its interaction with other cognitive variables, such as processing speed, when examining factors that influence mathematics performance. In the context of the current study, which investigates the relationship between mathematics vocabulary knowledge and mathematical achievement, controlling for working memory will allow for a more precise assessment of how vocabulary knowledge specifically contributes to mathematics performance, independent of the cognitive demands imposed by cognitive abilities.

2.2.3. Non-Verbal Reasoning

Non-verbal reasoning refers to the cognitive ability to understand and analyze visual information, as well as to solve problems using visual thinking. Cognitive processing includes tasks such as identifying correlations, deriving overarching principles, formulating concepts, and inferring relationships, many of which do not rely on language or linguistic skills. Tasks that evaluate cognitive abilities in this type of thinking

often involve manipulating and altering visual patterns, preserving spatial orientation in relation to objects, and integrating several components to recognize a given configuration within a visual field. Non-verbal reasoning is closely associated with fluid intelligence (Gf), which pertains to the capacity to understand and solve novel problems without depending on preexisting knowledge (Horn and Cattell, 1966).

Research consistently highlights the strong connection between non-verbal reasoning abilities and mathematical performance across different age groups and educational levels (Fuchs *et al.*, 2006; Taub *et al.*, 2008; Reinhold *et al.*, 2020). Fuchs *et al.* (2006) explored the cognitive abilities of third graders and found that non-verbal problem-solving, which includes non-verbal reasoning, concept formation, and language, had a significant positive impact on students' ability to solve arithmetic problems. This study underscores the importance of visual-spatial reasoning in mathematical problem-solving, particularly in tasks that require the application of abstract concepts.

Expanding on this, Taub *et al.* (2008) investigated the relationship between intelligence, cognitive abilities, and academic performance in mathematics across a broader age range, from 5 to 19 years old. Their findings revealed that fluid reasoning, crystallized intelligence, and processing speed directly influence mathematical achievement, with general intelligence indirectly contributing to better performance across all age groups. This suggests that students who excel in non-verbal reasoning are better equipped to tackle complex mathematical tasks, as they can more effectively engage with the visual and spatial components of problems.

Similarly, Swanson and Beebe-Frankenberger (2004) focused on younger students, specifically first through third graders, and found that non-verbal reasoning, along with algorithmic recognition and working memory, significantly influenced arithmetic word problem performance. This indicates that non-verbal reasoning is not only crucial for understanding and manipulating visual information but also plays a role in the logical sequencing required for solving mathematical problems. Reinhold *et al.* (2020) extended these findings to older students, examining first-year university engineering

students. They demonstrated that spatial, verbal, numerical, and general reasoning abilities all contribute to complex word problem-solving skills, highlighting the critical role of these cognitive abilities in mathematical performance, particularly among older students.

Collectively, these studies illustrate the multifaceted nature of cognitive abilities in determining mathematical achievement. The consistent importance of non-verbal reasoning across different educational levels emphasizes its role not only in early arithmetic tasks but also in more advanced mathematical reasoning. These findings are particularly relevant to the current study, which seeks to clarify the connection between mathematical achievement and proficiency in mathematical vocabulary by examining the roles of processing speed, working memory, and non-verbal reasoning. Processing speed involves the efficiency of executing fundamental operations (Kail and Salthouse, 1994), working memory is essential for storing and manipulating data (Baddeley, 1992), and non-verbal reasoning enables the understanding and analysis of visual information without reliance on language skills (Horn and Cattell, 1966). By investigating these cognitive abilities in tandem, this study aims to provide a comprehensive understanding of the factors that underpin mathematical achievement, particularly in relation to mathematical vocabulary knowledge.

2.3. Mathematics Vocabulary and Mathematics Achievement

When students begin formal education, they encounter a distinct type of language known as academic language, which includes not only the grammar and linguistic functions of language but also the subject-specific vocabulary used across various academic disciplines (Snow and Uccelli, 2009). Academic language is distinct from everyday conversational language and requires a specific understanding of vocabulary and grammar to achieve academic success.

In mathematics, this academic language manifests as a specialized form of communication that requires competence in both symbols and mathematics-specific vocab-

ulary (Thompson and Rubenstein, 2000). Mastery of mathematics involves not only the ability to use symbols and perform numerical operations but also the acquisition of domain-specific vocabulary in both written and oral forms (Dunston and Tyminski, 2013). Without formal instruction in this vocabulary, students often struggle to learn new concepts, as they cannot easily link these concepts to their existing knowledge base (Monroe and Orme, 2002). For example, understanding the symbol "=" requires familiarity with the phrase "equal to"; without this knowledge, comprehending equality becomes challenging. Therefore, a strong grasp of mathematical vocabulary is essential for enhancing cognitive abilities and improving overall mathematical skills and comprehension.

However, the development of mathematical vocabulary is not without its challenges. Rubenstein and Thompson (2002) identified numerous obstacles that students face when learning mathematical vocabulary. One of the primary challenges is the dual meanings of terms used in both everyday language and mathematical contexts (e.g., the word table can refer to both a piece of furniture and a way to display data). Additionally, students may struggle with terms that have precise mathematical definitions but are shared with everyday language. For instance, the word "odd" can describe uniqueness in everyday language, whereas in mathematics, it refers to numbers that are not divisible by two. Further challenges include terms with multiple definitions, those specific to mathematics, terms with different meanings across disciplines, and those with homophones or homographs. Students also encounter difficulties with terms that have similar relationships but distinct meanings, terms with multiple translations, irregular spellings, variations in verbalization, and informal terms often used in place of formal mathematical terminology (Rubenstein and Thompson, 2002).

The Turkish mathematics curriculum emphasizes the importance of mastering and applying mathematical vocabulary. The 2018 mathematics curriculum explicitly outlines the benefits of this mastery before presenting the objectives for each topic. Out of the 13 main objectives, four directly relate to mathematical language (MoNE, 2018):

(i) Students will develop mathematical literacy skills and use them effectively.

(ii) Students will understand mathematical concepts and apply these concepts in daily life.

(iii) Students will use mathematical terminology and language correctly to explain and share mathematical ideas logically.

(iv) Students will use the language of mathematics to make sense of relationships between people and objects and the relationships between objects themselves.

Moreover, the curriculum specifies technical terms to be covered within each subtopic. For instance, under the unit "Numbers and Operations," the curriculum specifies that the term "scientific notation" must be introduced in the context of exponential numbers. Such examples are prevalent throughout the curriculum. However, classroom implementation is also a critical factor in developing students' mathematical vocabulary.

Understanding mathematical vocabulary is essential for effective learning and is a key component of the curriculum. This study aims to explore the significance of mathematical terms, emphasizing the need for a comprehensive understanding of these terms in educational contexts. By investigating the role of mathematical vocabulary, this research seeks to provide insights into how language supports mathematical achievement and how curriculum and instruction can be aligned to improve students' mastery of mathematical concepts.

2.4. Categories of Mathematics Vocabulary

Mathematics vocabulary is often classified into various categories, with subcategories differentiated based on their specific characteristics and uses. Monroe and Panchyshyn (1995) proposed a classification system that divides mathematics vocabulary into four groups: technical and specific to mathematics (e.g., rhombus, equation, fraction), shared by both everyday language and mathematics (e.g., base, square, expression), symbolic (e.g., three, 1/2, 145), and general language used in everyday math-

ematics (e.g., terms commonly encountered in mathematical contexts). Building on this categorization, Powel and Nelson (2017) conducted a study to assess mathematics vocabulary knowledge in first-grade students. The study involved 104 participants and utilized a measurement tool specifically developed to evaluate students' understanding of different types of mathematical vocabulary. The vocabulary categories chosen for this assessment were heavily influenced by the framework established by Rubenstein and Thompson (2002), which underscores the importance of distinguishing between types of vocabulary in mathematics education. Moreover, the framework consisted of Monroe and Panchyshyn's (1995) work on mathematics vocabulary classification. The results of the study revealed that students exhibited varying levels of success in identifying different types of vocabulary, highlighting the need for tailored instructional approaches that address the specific challenges associated with each category.

Further emphasizing the importance of specific vocabulary types, Stevens *et al.* (2024) focused on word-problem vocabulary in their study of 75 third graders experiencing difficulties in mathematics. By analyzing data from a randomized control trial, the researchers found that word-problem vocabulary alone accounted for 27% of the variance in word-problem performance. This finding underscores the significant role that specialized mathematical vocabulary plays in students' ability to comprehend and solve word problems, which are a common component of mathematics assessments. The study suggests that focusing on the specification of vocabulary based on measured achievement can provide valuable insights into the relationship between vocabulary knowledge and mathematical performance.

Although various studies have acknowledged the importance of different types of mathematics vocabulary, few have included a comprehensive analysis of these categories in relation to mathematics achievement. Peng and Lin (2019) addressed this gap by examining the relationship between types of mathematics vocabulary and mathematics abilities in fourth-grade Chinese students. Their study analyzed the impact of vocabulary related to measurement, geometry, and numerical operations; categories aligned with the Chinese elementary mathematics curriculum. The findings indicated

that each category of vocabulary had a distinct effect on students' ability to solve word problems and perform calculations, emphasizing the need for a nuanced understanding of how different types of vocabulary contribute to mathematical success.

In light of these studies, the current research aims to categorize mathematics vocabulary in a way that reflects its emphasis within the curriculum, similar to the approach used by Peng and Lin (2019). This study will focus on three primary groups of mathematics vocabulary: (i) numbers, operations, and algebra vocabulary, (ii) measurement and data vocabulary, and (iii) geometry vocabulary. These categories are defined based on the relationships and concepts outlined by Van de Walle *et al.* (2013), which provide a clear framework for understanding the interconnectedness of these vocabulary types. For example, algebraic vocabulary is included under numbers and operations because algebra requires the generalization of arithmetic principles. Similarly, vocabulary related to data is combined with measurement vocabulary, as statistics and graphs are essential tools for describing and interpreting quantitative information about the world. This approach aims to provide a comprehensive understanding of how mathematics vocabulary supports students' overall mathematical achievement.

2.5. The Role of High-Stake Exams Like LGS in the Turkish Education System

In Turkey, high-stakes exams have long been pivotal in determining students' academic futures, particularly in the context of high school placement. For nearly three decades, these exams have shaped the educational trajectories of students by serving as the primary criteria for admission to selective high schools, which are often seen as gateways to better educational and career opportunities (Caner and Bayhan, 2020). Over time, the structure of these exams has evolved, reflecting ongoing efforts to manage the intense competition for high school placement. The Level Assessment Examination (SBS), in use from 2007 to 2013, and the Transition from Basic to Secondary Education Examination (TEOG), implemented from 2014 to 2017, both involved multiple assessments across several grades. In contrast, the current system, known as the

High School Entrance Exam (LGS), introduced in 2018, is distinct from its predecessors in both its structure and impact. The LGS emphasizes complex mathematical problem-solving, which has significantly challenged students, particularly in terms of preparation and performance. According to a comparative study, LGS mathematics questions are more complex and require multi-step problem-solving compared to the TEOG, increasing pressure on both students and educators to adapt their strategies (Baştürk and Taştepe, 2022). Each change in the examination system has also led to shifts in teaching methods, with instruction increasingly tailored to the specific format and style of the exam. Although the core curriculum remains consistent, teaching has increasingly become exam-oriented, which is a direct consequence of the high-stakes nature of these exams. Despite these structural changes, the central role of high-stakes exams in shaping educational outcomes has remained a constant, underscoring their critical importance in the Turkish education system and beyond.

The current high school entrance examination, known as the LGS, represents the latest iteration of Turkey's high-stakes testing system. Introduced in 2018, the LGS is distinct from its predecessors in both its structure and its impact on the education system (Beyendi, 2018). The exam is administered once a year at the end of eighth grade. It includes two parts and is administered in two sessions. Initially, students complete tests in Turkish, History of the Turkish Revolution, Religious Culture, and English. Following a break, they proceed to the second part of the examination, which includes Mathematics and Science tests. Each subject area contains questions designed to assess students' skills in reading comprehension, interpretation, inference, problem-solving, analysis, critical thinking, scientific process, and other skills aligned with the objectives outlined in the 8th-grade curriculum (MoNE, 2024). While the core learning objectives remain consistent, the difficulty distribution of the LGS tests has shown variation from year to year. This fluctuation is particularly evident in the Turkish and Mathematics sections, which carry the highest weight coefficients within the exam, making them crucial for overall achievement. Such variations highlight the dynamic nature of the exam's structure and the ongoing adjustments made to maintain its rigor and fairness. From 2018 to 2022, the Ministry of National Education has published

reports detailing the average item difficulty, average item discrimination, and internal consistency (reliability) coefficients for the LGS tests (MoNE, 2018b, 2019, 2020, 2021, 2022). These data, presented in Table 2.1, reveal that fluctuations have been observed in these metrics across different years.

Table 2.1. LGS item analysis and reliability analysis results according to years.

		2018	2019	2020	2021	2022
Turkish	Item Difficulty	0.62	0.59	0.50	0.47	0.46
	Item Discrimination	0.56	0.59	0.38	0.41	0.39
	Internal Consistency	0.84	0.87	0.82	0.82	0.81
Mathematics	Item Difficulty	0.24	0.25	0.26	0.21	0.24
	Item Discrimination	0.31	0.57	0.30	0.31	0.44
	Internal Consistency	0.65	0.84	0.77	0.76	0.84
Note: Item discrimination *d≥0.50 Very high discrimination,* *0.49≥d≥0.40 High discrimination,* *0.39≥d≥0.30 Adequate discrimination*						

These observations underscore the importance of continuous monitoring and adjustment of the LGS to ensure its effectiveness as a fair and reliable measure of student achievement. The fluctuations in item difficulty, discrimination, and internal consistency across the years, particularly in the critical Turkish and Mathematics sections, indicate that the exam is responsive to changing educational needs and conditions. The variability in exam difficulty and structure, as observed in recent LGS assessments, has required teachers to continuously adapt their instruction to better prepare students for the unpredictable nature of the exam. According to a study on teacher perspectives, educators have expressed the need for flexible and adaptive teaching strategies to respond to the changing demands of the LGS, highlighting the dynamic nature of this

high-stakes exam (Güler, 2019). However, with reports for the most recent years still pending, it remains crucial to keep analyzing these trends to maintain the integrity and fairness of the examination system.

This variability and the societal pressures associated with LGS further underscore the necessity of examining factors like mathematics vocabulary and achievement to understand student performance across different cohorts. In the context of this study, which examines the relationship between mathematics vocabulary and mathematics achievement, the LGS Mathematics scores are particularly valuable as a variable. Beyond the classroom, the LGS has had a profound impact on families, with many parents expressing concerns about the stress and anxiety associated with the high-stakes nature of the exam. This societal pressure further underscores the importance of research focused on supporting students, particularly those most vulnerable to the demands of high-stakes testing (Kuzu et al., 2019). While the LGS does have certain limitations, as previously discussed, including year-to-year variability in difficulty and discrimination indices, it remains one of the most comprehensive and widely accepted measures of student academic performance in Turkey. Despite these limitations, the high-stake nature of the LGS allows for a consistent comparison of student abilities across different cohorts, making it a suitable metric for assessing both mathematics achievement and reading comprehension. Consequently, the use of LGS scores in this study is justified as it provides a robust basis for analyzing factors influencing mathematics achievement and reading comprehension within the current educational framework.

2.6. Studies on Mathematics Vocabulary and Mathematics Achievement

Research has consistently highlighted the critical role of mathematics vocabulary (MV) in enhancing mathematical performance. A comprehensive meta-analysis by Lin *et al.* (2021) synthesized data from 40 different studies, encompassing a total of 7,988 participants, to explore the relationship between MV and mathematical performance. The findings indicated a moderate correlation between MV and mathematical performance, suggesting that a stronger grasp of mathematics-specific terminology is

associated with better performance in mathematics. Notably, this relationship held true even after accounting for cognitive skills, indicating that MV independently influences mathematical performance. Additionally, the study found that the impact of MV was more pronounced for higher-order mathematics tasks, such as problem-solving and abstract reasoning, compared to fundamental arithmetic tasks. This highlights the importance of a robust mathematics vocabulary for mastering complex mathematical concepts and procedures.

Expanding on the foundation laid by Lin *et al.*, Purpura and Logan (2015) investigated the relationship between mathematical language, the approximate number system (ANS), and early mathematical performance in preschool students aged between 3.12 and 5.26 years. Their study revealed that both mathematical language and ANS significantly influence early math skills at various developmental stages, suggesting the importance of early exposure to mathematical vocabulary to build a strong foundation for later mathematical learning. Similarly, Powell *et al.* (2017) examined the performance of 3rd and 5th-grade students in mathematics vocabulary, finding that both general vocabulary and mathematical computation were predictors of mathematics vocabulary knowledge. The study also noted that the influence of general vocabulary and mathematical computation on mathematics vocabulary varied based on the level of mathematics vocabulary. These findings collectively underscore the critical role of vocabulary in supporting mathematical development from an early age and highlight the need for targeted instructional strategies that address vocabulary acquisition at various developmental stages.

Furthering the discussion on the specificity of vocabulary types, Peng and Lin (2019) studied the relationship between types of mathematics vocabulary and mathematics achievement in fourth-grade Chinese students. Their research analyzed the effect of vocabulary related to measurement, geometry, and numerical operations on the achievement of word problems and calculations. Even after controlling for general vocabulary, IQ, working memory, and processing speed, mathematics vocabulary continued to have a significant effect on mathematics achievement. Interestingly, vo-

cabulary related to measurement was the most influential in predicting word problem-solving performance, likely due to the focus on measuring concepts in the problems. This finding emphasizes the need to consider the specific types of vocabulary that are most impactful in different mathematical tasks, suggesting that curriculum developers and educators should tailor instruction to emphasize the most relevant vocabulary for specific mathematical skills.

Turan and De Smedt (2022) conducted a systematic literature review on mathematical language and preschool children's abilities. Their analysis of 18 studies revealed a significant association between preschoolers' understanding of mathematical language and their mathematical abilities, particularly in numeracy performance. They concluded that the mathematical language used at school and home is a strong predictor of later mathematical knowledge, highlighting the importance of early and consistent exposure to mathematical vocabulary. This reinforces the findings of earlier studies and further underscores the need for early intervention and consistent reinforcement of mathematical language in both educational and home settings.

Despite the extensive research on elementary-grade students, there remains a notable gap in the literature concerning the correlation between mathematics vocabulary and mathematics achievement in students beyond the fifth grade. Ünal *et al.* (2021) addressed this gap by examining the relationship between mathematics vocabulary knowledge and mathematics achievement in eighth-grade students, controlling for general vocabulary. Their study compared Turkish and US students, finding that for higher-achieving Turkish students and US students, mathematics vocabulary knowledge predicted mathematics achievement. Additionally, mathematics vocabulary mediated the relationship between general vocabulary and mathematics achievement for these groups. However, for low-achieving Turkish students, general vocabulary was the only predictor of mathematics achievement. This highlights the varying impact of vocabulary knowledge on different achievement levels and underscores the importance of targeted instructional strategies for diverse student populations.

The investigation into the relationship between mathematics vocabulary and mathematics achievement is not only supported by empirical evidence but is also essential for developing targeted educational strategies. By focusing on mathematics vocabulary, educators can better support students in mastering complex mathematical concepts, ultimately leading to greater academic success. The current study aims to contribute to this literature by providing more insight into the relationship between mathematics vocabulary and mathematics achievement for higher grades and extending the available literature by further controlling for cognitive and reading skills.

3. METHODOLOGY

The methodology of the study is described in the following parts: the design, the population and sample, the instrument, the data collection procedure, and the data analysis.

3.1. The Design of this Study

According to Creswell (2012), the study utilizes a non-experimental, correlational research design to investigate the relation between multiple factors. Specifically, the study assesses participants' knowledge of mathematics vocabulary and their mathematics achievement. Mathematics vocabulary knowledge is measured by a test developed by Unal *et al.* (2021), administered during a scheduled 20-minute class period. Mathematics achievement is assessed using the results from the high school entrance exam (LGS 2024), which evaluates both mathematics and reading comprehension in Turkish.

Additional factors measured to control for their influence include general vocabulary proficiency and cognitive abilities such as processing speed, working memory, and non-verbal reasoning. These tests were administered through two different online platforms during a scheduled 40-minute class period at school.

3.2. The Population and Sample

Participants in this study were chosen using convenience sampling, as it allows easy access to the participants (Gay *et al.*, 2012). The participants are eighth-grade students from a state school in the Çatalca district of Istanbul, where the researcher conducted the study with support from the school's mathematics teacher. Eighth-grade students are typically between the ages of 13 and 15. The school has a total of 220 students across eight classes, with a balanced distribution of male and female students. The students involved in the study represent a range of socioeconomic backgrounds,

spanning from low to middle-income levels. In the current study, 108 students participated after obtaining parental consent. However, only 103 of the collected data were usable due to missing information. Among the participants, 50 (48.5%) were male and 53 (51.5%) were female. The students' ages ranged from 13 to 15, with the majority being 14. The descriptive data gathered from the participants shows a range of educational levels among parents. This includes individuals with no formal schooling as well as those with graduate-level degrees. There were two participants stating their mothers were illiterate. It is important to note that the majority of the sample's parents have completed high school, indicating a diverse range of socio-economic backgrounds. As a result, the sample could be considered moderately representative of the population. Although the study was not initially designed to focus solely on low-achieving students, the demographic and academic performance data collected revealed that the sample was predominantly composed of students with lower mathematics achievement. This unintended focus allows for a unique exploration of the challenges specific to this group.

Table 3.1. Background information of participants.

	Sex		**Mothers' Education**			**Fathers' Education**		
	Female	**Male**	**1-2-3***	**4***	**5-6***	**1-2-3***	**4***	**5-6***
N	53	50	51	27	25	38	44	21
%	51.5	48.5	49.5	26.2	24.3	63.1	42.7	20.4
Mean			3.52			3.73		
SD			1.235			1.113		
Note: 1* = illiterate 2*=primary school graduate, 3*=middle school graduate, 4* = high school graduate, 5* = bachelor's degree and 6*master's degree and above								

3.3. The Instruments

In investigating the differential relation between mathematics vocabulary and mathematics achievement, participants were assessed in several ways. First, the participants received a 36-question multiple-choice test and had 20 minutes to complete it. Secondly, their mathematics achievement was reported by the high school en-

trance exam (LGS), and their Turkish test results of LGS were reported as a means of reading comprehension. Finally, participants' general vocabulary knowledge, processing speed, and working memory were measured through an online survey prepared to apply Woodcock-Johnson III Achievement and Cognitive subtests that the details mentioned below (Woodcock *et al.*, 2001). Non-verbal reasoning skills were measured by an online Wisconsin Card Sorting Test prepared by the thesis advisor on an online platform (OpenLab).

3.3.1. Mathematics Vocabulary Test

Ünal *et al.* (2021) designed a measurement test for mathematics vocabulary according to sixth-, seventh-, and eighth-grade mathematics books by the Ministry of National Education (MoNE). The test consists of 36 multiple-choice questions to be completed in 20 minutes. The current study aims to use the mathematics vocabulary test by sorting the vocabulary questions into three subgroups, numerical and operation and algebra, measurement and data, and geometry, to investigate their relationship with mathematics achievement. All 36 items from the test are planned to be used for data gathering, although three items are related to the function topic, which the students in Turkey encounter in high school according to the current native mathematics curriculum (MoNE, 2018). The test covers those three questions because the study in which the test was developed aimed to compare the US and Turkey samples, and the US core standards cover the topic in eighth grade. Also, Ünal *et al.* (2021) stated that the reason for keeping the questions in the text was that participants would find the correct answer by eliminating the known choices in the question. The original study did not show any significant changes in reliability when the mentioned questions were excluded. The reliability score of the test in the study conducted by Ünal *et al.* (2021) was reported as an alpha value of 0.79. The data analysis was conducted using a total of 36 items in the test. In the present study, the Cronbach's alpha value for the study sample was 0.77.

The test questions are grouped under three categories (see Table 3.2) according to curriculum emphasis and the relation between the concepts according to Van de Walle *et al.* (2013). Peng and Lin's (2019) study was the guidance for choosing the curriculum-based structure of mathematics vocabulary. Since the concepts in the pre-prepared MVT test were not equally distributed, the number of questions under each group was unequal.

Table 3.2. Groups of mathematics vocabulary types and corresponding vocabulary.

Number and Operations and Algebra N= 18	**Measurement and Data N= 10**	**Geometry N= 8**
Q1 – irrational numbers	Q19- rise	Q22- center of dilation
Q2 – real numbers	Q20 - run	Q23- center of rotation
Q3 – base	Q21- slope	Q24 - dilation
Q4 – perfect square	Q28- rotational symmetry	Q25- reflection
Q5 – exponential numbers	Q30- corresponding angles	Q26 - translation
Q6 – radical expression	Q31- corresponding parts	Q27 - rotation
Q7 – scientific notation	Q32- similar figures	Q29 – transformation
Q8 – square root	Q34 – best fitting line	Q33- intersecting line
Q9 – linear equation	Q35- ordered pair	
Q10 – slope intercept form	Q36 – scatter plot	
Q11 – function		
Q12 – coefficient		
Q13- constant terms		
Q14 – like terms		
Q15 – variable		
Q16 – terms of expression		
Q17- numerical expressions		
Q18 – algebraic expressions		

3.3.2. Mathematics Achievement

Students' high school entrance exam (LGS) scores are used as their mathematics achievement scores. In the LGS, the test consists of two parts and is applied in two sections. First, students take the Turkish, History of the Turkish Revolution, Religious Culture, and English tests with 50 questions for 90 minutes. After 45 minutes of break, participants take the second part of the exam, which covers Mathematics and Science tests and consists of 40 questions. For the second part of the exam, students are given 80 minutes to complete the exam. For each field, there are questions that measure the student's reading comprehension, interpretation, inference, problem-solving, analysis, critical thinking, scientific process, and similar skills based on the objectives determined in the 8th-grade curriculum (MoNE, 2024).

The mathematics test consists of 20 questions covering 8th-grade mathematics course topics. However, the topics need background knowledge from previous years. For instance, the first unit in the curriculum is multiples and factors, which students first encounter in sixth grade per the 2018 national education curriculum by the MoNE. Similarly, the second unit, exponents, requires competence in operations with integers, which is a seventh-grade subject. The mathematics curriculum of eighth grade can be defined as having a spiral structure in this respect (MoNE, 2018).

Table 3.3. Example question 1 from the LGS exam.

English	**Turkish**
Which of the following is the algebraic expression that gives the length in centimeters of the perimeter of a square with a side length of (x+2) cm? A) x+8 B) 4x+2 C) 4x+4 D) 4x+8	Bir kenar uzunluğu (x+2) cm olan karenin çevresinin uzunluğunu santimetre cinsinden veren cebirsel ifade aşağıdakilerden hangisidir? A) x+8 B) 4x+2 C) 4x+4 D) 4x+8

Table 3.4. Example question 2 from the LGS exam.

English	**Turkish**
Which of the following is an irrational number? A) $\sqrt{14}$ B) 1, $\bar{2}$ C) $\sqrt{1.44}$ D) 12	Aşağıdakilerden hangisi bir irrasyonel sayıdır? A) $\sqrt{14}$ B) 1, $\bar{2}$ C) $\sqrt{1.44}$ D) 12

The LGS is designed for students to apply to their preferred high schools that consider the exam scores as part of their admissions process. These schools are considered high-quality schools, whereas others accept students without considering LGS scores. Consequently, the LGS serves as a high-stake selective assessment. Since the MoNE has yet to disclose the specifics of the question analysis, the researchers rely on the high-stake nature of the exam to ensure its reliability and validity.

Examining the mathematics and vocabulary tests highlights the importance of mathematics vocabulary knowledge, particularly evident in the example questions from the 2024 LGS provided (see Table 3.3 and Table 3.4). The questions on the LGS 2024 mathematics exam are available on the MoNE website (MoNE, 2024c).

3.3.3. Reading Comprehension

The reading comprehension skills of the participants were thoroughly assessed based on the results of the LGS Turkish test. This comprehensive examination consists of 20 questions that cover a wide range of topics from the 8th-grade Turkish curriculum, as outlined by the MoNE in 2024. The questions are designed to primarily assess word and paragraph comprehension, aligning closely with the key areas emphasized in the curriculum. Notably, the participants' Turkish test results from the LGS were used as an essential indicator in the subsequent data analysis.

An example question from the 2024 LGS exam is provided to illustrate the structure of the questions and the measure of reading (see Table 3.5). Although the MoNE has not disclosed the specifics of the question analysis, the researchers rely on the high-stake nature of the exam to ensure its reliability and validity. The test is inherently selective, as it is used to determine student acceptance into high schools. The Turkish exam questions for LGS 2024 can be found on the MoNE website (MoNE, 2024d).

Table 3.5. An example from LGS 2024 Turkish questions (MoNE,2024d).

English	**Turkish**
One of the primary elements that make a nation a nation is language. Nations that cannot develop and enrich their mother tongue and cannot protect it from the invasions of foreign languages can neither create a national culture nor preserve their existing cultures. Degeneration and alienation are not limited to language but lead to the disappearance of all values over time and cause irreparable damage to national unity. A nation that neglects its language in science, art, and education, fails to use it, and does not teach its children the necessity of preserving their language is doomed to extinction. Which of the following conclusions cannot be drawn from this text?	Milleti millet yapan unsurların başında dil gelir. Ana dilini geliştirip zenginleştiremeyen, yabancı dillerin istilalarından koruyamayan milletler ne millî bir kültür oluşturabilir ne de oluşmuş kültürlerini koruyabilirler. Yozlaşma ve yabancılaşma dille sınırlı kalmayarak zamanla bütün değerlerin yok olmasına ve millî birliğin, telafisi imkânsız zararlar görmesine sebep olur. Bilim, sanat ve eğitimde kendi dilini ihmal edip kullanmayan ve kendi diline sahip çıkması gerektiğini evlatlarına öğretemeyen bir millet yok olmaya mahkûmdur. Bu metinden aşağıdaki yargıların hangisine ulaşılamaz?

Table 3.5 An example from LGS 2024 Turkish questions (MoNE,2024d). (cont.)

English	**Turkish**
A) In order to preserve their language, nations must process elements of national culture in art. B) A nation that cannot prevent alienation in its language is in danger of losing its existence. C) Nations that want to sustain their existence must transmit language awareness to younger generations. D) Language is an element of the bond between individuals of a nation.	A) Milletler dilini koruyabilmek için sanatta, millî kültüre ait unsurları işlemelidir. B) Dilindeki yabancılaşmayı önleyemeyen bir milletin varlığı tehlikeye düşer. C) Varlığını sürdürmek isteyen milletler dil bilincini genç nesillere aktarmalıdır. D) Dil, bir milletin bireyleri arasındaki bağ kuvvetlerinden bir unsurdur.

3.3.4. Woodcock-Johnson III Achievement and Cognitive Tests

The Woodcock-Johnson III (WJ III) is a comprehensive assessment tool that includes two separate batteries: the WJ III Tests of Cognitive Abilities (WJ III COG) and the WJ III Tests of Achievement (WJ III ACH). Collectively, these batteries form a comprehensive and diverse system for assessing general intellectual capacity (g), specialized cognitive capacities, oral language, and academic accomplishment across a wide range of ages (Woodcock *et al.*, 2001). A total of three subtests were used to assess the general vocabulary, processing speed, and working memory skills of participants, with one from achievement and two from the cognitive battery. The tests were adapted into Turkish by a panel of academics, including the thesis advisor. The details for the three subtests are provided in the following sections.

3.3.4.1. General Vocabulary. General vocabulary skills were assessed using the ''Reading Vocabulary" section of the Woodcock-Johnson III achievement tests (Woodcock *et al.*, 2001). The test consists of three parts: measuring for synonyms, antonyms and

completing analogies. The test is validated for ages 5 to 79. In part A, participants need to provide synonyms of the given 12 words; in part B, participants need to provide antonyms of the given 23 words; and finally, in part C, participants need to complete the 18 analogies according to the given example at the beginning of the test. Each correct answer is worth one point in each part of the test. An example question from the original test is presented with a Turkish sample.

Table 3.6. A sample question from the WJ-3 reading vocabulary section (Woodcock *et al.*, 2001).

English	**Turkish**
Read each of these words out loud and tell me another word that means the same.	'Kuvvetli' sözcüğü 'güçlü' anlamına gelen başka bir sözcüktür. "Tümce" sözcüğü "cümle" anlamına gelen bir başka sözcüktür. Bu örnekler gibi sıradaki sorularda verilen kelimelerle aynı anlama gelen eş anlamlı kelimeleri yazınız.
1. puppy	8. halk
12. entire	15. malumat
25. fallow	18. hüzün

Turkish version of the test was adapted into an online survey to facilitate easy access to participants. The survey consisted of 53 items, and participants provided written answers. Each correct answer was worth one point, following the WJ-III scoring guide (Herbert, 2005).

3.3.4.2. Processing Speed Test. The processing speed of students was measured using the "Decision Speed" section of Woodcock-Johnson III Cognitive Tests, which is designed for individuals aged 4 to 80. Reliability metrics were computed for each WJ III assessment within their intended application, covering all normative participants evaluated at each specified technical age category (Schrank *et al.*, 2001).

The test is administered over a three-minute period, during which participants must identify two related objects out of a set of seven as quickly as possible. There are 40 such questions, and participants are required to answer as many as possible within the time limit. Each correct answer is awarded one point.

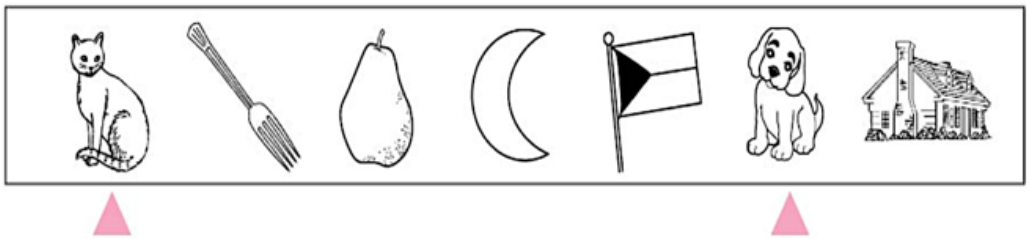


Figure 3.1. A sample question from the WJ-3 decision speed section (Herbert, 2005).

3.3.4.3. Working Memory Test. Working memory was measured using the "Numbers Reversed" section of WJ III cognitive tests. The test requires participants to repeat a series of numbers in reverse order. For example, if given the sequence "6, 5, 2", participants must respond with "2, 5, 6". This task requires them to hold the numbers in their minds temporarily to reverse the sequence.

The test is designed for individuals aged 4 to 80, as indicated by Schrank *et al.* (2021), to measure working memory. The test consists of 25 items where participants are presented with sequences of numbers at a rate of one number per second and are asked to recall the sequence in reverse order. Each correct response earns one point. An example question is provided to illustrate the task. The Turkish version of the test was adapted into an online platform while maintaining all implementation rules. Participants were informed at the beginning that they would only hear the audio once and must provide their responses immediately.

Table 3.7. A sample question from the WJ-3 numbers reversed section (Woodcock *et al.*, 2001).

English	**Turkish**
"I am going to say some numbers. Then you say them backward. For example, if I say "3...4" you would say "4...3." 11. ...6...3...9 19....7...3...9...5...2 28....9...7...2...6...4...1...3	"Bazı sayılar söyleyeceğim. Sonra onları tersten söyleyeceksiniz. Örneğin, eğer ben "3...4" dersem siz "4...3" diyeceksiniz. 11. 1...6...3...9 19. 4...7...3...9...5...2 28. 5...9...7...2...6...4...1...3

3.3.5. Non-verbal Reasoning Test

The Wisconsin Card Sorting Task (WCST), developed by Berg in 1948, assesses an individual's capacity to adapt cognitive strategies and modify and supervise working memory representations. In the current study, the test is delivered online and prepared by the researchers. Participants are provided with cards to categorize based on color, shape, or quantity without being instructed on which criterion to employ. Feedback is given for each trial, indicating whether the response is correct or incorrect, allowing participants to deduce the current sorting criterion. However, the criteria change unexpectedly, requiring participants to adjust their cognitive framework and revise their mental representations.

The accuracy of responses and the number of perseverative mistakes are measured and reported for analysis. The WCST is a widely used neuropsychological tool for evaluating executive function. A meta-analysis conducted by Kopp *et al.* (2019) found low to medium correlations between WCST performance and fluid intelligence. This suggests that while the WCST measures aspects of executive function related to fluid reasoning, it also assesses other cognitive processes distinct from traditional intelligence metrics. The study concluded that the WCST has a moderate correlation with fluid intelligence (Kopp *et al.*, 2019).

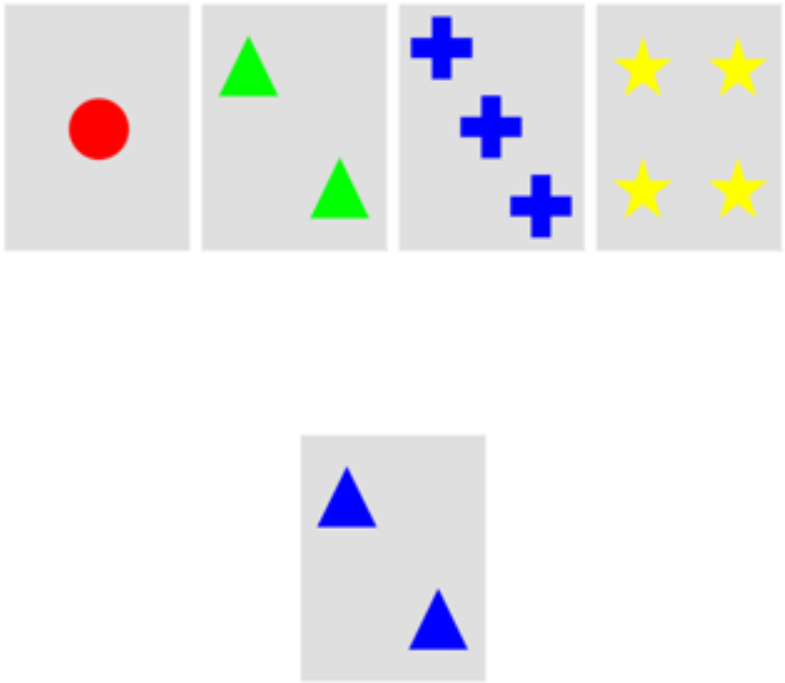


Figure 3.2. A sample question from the wisconsin card sorting test.

3.4. Data Collection Procedure

The data collection for this study was conducted in the following sequence: (1) Math Vocabulary Test, (2) Woodcock-Johnson III Tests, and (3) Wisconsin Card Sorting Test. The entire session took approximately 60 minutes.

First, students completed the Math Vocabulary Test. Following this, the WJ III Tests were administered: decision speed, numbers reversed, and reading vocabulary. The final part of the session involved the WCST, where participants categorized cards based on changing criteria.

The MoNE conducted the LGS exam before and after the data collection period at the school. The Turkish test results from the LGS 2024 exam were used to measure reading comprehension, providing a reliable assessment of participants' comprehension skills. The researcher collected the results from the participants' school.

3.4.1. Examining Mathematics Vocabulary Test

Items in the MVT are presented in Appendix A (in Turkish, as administered). The vocabulary and their corresponding objectives from the curriculum are presented in Table 3.2 (MoNE, 2018). The tests consisted of 36 questions related to mathematics vocabulary taught during formal middle schooling. Three questions (11, 34, and 36) were about topics not explicitly taught in middle school but were retained for comparison with the original study to assess the reliability score of the test. The original study showed that the reliability score remained high even after these questions were excluded; thus, they were included in this study for comparability.

Table 3.8. MVT items and their corresponding objectives from the curriculum.

	Targeted Vocabulary	**Corresponding Middle School Objective**
Q 1	Irrational Numbers	M.8.1.3.8. Recognizes real numbers and associates them with rational and irrational numbers.
Q 2	Real numbers	M.8.1.3.8. Recognizes real numbers and associates them with rational and irrational numbers.
Q 3	Base	M.8.1.2.1. Calculates the integer powers of integers.
Q 4	Perfect Square	M.8.1.3.1. Determines the relationship between positive square numbers and their square roots.
Q 5	Exponential Numbers	M.8.1.2.1. Calculates the integer powers of integers.

Table 3.8 MVT items and their corresponding objectives from the curriculum. (cont.)

	Targeted Vocabulary	**Corresponding Middle School Objective**
Q 6	Radical Expression	M.8.1.3.3. Writes a square-root expression as $a\sqrt{b}$ and takes the coefficient into the root in the expression $a\sqrt{b}$
Q 7	Scientific Notation	M.8.1.2.5. Expresses and compares very large and very small numbers in scientific notation.
Q 8	Square Root	M.8.1.3.1. Determines the relationship between positive square numbers and their square roots.
Q 9	Linear Equation in Two Variables	M.8.2.2.3. Expresses how one of two variables with a linear relationship change in relation to the other using a table and equation.
Q 10	Slope Intercept Form	M.8.2.2.6. Explains the slope of a line using models and relates linear equations and graphs to the slope.
Q 11*	Function	The vocabulary is not covered in the middle school objectives
Q 12	Coefficient	M.6.2.1.1. Writes an algebraic expression appropriate to a given verbal situation and writes a verbal situation appropriate to a given algebraic expression. (Explanation c. The concepts of term, constant term, like terms, and coefficient are addressed.)
Q 13	Constant Terms	M.6.2.1.1. Writes an algebraic expression appropriate to a given verbal situation and writes a verbal situation appropriate to a given algebraic expression. (Explanation c. The concepts of term, constant term, like terms, and coefficient are addressed.)

Table 3.8 MVT items and their corresponding objectives from the curriculum. (cont.)

	Targeted Vocabulary	**Corresponding Middle School Objective**
Q 14	Like Terms	M.6.2.1.1. Writes an algebraic expression appropriate to a given verbal situation and writes a verbal situation appropriate to a given algebraic expression. (Explanation c. The concepts of term, constant term, like terms, and coefficient are addressed.)
Q 15	Variable	M.6.2.1.1. Writes an algebraic expression appropriate to a given verbal situation and writes a verbal situation appropriate to a given algebraic expression. (Explanation a. It is specified that letters used in algebraic expressions represent numbers and are called "variables.")
Q 16	Terms of Expression	M.6.2.1.1. Writes an algebraic expression appropriate to a given verbal situation and writes a verbal situation appropriate to a given algebraic expression. (Explanation c. The concepts of term, constant term, like terms, and coefficient are addressed.)
Q 17	Numerical Expressions	M.6.2.1.1. Writes an algebraic expression appropriate to a given verbal situation and writes a verbal situation appropriate to a given algebraic expression.
Q 18	Algebraic Expressions	M.6.2.1.1. Writes an algebraic expression appropriate to a given verbal situation and writes a verbal situation appropriate to a given algebraic expression.
Q 19	Rise	M.8.2.2.6. Explains the slope of a line using models and relates linear equations and their graphs to the slope.

Table 3.8 MVT items and their corresponding objectives from the curriculum. (cont.)

	Targeted Vocabulary	**Corresponding Middle School Objective**
Q 20	Run	M.8.2.2.6. Explains the slope of a line using models and relates linear equations and their graphs to the slope.
Q 21	Slope	M.8.2.2.6. Explains the slope of a line using models and relates linear equations and their graphs to the slope.
Q 22	Center of Dilation	M.8.3.2.3. Creates the image of polygons resulting from translations and reflections.
Q 23	Center of Rotation	M.8.3.2.3. Creates the image of polygons resulting from translations and reflections.
Q 24	Dilation	M.8.3.2.3. Creates the image of polygons resulting from translations and reflections.
Q 25	Reflection	M.8.3.2.3. Creates the image of polygons resulting from translations and reflections.
Q 26	Translation	M.8.3.2.3. Creates the image of polygons resulting from translations and reflections.
Q 27	Rotation	M.8.3.2.3. Creates the image of polygons resulting from translations and reflections.
Q 28	Rotational Symmetry	M.8.3.2.3. Creates the image of polygons resulting from translations and reflections.
Q 29	Transformation	M.8.3.2.3. Creates the image of polygons resulting from translations and reflections.
Q 30	Corresponding Angles	M.7.3.1.2. Identifies and examines corresponding, alternate interior, alternate exterior angles formed by a transversal with two parallel lines, determines which angles are equal or supplementary, and solves related problems.

Table 3.8 MVT items and their corresponding objectives from the curriculum. (cont.)

	Targeted Vocabulary	**Corresponding Middle School Objective**
Q 31	Corresponding Parts	M.8.3.3.1. Relates congruence and corresponding figures and determines the side and angle relationships of congruent and corresponding(similar) figures.
Q 32	Similar Figures	M.8.3.3.1. Relates congruence and corresponding figures and determines the side and angle relationships of congruent and corresponding(similar) figures.
Q 33	Transversal	M.7.3.1.2. Analyzes the properties of corresponding, alternate, interior alternate, and exterior alternate angles formed by two parallel lines intersected by a transversal; determines which angles are equal or supplementary; solves related problems.
Q 34*	Best Fitting Line	The vocabulary is not covered in the middle school objectives
Q 35	Ordered pair	M.8.2.2.2. Recognizes the coordinate system with its properties and represents ordered pairs.
Q 36*	Scatter Plot	The vocabulary is not covered in the middle school objectives
*= The topics related to targeted vocabulary in the questions were not explicitly taught in middle school.		

In the spring semester of the 2023-2024 academic year, after teaching the curriculum objectives according to the MoNE's annual plan, the MVT was administered to eighth-grade students in a state school in order to measure their mathematics vocabulary knowledge.

Due to the lack of a large enough exam room to accommodate all 108 students simultaneously, the test was administered in participants' classrooms during their math-

ematics classes over a two-week period. Participants were informed that their responses would be used for research and were encouraged to answer sincerely. They were given 20 minutes to complete the test, consistent with the timing used in the original study by Ünal *et al.* (2021). All participants were able to complete the test within the allotted time.

3.4.2. Conducting WJ III Online Survey

The participants' mathematics vocabulary was evaluated, and they were asked to complete an online survey. They only entered their student ID as their participant number for the study. The survey first asked descriptive questions about their gender, number of siblings, and their parents' education levels. The survey was created using the Qualtrics website (Qualtrics, Provo, UT). The remaining part of the survey included three WJ III subtests, for which we obtained permission from the academics who developed the Turkish version of the test, including the thesis advisor. During the preparation of the online test, meticulous care was taken to ensure that the original paper-based test was administered in accordance with the rules. The duration of the survey depended on the participants' own paces and ranged from 10 minutes to 45 minutes, as indicated by the survey metadata. The survey had three parts, which were examined separately.

3.4.2.1. Processing Speed Test. This part of the survey was based on the "Decision Speed" section of the WJ III Cognition Tests (Herbert, 2005). The total duration of the test was determined by the manual guide of the WJ III Test, and the participants had exactly 3 minutes to complete the test. There were 40 items in the test for the participants. First, participants were given two example questions for guidance. After the examples, which were not scored, were completed, the participants started their three minutes. Their aim was to answer as many questions as possible within three minutes, and the participants were informed about it. Participants must choose two related objects in each question among the seven presented objects. Participants completed the survey after undergoing MVT and using their cell phones, as the survey platform is

optimized for mobile usage. QR code distribution was employed for simplicity. When 3 minutes were completed, the survey automatically changed to the Working Memory test.

3.4.2.2. Working Memory Test. This section of the survey was created based on the ''Reversed Number" section of the WJ III Cognition Tests (Herbert, 2005). Participants completed the test on their mobile phones while wearing headphones provided by the researcher. The test involved listening to an audio track for each question. It comprised 25 questions, and participants received instructions in the first audio. The difficulty of the items increases as the survey progresses, with longer sequences toward the end. During the test, participants were told that they could only listen to each audio once and were asked to write down the numbers they heard in reverse order. There was no time restriction for each question in the test. Once the second part of the survey was finished, participants were instructed to proceed to the final part of the survey.

3.4.2.3. General Vocabulary Test. The last section of the survey was prepared based on the ''Reading Vocabulary" section of the WJ III Achievement Tests (Herbert, 2005). Participants continued to answer the questions on their mobile devices. The test involved 53 items consisting of three sections: synonyms, antonyms, and analogies, and participants were asked to provide a word as an answer. After completing all three sections, participants were informed that the test was over.

3.4.3. Conducting Wisconsin Card Sorting Test

The last part of the data collection process was to apply the Wisconsin Card Sorting Test to the participants. OpenLab website was utilized for this process. Participants received the test via QR code and completed it on their mobile devices. The test was designed to be touch-screen friendly. The test duration was 6 minutes, and 60 items were to be completed. After a brief explanation of the test, participants initially

attempted to identify the relationship between the given card and others, aiming to understand and adapt to the rule changes. When participants were slow to react to the question, the test warned them and changed to another question, and this data was saved in the database. Only correct answers out of 60 responses were used in data analysis.

3.4.4. Examining High School Entrance Exam Results

Participants were at a critical transition point as eighth grade marks the culmination of middle school education in Turkey. To gain admission to a high-quality state or private high school, students are required to take the high-stakes High School Entrance Exam (LGS). In the 2023-2024 academic year, the LGS was administered on June 2, 2024, with results publicly announced on June 28, 2024. Although participation in the exam was optional, the vast majority of students chose to take part, as the exam serves as a gateway to prestigious educational institutions.

The LGS exam is divided into two distinct sections. The first section, lasting 90 minutes, tests students on Turkish, Revolutionary History, English, and Religion. Following a 45-minute break, the second section, which lasts 80 minutes, assesses students in Mathematics and Science. These subjects are cautiously measured according to eighth-grade curriculum objectives to reflect core competencies essential for high school education.

In the 2023-2024 LGS, the overall participation rate across the country was 95.61%, according to the Ministry of National Education (MoNE, 2024). Out of all examinees, 352 students nationwide achieved perfect scores by answering all questions correctly. The average correct scores in the Mathematics and Turkish sections were 6.54 out of 20 questions and 9.63 out of 20 questions, respectively.

For the current study's sample, the mean correct scores were slightly lower, with participants achieving an average of 6.03 in Mathematics and 9.93 in Turkish. However,

the school from which the sample was drawn exhibited higher average scores when considering all students who took the exam. Specifically, the school's Mathematics mean score was 6.71, and the Turkish mean score was 10.96. It is worth noting that the represented sample within this study differs in mean scores due to the selective participation of students in the research. Given that the mean scores of the study's participants were lower than the overall school average, it can be inferred that the participants were predominantly low-achieving students.

To ensure the accuracy and validity of the data used in this study, the researcher obtained the exam results directly from the school administrators of the participants' school. This direct collection method provided a reliable basis for the analysis and ensured that the data accurately reflected the academic performance of the participants.

3.5. Data Analysis

The study's findings will be analyzed in three main parts: analyzing instrument scores, conducting multiple linear regression analysis to examine the relationship between mathematics achievement and mathematics vocabulary while controlling for other variables, and carrying out multiple regression analysis to explore the relationship between mathematics achievement and types of mathematics vocabulary while holding the other variables constant. These analyses will address the study's two primary research questions.

The data analysis for this study is designed to address two primary research questions. The first question investigates the extent to which mathematics vocabulary knowledge predicts mathematics achievement while controlling for language skills (general vocabulary and reading comprehension) and essential cognitive skills (processing speed, working memory, and non-verbal reasoning).

The second question explores whether there is a differential relationship between types of mathematics vocabulary knowledge-specifically, vocabulary associated with

measurement and data, geometry, and numerical operations and algebra-and mathematics achievement, while also controlling for the aforementioned language and cognitive skills.

3.5.1. MVT Scoring

Each correct answer was awarded 1 point, with responses coded as 1 for correct and 0 for incorrect. Total and component scores, including types of math vocabulary such as measurement and data, geometry, and numerical operations and algebra, were entered into SPSS version 29 for analysis. Cronbach's alpha for the test was $r = 0.77$. Descriptive analysis indicated slight skewness, with most scores clustering around one standard deviation below the mean, suggesting that the sample tended to have a low level of math vocabulary knowledge across these areas.

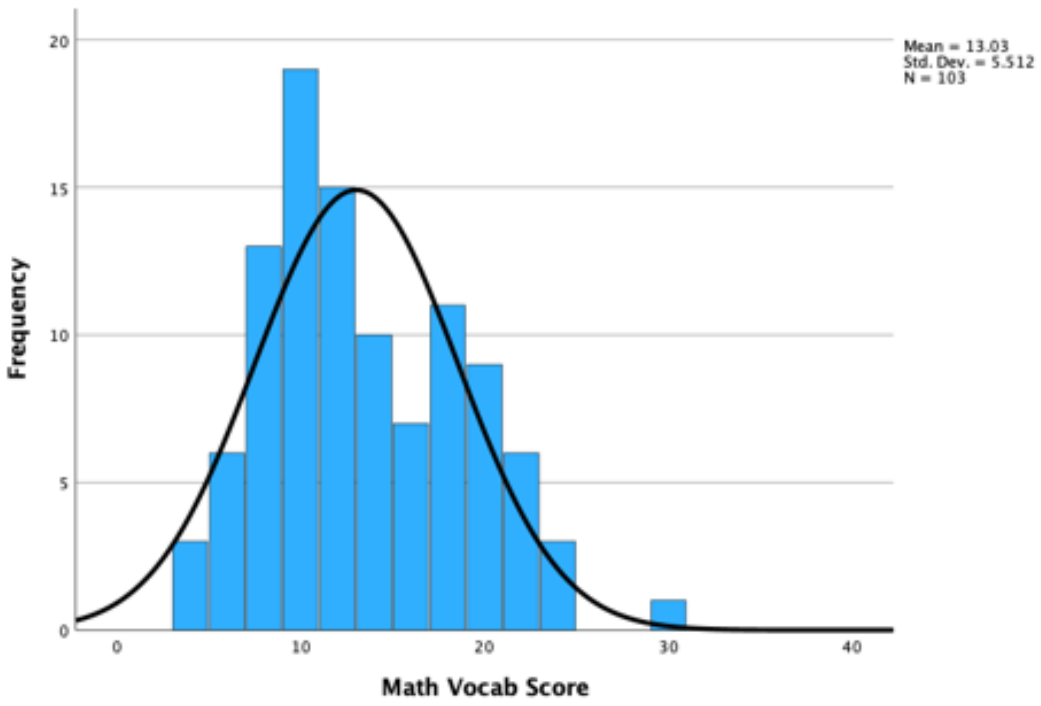


Figure 3.3. Histogram of mathematics vocabulary test results.

3.5.2. Processing Speed

In the test, participants were given 1 point for every correct pair of items they selected. If they were unable to choose the correct two objects, they received 0 points. There were no partial scores for this test. The highest score achievable in the test was 40 points; in the current sample, the highest score obtained was 30 points. The mean score for the participants was 18.38, with a standard deviation of 5.35.

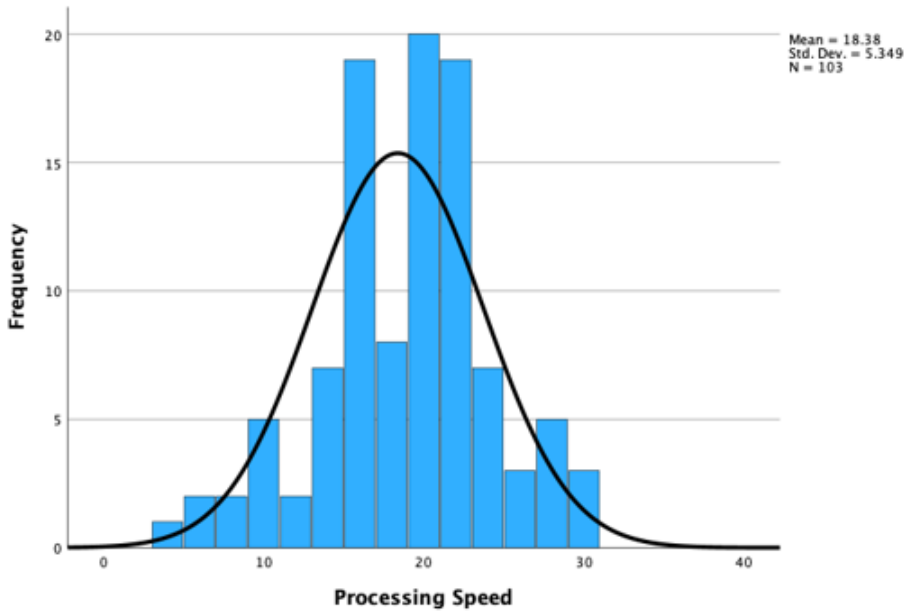


Figure 3.4. Histogram of processing speed results.

3.5.3. Working Memory

In the second part of the survey, the scoring was performed using the survey's scoring tool. The scoring tool recorded the precise order of numbers entered by participants, providing the total correct responses to the researcher. Participants earned one point for correctly identifying the reversed order of the number sequence. No partial points were granted for partially correct answers at the beginning or end. The participants' test scores were utilized as working memory scores in the data analysis. The mean score of the participants was 12.9, with a standard deviation of 6.81.

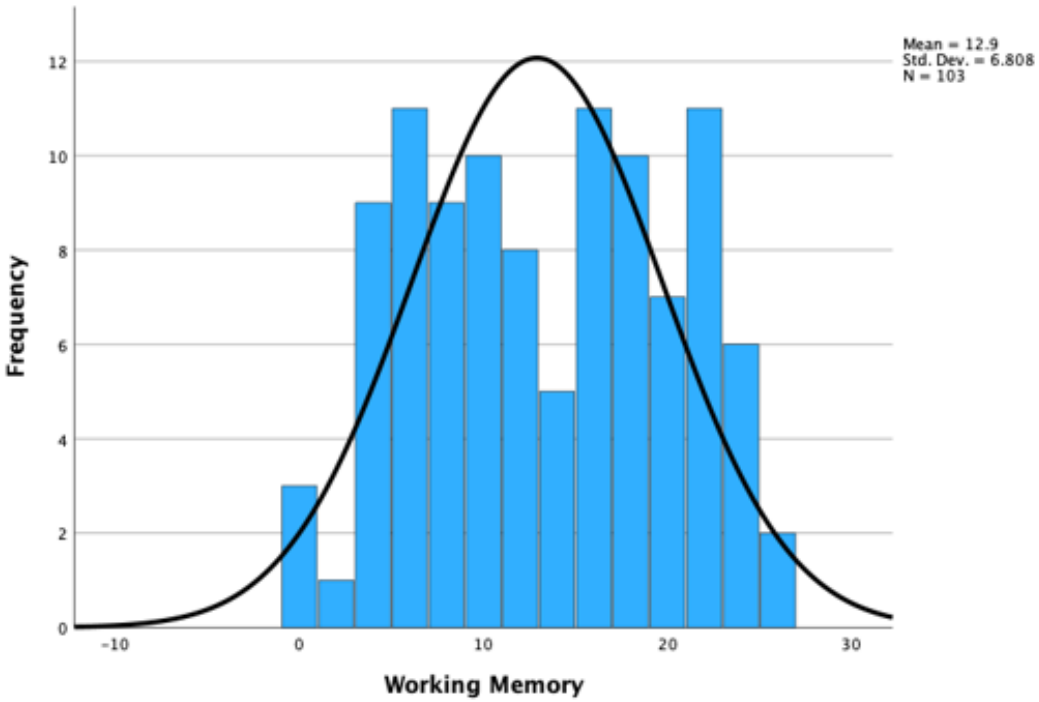


Figure 3.5. Histogram of working memory scores.

3.5.4. Wisconsin Card Sorting Test

Analyzing the data gathered from the online test conducted through OpenLab reveals insightful information about the participants' performance and cognitive abilities. The data provided key metrics such as the number of true responses, false responses, and preservation errors, shedding light on how individuals engage with the test content. Focusing on the total number of correct responses, ranging from the lowest score of 12 to the highest score of 51 out of 60 attempts, can provide a deeper understanding of the participants' adaptive reasoning skills and cognitive processes. Therefore, the number of correct responses is utilized in the data analysis to represent the non-verbal reasoning skills of the participants. To measure the reliability of the instrument, each question of the WCST is coded as 1 for true and 0 for incorrect or unanswered questions. After entering each participant's 60 responses to WSCT, a reliability analysis was conducted using SPSS version 29. The reliability score of the test for the current sample was $r = 0.83$. The results indicate good reliability and internal consistency (Cronbach , 1951).

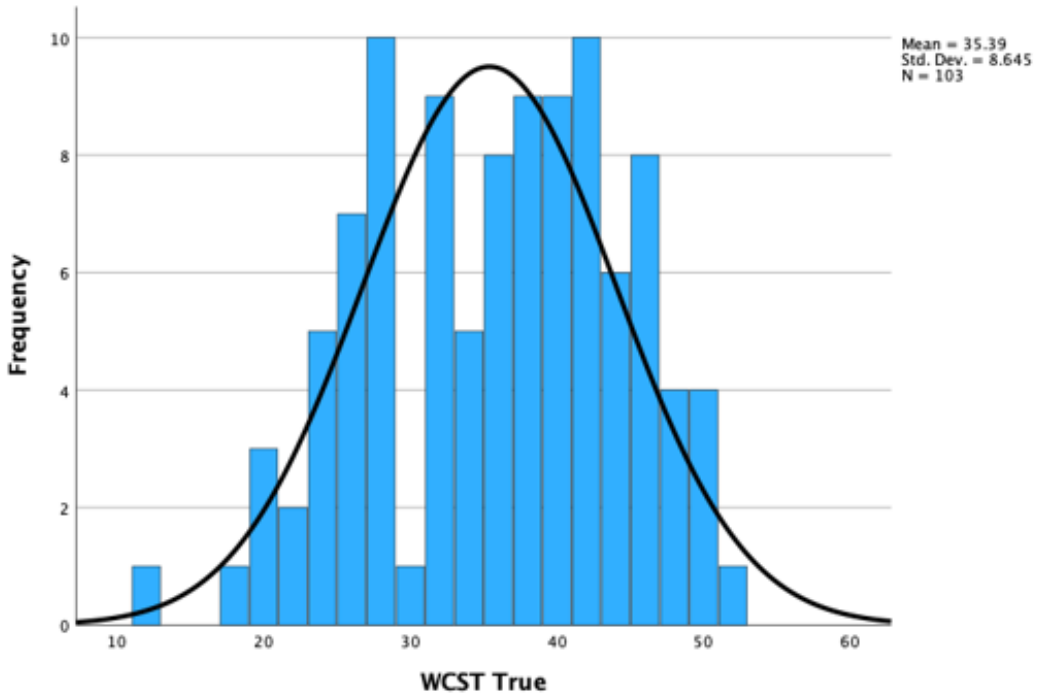


Figure 3.6. Histogram of Wisconsin card sorting test results.

3.5.5. General Vocabulary

While reviewing the survey results, the Qualtrics scoring tool was utilized. Each correct answer was supposed to receive 1 point. However, it was observed that certain correct answers were not awarded points. As a result, the researcher had to manually review each participant's response due to this inconvenience. The highest possible score from the test was 53, and in the current sample, the highest total score is noted as 46 points. The mean score of the participants was 13.03, with a standard deviation 8.69.

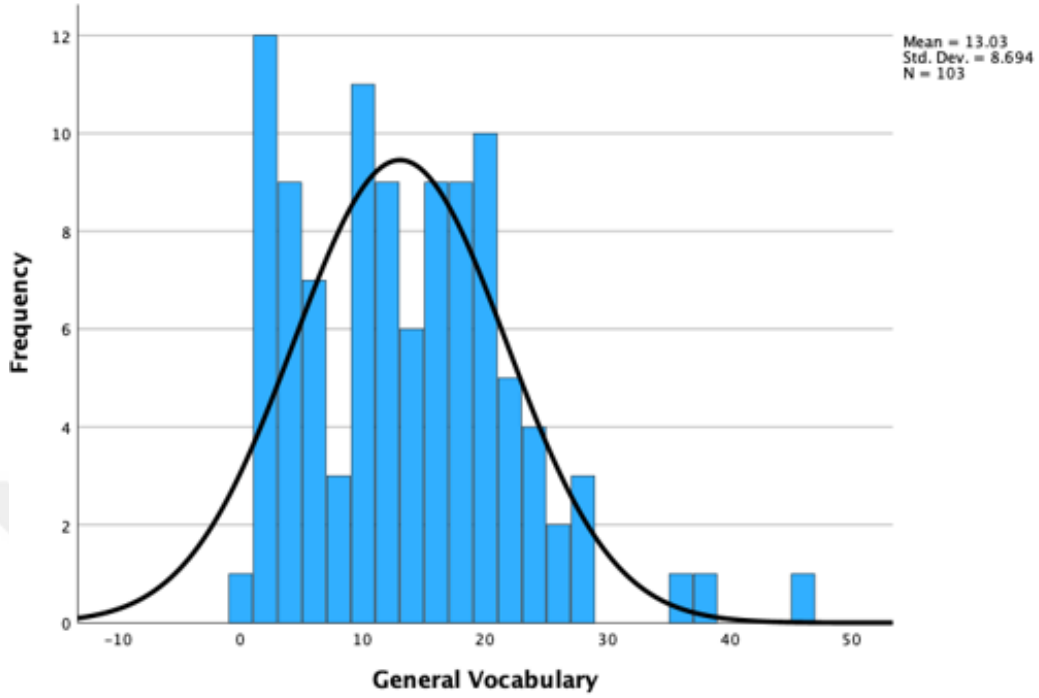


Figure 3.7. Histogram of general vocabulary knowledge scores.

3.5.6. Mathematics Achievement and Reading Comprehension Scores

The participants' LGS exam results were used to measure mathematics achievement and reading comprehension scores in the study. Only the correct answers in the tests were considered for evaluation. Math achievement scores were determined based on the number of correct answers in the mathematics test, while reading comprehension scores were based on the number of correct answers in the Turkish test. The MoNE only announced the results to the participants; the information about exactly which questions were answered correctly and which were not is not announced in the results. Therefore, the current study can only report descriptive information about the collected data. The average scores were 6.03 for the mathematics test and 9.93 for the Turkish test.

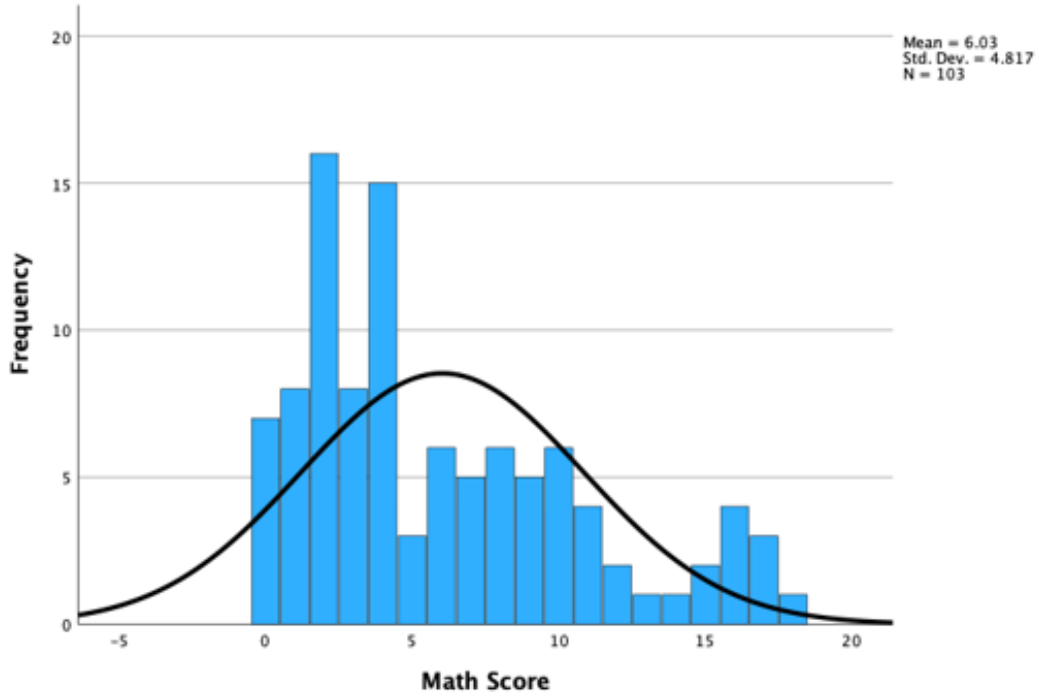


Figure 3.8. Histogram of mathematics scores.

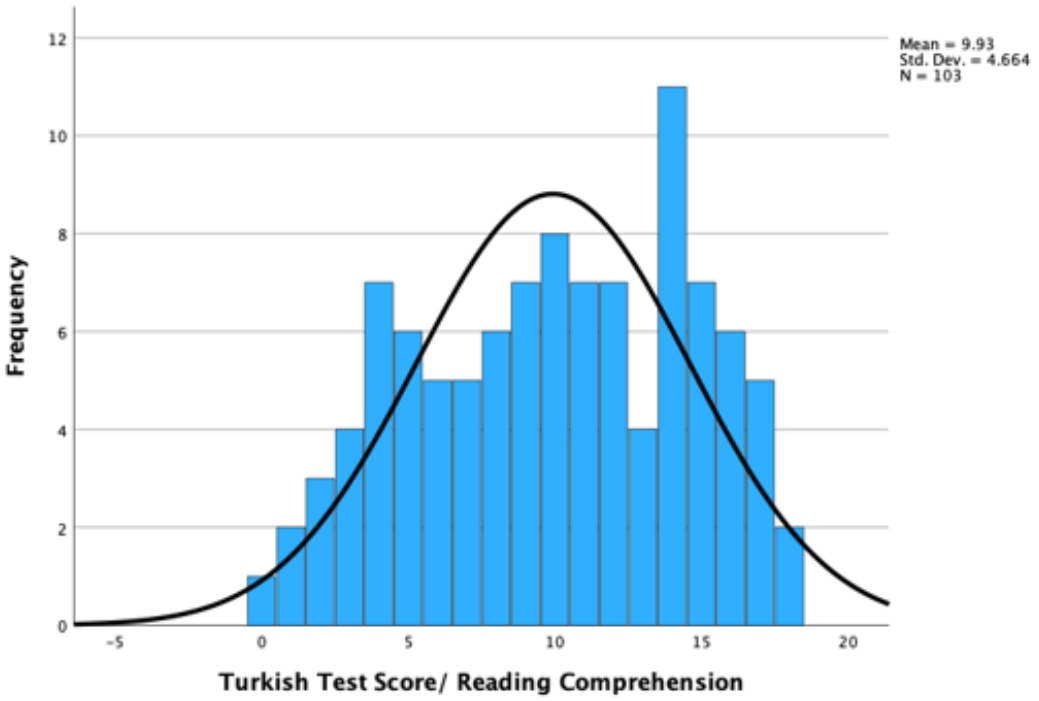


Figure 3.9. Histogram of Turkish test scores.

3.5.7. Regression Analysis

The first research question in the current study was to examine the extent to which mathematics vocabulary knowledge predicts mathematics achievement while controlling for language skills (general vocabulary and reading comprehension) and essential cognitive skills (processing speed, working memory, and non-verbal reasoning). To address this question, multiple regression models were run to analyze the predictive power of mathematics vocabulary knowledge on mathematics achievement, accounting for the effects of the specified language and cognitive skills.

First, correlations among variables were calculated to check the relation between the variables. To effectively address the requirements of the question, utilizing regression analysis is essential for accurate prediction and comprehensive explanation (Huck, 2012). Therefore, firstly, simple regressions were conducted between mathematics achievement scores and the six variables: mathematics vocabulary, general vocabulary, reading comprehension, processing speed, working memory, and non-verbal reasoning. Then, preparation for multiple regression was completed.

Before the analysis, the linearity, multicollinearity, and heteroscedasticity assumptions of multiple linear regression were tested. First, the linearity assumption was tested by sketching scatter plots. The multicollinearity assumption was tested by calculating correlations between independent variables, and afterward, a correlation matrix was examined. Last, the heteroscedasticity assumption was tested by sketching residual plots. Then, model fitting to decide on the control model was completed. Afterward, the mathematics vocabulary variable was included in the control model. The results of each step mentioned are provided in the following results section.

The second research question inquired whether there is a distinct correlation between various types of mathematics vocabulary knowledge - specifically, the vocabulary associated with measurement and data, geometry, or numerical operations and algebra - and mathematics achievement while controlling for language skills (general vocabulary

and reading comprehension) and essential cognitive skills (processing speed, working memory, and non-verbal reasoning).

The examination of the second research question followed similar steps to those used in analyzing the first research question. Initially, correlations between mathematics vocabulary types and mathematics scores were computed. Subsequently, three simple regressions were conducted to investigate the relationship between types of mathematics vocabulary scores and participants' mathematics scores. Then, assumption checking for multiple regression was completed. The same control model in the first question was used in the analysis of the second research question as the dependent variable, and the independent variables were not different. The results of each step mentioned are provided in the following results section.

4. RESULTS

The primary purpose of the study is to investigate the differential relationship between mathematics achievement and mathematics vocabulary knowledge for eighth-grade Turkish students, controlling the possible predictors of math achievement based on the review of related literature: general vocabulary knowledge, reading comprehension skills, processing speed, working memory, and non-verbal reasoning. In order to achieve this goal, multiple linear regression analyses were conducted. The differential relationship between mathematics vocabulary knowledge and its types and mathematics achievement was investigated. In this chapter, the results of the analyses were reported to answer two key research questions. Descriptive and inferential statistics were used to demonstrate the results.

In this section, the findings of the current study will be presented in three parts related to the research questions: (i) preliminary analysis of variables in the study descriptive statistics and assumptions of multiple regression, (ii) the multiple regression of mathematics achievement to mathematics vocabulary, and (iii) the multiple regression of mathematics achievement and types of mathematics vocabulary.

4.1. Preliminary Analysis

4.1.1. Mathematics Achievement and Predictors

In this section, descriptive statistics are provided for key variables, including mathematics achievement, mathematics vocabulary scores, and the specific types of mathematics vocabulary-number, operation, and algebra; measurement and data; and geometry. Additionally, general vocabulary knowledge, reading comprehension, processing speed, working memory, and non-verbal reasoning are included to give a comprehensive overview of the cognitive and linguistic characteristics of the participants. Table 4.1 presents the mean, median, and maximum values, along with standard devi-

ations, skewness, and kurtosis for these variables. These descriptive statistics not only summarize the central tendencies and distributions of the data but also offer critical insights into the nature of the sample. Notably, the results indicate that the participants were predominantly low achieving in mathematics, as evidenced by the mean correct score of 6.03 out of 20 questions, suggesting an achievement rate of just 30% for the group. This finding is particularly valuable in understanding the nuanced relationship between mathematics vocabulary and achievement within this specific population. This information lays the groundwork for the subsequent inferential analyses, providing context for interpreting the relationships among the variables within the framework of low-achieving students.

Table 4.1. Descriptive data of dependent variable and each predictor.

Variable	**Mean**	**Median**	**Max.**	**Std.**	**Skewness**	**Kurtosis**
Mathematics Achievement	6.03	4	18	4.82	0.846	-0.206
Math Vocabulary Total	13.03	12	30	5.51	0.488	-0.319
*Number and Operations and Algebra Vocabulary**	7.32	7	16	3.25	0.512	-0.305
*Measurement and Data Vocabulary**	2.89	3	7	1.70	0.340	-0.227
*Geometry Vocabulary**	2.91	3	7	1.72	0.385	-0.520
General Vocabulary	13.03	12	46	8.70	0.783	1.162
Reading Comprehension	9.93	10	18	4.67	-0.187	-1.010
Processing Speed	18.38	19	30	5.35	-0.339	0.444

Table 4.1 Descriptive data of dependent variable and each predictor. (cont.)

Variable	Mean	Median	Max.	Std.	Skewness	Kurtosis
Working Memory	12.90	13	25	6.81	-0.014	-1.167
Non-verbal Reasoning	35.39	36	51	8.65	-0.287	-0.647
*Note: * Three variables are subcategories of mathematics vocabulary knowledge*						

4.1.2. Testing the Assumptions of Multiple Regression

Keith (2015) outlines four fundamental assumptions that must be verified to ensure the validity of results from multiple regression analysis and to interpret the regression coefficients accurately. These assumptions include linearity, independence of observations, homoscedasticity, and normality of residuals. According to Tabachnick and Fidell (2014), examining residual scatterplots is an effective method to test the assumptions of normality, linearity, and homoscedasticity between predicted dependent variable and errors of prediction. The linearity assumption is one of the most important assumptions for multiple linear regression analysis (Keith, 2015).

Visual inspection of scatterplots and partial regression plots indicated no violation of the linearity assumption. Additionally, residual plots for each predictor were examined for linearity concerns. Although some residuals exceeded 95%, they remained within the acceptable 5% margin of error, confirming that the linearity assumption is not violated for any predictor. Furthermore, the homoscedasticity assumption was evaluated through residual scatterplots, which showed no discernible pattern, indicating that this assumption was also met.

The independence of errors assumption was checked with Durbin-Watson Statistics, residual plots, and p-p plots in each simple regression analysis of mathematics vocabulary to predicters. None of the independent variables has violated the independence of error assumption. The multicollinearity assumption was examined by a

correlation matrix between independent variables. Table 4.2 and Table 4.5 shows the correlations between dependent and independent variables. Even though no perfect correlation was spotted among variables, according to Tabachnick and Fidell (2014), even a correlation of 0.5 or 0.6 can pose difficulties in testing and interpreting regression results. The correlation between general vocabulary and reading comprehension was significant (r= 0.6, $p < 0.01$). This correlation was examined in the model fitting part, and certain measures were taken.

The assumptions of multiple regression were examined using a series of diagnostic graphs and tests for outliers, normality of residuals, homoscedasticity, multicollinearity, linearity, model specification, and independence of errors. Therefore, the regression models provided an acceptable description of the data, as no violations of the assumptions were observed.

4.2. Mathematics Achievement and Mathematics Vocabulary

4.2.1. Bivariate Correlations Among Variables

Bivariate correlations among the dependent and predictor variables are shown in Table 4.2. Results indicated that mathematics achievement scores were significantly correlated with mathematics vocabulary test scores (r= 0.61, $p < 0.01$). Thus, participants with higher mathematics vocabulary knowledge tend to achieve higher mathematics scores. Mathematics achievement results positively correlate with general vocabulary knowledge (r= 0.530, $p < 0.01$), suggesting that better vocabulary skills are related to better mathematics performance.

Table 4.2. Bivariate correlation matrix.

	Math Score	**MVT Score**	**General Voc.**	**Reading Comp**	**Processing S.**	**Working Me.**
MVT Score	0.607**	1				
General Vocabulary	0.530**	0.552**	1			
Reading Comprehension	0.716**	0.493**	0.600**	1		
Processing Speed	0.275**	0.199**	0.074	0.211*	1	
Working Memory	0.349**	0.357**	0.443**	0.276**	0.043	1
Non-verbal Reasoning	0.197*	0.184	0.215*	0.133	0.070	0.221*
Note. * indicates p $<$ 0.05. ** indicates p $<$ 0.01 MVT: Mathematics Vocabulary Test						

According to the correlation matrix, the strongest correlation observed is between mathematics achievement and reading comprehension ($r = 0.716$, $p < 0.01$), indicating that students who excel in mathematics also have strong reading comprehension skills. Mathematics scores of participants show a moderate positive correlation with processing speed ($r = 0.275$, $p < 0.01$). This suggests a relationship between faster cognitive processing and better mathematics scores. Examining the correlation between mathematics achievement and working memory, a moderate positive correlation exists between them ($r = 0.349$, $p < 0.01$), indicating that strong working memory is associated with higher mathematics performance. Finally, mathematics scores have a small but significant positive correlation with non-verbal reasoning skills ($r = 0.197$, $p = 0.047$). Table 4.2 also reveals positive relations among the independent variables. This fact was considered in the model fitting by multiple regression analysis.

4.2.2. Model Testing by Multiple Linear Regression Analysis

First, mathematics achievement and all of the variables were analyzed in the simple linear regression models. The summary of the results of each analysis is presented in Table 4.3. A simple regression analysis revealed that mathematics vocabulary alone explains 37% of the variance in mathematics achievement. However, the literature emphasizes the importance of considering language skills and cognitive abilities when assessing mathematics ability and achievement.

To address this, the analysis was extended to include general vocabulary, reading comprehension, processing speed, working memory, and non-verbal reasoning. This comprehensive approach aimed to determine whether mathematics vocabulary continues to significantly explain the variance in mathematics achievement after controlling for these additional factors.

Examining the simple regression analysis of mathematics achievement to each predictor in the current study yields the result that some of the variables do not have a strong predicting effect on the dependent variable, mathematics achievement.

However, according to Tabachnick and Fidell (2014), even though considering a single independent variable does not increase R^2, several independent variables considered together may do. Additionally, the reviewed literature suggests the relationship between mathematics achievement and cognitive abilities. Therefore, processing speed, working memory, and non-verbal reasoning were included in the models of multiple regressions.

Table 4.3. Summary of simple regression analysis of mathematics achievement on each predictor.

Predictor	***B***	***SE B***	β	***t***	***p***	R^2
Math Vocabulary	0.530	0.069	0.607	7.67	<0.001	0.37
General Vocabulary	0.294	0.047	0.530	6.29	<0.001	0.28
Turkish Score	0.739	0.072	0.716	10.30	<0.001	0.51
Processing Speed	0.247	0.086	0.275	2.87	0.005	0.08
Working Memory	0.247	0.066	0.349	3.739	<0.001	0.12
Non-verbal Reasoning	0.110	0.054	0.197	2.015	0.047	0.04

To determine the control model for the multiple regression analysis, the control variables related to reading skills – general vocabulary and reading comprehension – were first entered in Model A. The results indicated that these reading skills together significantly predicted mathematics achievement, explaining 52.8% of the variance (R^2= 0.528). However, although the two variables together significantly predicted mathematics achievement, general vocabulary was not a significant predictor on its own. This may be due to the high correlation between general vocabulary scores and reading comprehension scores (r= 0.60, p <0.001), suggesting that reading comprehension alone could account for the variance in mathematics scores attributed to the general vocabulary. To address multicollinearity issues, general vocabulary was removed from the analysis. Model β was then constructed by adding processing speed, working memory, and non-verbal reasoning scores to reading comprehension. The results showed that Model B had a significant effect. The standard errors for the reading comprehension variable decreased, while the t-values and standardized coefficients increased compared to Model A. Consequently, Model B was selected as the control model.

Finally, a new model (Model C) was constructed to explain the variance in mathematics achievement by mathematics vocabulary knowledge. According to the final model C, 62% of the mathematics achievement is explained by mathematics vocabulary, reading comprehension, processing speed, working memory, and non-verbal reasoning altogether. According to the results, the increase in the explained variance was significant (ΔR^2= 0.06). The final independent variable, mathematics vocabulary, explained an additional six percent variability above and beyond what already had been explained by the first four variables in Model B (ΔR^2= 0.06). The standard errors of variables decreased, except for reading comprehension and the t-values increased, indicating a better model fit.

Table 4.4. Multiple regression models of the first research question.

Predictor	**Model A**	**Model B**	**Model C**
Intercept	- (0.783) -1.891	-** -1.746 -3.091	-*** -1.644 -3.652
Math Vocabulary			0.290*** (0.066) 3.822
General Vocabulary	0.157 (0.048) 1.831		
Reading comprehension	0.621*** (0.089) 7.235	0.637*** (0.074) 8.910	0.522*** (0.076) 7.089
Processing Speed		0.129 (0.062) 1.876	0.100 (0.058) 1.540
Working Memory		0.152* (0.050) 2.131	0.086 (0.049) 1.252

Table 4.4 Multiple regression models of the first research question. (cont.)

Predictor	**Model A**	**Model B**	**Model C**
Non-Verbal Reasoning		0.069 (0.039) 1.002	0.048 (0.036) 0.734
R^2	0.53	0.56	0.62
F	55.966	30.963	31.131
(df)	-2.100	(4.98)	(5.97)
p	<0.001	<0.001	<0.001
Cell entries are standardized b coefficents, (standard errors), and t-statistics p <0.10, *p < 0.05, **p <0.01, ***p < 0.001			

According to the final model, every four-point change in mathematics vocabulary score results in a one-point change in mathematics achievement. After reading comprehension, the second most important variable in the model is the knowledge of mathematics vocabulary. The increase in mathematics vocabulary knowledge can benefit students' mathematics competencies.

4.3. Mathematics Achievement and Mathematics Vocabulary Types

4.3.1. Bivariate Correlations Among Variables

Bivariate correlations between mathematics achievement and mathematics vocabulary types are presented in Table 4.5. Results indicated a significant relationship between mathematics achievement and types of mathematical vocabulary. Vocabulary associated with numbers and operations and algebra has the strongest correlation comparing the other types ($r = 0.58$, $p < 0.01$). Thus, having a good knowledge of number, operation, and algebra vocabulary can help higher mathematical achievement. However, the correlation between mathematics scores and measurement and data vocabulary is moderately significant ($r = 0.41$, $p <0.01$), indicating the positive effect of measurement and data vocabulary knowledge on mathematics achievement. Geometry vocabulary knowledge also significantly affects mathematics achievement ($r = 0.40$,

$p < 0.01$). The overall relationship provides sufficient reason to conduct a multiple regression analysis.

Table 4.5. Bivariate correlation of mathematics achievement and mathematics vocabulary types.

	Math Score	**Number of Operation and Algebra Vocab.**	**Measurement and Data Vocabulary**
Number, Operation and Algebra Vocab.	0.579**	1	
Measurement and Data Vocabulary	0.409**	0.416**	1
Geometry Vocabulary	0.398**	0.551**	0.415**
Note. * indicates $p < 0.05$. ** indicates $p < 0.01$			

4.3.2. Model Testing by Multiple Linear Regression Analysis

The goal is to explore how students' math performance is related to various types of mathematics vocabulary while also considering their language skills and cognitive abilities. The process for determining the control model is the same as the previous model fitting because the dependent and controlled variables remain unchanged. Therefore, in this section, conducting simple regressions of mathematics achievement on each mathematical vocabulary type is the first step to understanding how predictors affect the dependent. Three simple regressions were conducted in this sense. The summary of the results of each analysis is presented in Table 4.6. Each regression analysis was significant in predicting the variance in mathematics achievement. However, these analyses alone are only meaningful when controlling for other factors that affect mathematics achievement.

Table 4.6. Summary of simple regression of mathematics score to mathematics vocabulary types.

Predictor	***B***	***SE B***	β	***t***	***p***	R^2
Number, operation, and Algebra Vocabulary	0.860	0.120	0.579	7.145	¡0.001	0.34
Measurement and Data Vocabulary	1.157	0.257	0.409	4.506	¡0.001	0.17
Geometry Vocabulary	1.113	0.256	0.398	4.355	¡0.001	0.16

The control model decided on the first research question, and the model fit was used in the model fitting for the second research question. To check the differential relationship between types of mathematics vocabulary -specifically, the vocabulary associated with measurement and data, geometry, or numerical operations and algebra- and mathematics achievement, several models were created for compression and decision. A summary of the models is presented in Table 4.7.

The first multiple regression analysis in the table is the decided model of control variables, leaving the general vocabulary behind among control variables because removing it from the model did not change the explained variance in mathematics achievement significantly. Model D in Table 4.7 summarizes the multiple regression predicting mathematics scores with three mathematics vocabulary types. According to results, all three types together explained 37% of the variance in mathematics achievement ($R^2 = 0.37$). All three types together explained more variance in mathematics achievement than number, operation, and algebra vocabulary; however, this change in the R^2 was not significant than the R^2 value in simple regression analysis of mathematics score to number, operation, and algebra vocabulary only. This means that number, operation, and algebra vocabulary knowledge might predict mathematics achievement more than the other types of mathematics vocabulary. To make this inference, other factors affecting math achievement should be added as a control model.

Model E was employed to check how much variance in mathematics achievement is explained by mathematics vocabulary knowledge controlling language skills and cognitive abilities. In the final model for the second research question, 61% of the variance in mathematics scores was explained by all seven variables ($R^2 = 0.37$). Mathematics vocabulary types explained an additional 5% variance in mathematics achievement ($\Delta R^2 = 0.05$). Examining standardized β coefficients on Table 4.7, the most important predictor of mathematics achievement in the model is reading comprehension. Number, operation, and algebra vocabulary knowledge is the second most important in the model. With the control model's effect, the standard errors in three variables, types of vocabulary knowledge, decreased. Only the standardized coefficient of "number, operations, and algebra vocabulary" remained significant, only in one tail, while the coefficients of other types of mathematics vocabulary decreased significantly. According to the final model (Model E), every one-unit change in number, operation, and algebra vocabulary knowledge results in a 0.13 increase in participants' mathematics scores.

Table 4.7. Model fit for mathematics achievement and vocabulary types.

Predictor	**Model B***	**Model D**	**Model E**	**Model F**
Intercept	-**	-***	-***	-***
	-1.746			
		-1.007	-1.685	(0.866)
	-3.091			
		-1.087	-3.495	-3.950
Number, operation, and Algebra Vocabulary		0.466***	0.130*	0.290***
		(0.146)	(0.130)	(0.112)
		4.739	2.535	3.832
Measurement and Data Vocabulary		0.189*	0.080	0.080
		(0.255)	(0.210)	(0.205)
		2.096	1.075	1.103

Table 4.7 Model fit for mathematics achievement and vocabulary types. (cont.)

Predictor	**Model B***	**Model D**	**Model E**	**Model F**
Geometry Vocabulary		0.062 (0.275) 0.631	0.028 (0.223) 0.354	
Reading comprehension	0.637*** (0.074) 8.910		0.521*** (0.078) 6.883	0.551*** (0.077) 7.407
Processing Speed	0.129 (0.062) 1.876		0.095 (0.060) 1.42	
Working Memory	0.152* (0.050) 2.131		0.088 (0.050) 1.258	
Non-Verbal Reasoning	0.069 (0.039) 1.002		0.045 (0.037) 0.677	
R^2 F (df) p	0.56 30.963 (4.98) < 0.001	0.37 19.584 (3.99) < 0.001	0.61 21.402 (7.95) < 0.001	0.595 48.400 (3.99) < 0.001
Cell entries are standardized β coefficient, (standard errors), and t-statistics p <0.10, *p < 0.05, **p <0.01, ***p < 0.001				

An alternative model to Model D was employed to check whether the removal of geometry vocabulary knowledge significantly influences the explained variance in mathematics achievement. The results revealed that the R^2 almost stayed the same ($\Delta R^2 = 0.002$). Geometry vocabulary knowledge specifically did not have a prediction effect on mathematics achievement, considering, along with other types of mathematics vocabulary. As a result, Model F was constructed with two types of mathematics vocabulary (number, operations, and algebra and measurement and data) and the most significant predictor, reading comprehension. The model explained almost 60% variance in mathematics achievement. Measurement and data vocabulary again, was

not significant in explaining the variance in mathematics achievement in the model. Additionally, removing non-significant variables, cognitive abilities, from the analysis did not significantly change the outcome-the effect remained strong. According to the model, after reading comprehension, number, operation, and algebra vocabulary was identified as the second most important predictor of mathematics achievement.

5. CONCLUSION AND DISCUSSION

This chapter consists of discussions of the research findings, implications, limitations of the study, and recommendations for further studies. The research findings will be discussed in light of the research questions and relevant literature reviews. Educational implications will follow. Then, the current study's limitations and recommendations for further studies will be presented.

5.1. Mathematics Vocabulary and Mathematics Achievement

Based on the research findings, certain crucial considerations need to be taken into account. Firstly, the correlations observed in Table 4.2 and Table 4.5 between mathematics achievement and all the predicting factors are statistically significant, indicating that all the measured factors are connected to the dependent variable to some extent. However, this study specifically focuses on their combined effect.

The first goal of the study was to determine if there was a relationship between mathematics vocabulary and mathematics achievement for middle school students, above and beyond the influence of general vocabulary, reading comprehension, processing speed, working memory, and non-verbal reasoning (i.e., mathematics vocabulary as a predictor). It was found that mathematics vocabulary predicted mathematics achievement for eight-grade Turkish students above and beyond their language skills and cognitive abilities. Results showed that mathematics vocabulary alone explained 37% of the variance in mathematics achievement. However, the literature emphasizes the importance of considering language skills and cognitive abilities when assessing mathematics ability and achievement. To address this, the analysis was extended to include reading comprehension, processing speed, working memory, and non-verbal reasoning. The general vocabulary was removed from the analysis because it was insignificant compared to reading comprehension. The variable was excluded from the analysis because both variables measured language abilities. The general vocabulary

variable did not explain significant variance in mathematics achievement in the model and it was highly correlated with reading comprehension. Therefore, the control model was consisted of reading comprehension, processing speed, working memory, and non-verbal reasoning. Control variables together could explain 56% of the variance in mathematics achievement ($R^2 = 0.56$). The final model, which explained the variance in mathematics achievement by mathematics vocabulary knowledge, explained 62% of the achievement. Hence, 6% of the variance in mathematics achievement resulted from mathematics vocabulary knowledge controlling language and cognitive skills.

The first important finding was that every four-point change in mathematics vocabulary score results in a one-point change in mathematics achievement ($B_{mathvocab}$= 0.25). The mathematics vocabulary score predicted mathematics achievement significantly 6% of the variance in mathematics achievement (ΔR^2= 0.06). These results are particularly relevant when considering that the majority of the participants were identified as low-achieving in mathematics, as evidenced by their average score of 6.03 out of 20, or 30% achievement. This suggests that for students struggling academically, mathematics vocabulary plays a critical role in their ability to succeed in mathematical tasks. The low performance across the group highlights the importance of vocabulary as a foundational skill that could potentially be leveraged to improve overall achievement among low-achieving students. The results are consistent with the arguments in the literature as mathematics vocabulary is a moderate predictor of mathematics achievement (Powel *et al.*, 2017; Powell and Nelson, 2017; Forsyth and Powell, 2017; Peng and Lin, 2019; Lin *et al.*, 2021). Thus, higher proficiency in mathematics vocabulary leads to greater achievement in mathematics. Overall, the findings of this study suggest that a strong understanding of mathematics vocabulary is crucial for success in mathematics. The significant relationship between mathematics vocabulary and achievement underscores the importance of developing students' vocabulary skills to improve their overall performance in math. Educators and researchers should continue exploring ways to enhance mathematics vocabulary instruction to enhance students' mathematical abilities and outcomes ultimately.

Moreover, reading comprehension was the strongest predictor in the model. This result is also consistent with the previous studies (Grimm, 2008; Fuchs *et al.*, 2015; Peng *et al.*, 2020; Ünal, *et al.*, 2023). The final model of multiple regression for the first question revealed that every one-point change in reading comprehension results in a 0.52 standard deviation change in mathematics achievement (R^2= 62%). The connection between reading and mathematics is primarily attributed to domain-general processes, as asserted by Ünal *et al.* (2023). The skills acquired in reading, such as vocabulary and comprehension, are transferable to other subjects, including mathematics. Another example is provided by the research conducted by Ufer and Bochnick (2020) which examined the subject-specific language skills, such as mathematical vocabulary and text comprehension, by sampling 237 3rd graders. The study findings indicated that both mathematical vocabulary and comprehension of text played a significant role in predicting mathematics skills and learning progress. However, mathematical text comprehension had a stronger predictive relationship with mathematics achievement than vocabulary. The study concluded that enhancing both types of language skills is crucial for improving mathematics outcomes in elementary education (Ufer and Bochnik, 2020).

Finally, the results of the multiple regression analysis revealed that cognitive variables did not effectively predict mathematics achievement, contrary to the reviewed literature (Bull and Johnston, 1997; Floyd *et al.*, 2003; Fuchs *et al.*, 2006; Geary and Moore, 2016). Even though the correlations between cognitive abilities and the dependent variable appeared significant, and cognitive abilities individually predicted mathematics achievement in simple regression analysis, they were unable to predict any significant portion of it when combined with reading comprehension (see Table 4.3 and Table 4.4). The findings are intriguing because Bull and Johnston (1997) discovered that processing speed was the most significant predictor of mathematics achievement, even after controlling for reading abilities. In our current study, we also controlled for reading skills, but it appears that processing speed did not significantly impact mathematics achievement with other variables.

The reason behind this result could develop from several aspects. First, the difference in sample characteristics between the studies might play a role. The current study included a differentiated sample in terms of age, educational background, or cognitive development, which could influence the predictive power of cognitive variables. This focus on a low-achieving cohort could influence the predictive power of cognitive variables, as these students may engage differently with academic tasks compared to their higher-achieving peers. Second, the measures of cognitive abilities and mathematics achievement used in the current study differed from those used in previous research, affecting the comparability of results. Additionally, the interaction between cognitive abilities and reading comprehension might be more complex than previously understood, with reading comprehension possibly mediating the relationship between cognitive abilities and mathematics achievement. Lastly, the dual-process hypothesis of higher cognition proposes that individuals engage in the autonomous processing of familiar information, which requires fewer cognitive resources. In contrast, they engage in the controlled processing of novel information, which requires a greater allocation of cognitive resources (Evans and Stanovich, 2013). Hence, engaging in an academic task during the initial stages of learning involves greater cognitive effort and demands, whereas as one progresses and acquires more knowledge, cognitive abilities may become less involved, leading individuals to rely more on directly retrieving information from long-term memory (Peng and Kievit, 2020). The findings of insignificant cognitive abilities could contribute to the hypothesis, as the sample in the study is older than the groups mostly researched on the issue.

Overall findings in the first research question align with the meta-analysis conducted by Lin *et al.* (2020). Seven studies on mathematical vocabulary knowledge and mathematics achievement were controlled for the cognitive and comprehension skills of the participants, similar to the current study. Similar to the meta-analyses, the findings of this study are generally in line with the Developmental Function Hypothesis of Language for Mathematics proposed by Peng *et al.* (2020). According to the theory, individuals might use language to access mathematical knowledge and enhance working memory and reasoning while learning mathematics.

In the context of this study, the use of LGS Mathematics scores is particularly relevant given the exam's status as a high-stakes test that plays a critical role in shaping students' educational trajectories. Despite its limitations, such as variability in difficulty and discrimination indices across different years, the LGS remains a widely recognized measure of mathematics achievement in Turkey. The significant predictive effect of mathematics vocabulary on mathematics achievement, as evidenced in the study, becomes even more pronounced when considering the results of high-stakes exams like the LGS. For low-achieving students, the LGS scores provide valuable insight into the specific areas where these students struggle, particularly in mathematics vocabulary.

Given that the LGS is a crucial measure used to determine high school placements, it is not only a reflection of students' current academic abilities but also a determinant of their future educational opportunities. The study's findings, which highlight the role of mathematics vocabulary in predicting LGS Mathematics scores, suggest that enhancing vocabulary skills could be a key strategy for improving overall achievement, especially among students who perform poorly. The variability in LGS performance among these low-achieving participants underscores the importance of targeted interventions focused on vocabulary development as a means to boost their mathematics performance. This connection between vocabulary knowledge and LGS outcomes reinforces the need to consider high-stakes exam results in educational research, particularly when examining factors that influence academic success in critical subject areas like mathematics.

5.2. Types of Mathematics Vocabulary and Mathematics Achievement

In exploring the second research question, an examination of the relationship between mathematical vocabulary knowledge, mathematics achievement, and controlling language and cognitive factors involved the calculation of separate subcategories of vocabulary knowledge in addition to the overall MVT score. Three groups of mathematics vocabulary were used: (i) number, operation, and algebra, (ii) measurement and data, and (iii) geometry. Each simple regression analysis of one vocabulary group

on mathematics achievement was found to be significant. However, the multiple regression model with three predictor vocabulary types and dependent mathematics achievement revealed that the geometry vocabulary was no longer significant in predicting mathematics achievement. The control model was the same as the previous research question since the factors that the study controlled did not differ from the current question. The multiple regression model of mathematics vocabulary types on mathematics achievement controls for language skills and cognitive abilities. The model explained 61% of the mathematics achievement variance. However, with the entrance of control variables, only one number, operation, and algebra vocabulary were significant in the achievement. Only number, operation, and algebra mathematics knowledge significantly predicted mathematics achievement. However, the measurement and data vocabulary effect were no longer significant. Since there were several insignificant variables in the control model, the model was tested again without cognitive abilities to check whether two types of mathematics vocabulary found to be significant when tested for three types altogether can predict mathematics achievement with the strongest control variable, reading comprehension. The results showed that measurement and data type failed to be significant predictors. There are several points to discuss about the findings.

The significance that relies solely on number, operation, and algebra vocabulary may stem from the fact that this knowledge could account for the variation caused by the other two types. Although reading comprehension is the most influential variable overall, a strong knowledge of number, operation, and algebra vocabulary can significantly account for the variation in mathematical achievement even after controlling for reading comprehension.

The reason for the discrepancy could be attributed to the content of the mathematics achievement test. The test was comprehensive and aligned with the specified mathematics curriculum (MoNE, 2024a). As per the curriculum, different subjects were given varying emphasis and time allocation (MoNE, 2018). Numbers, operations, and algebra were prioritized in the curriculum, leading to these topics being more

heavily tested than others. This emphasis on numbers, operations, and algebra may explain why these topics show a strong correlation with mathematics achievement. In fact, a one-unit change in the vocabulary related to numbers, operations, and algebra accounts for 0.13 and 0.29 variance in mathematics achievement in the multiple regression models with and without cognitive variables, respectively. This aligns with the findings of Peng *et al.* (2019), who found that measurement and geometry vocabulary predict mathematics achievement, which was measured by a test in which measurement and geometry were the overweighted topics. Researchers also suggested that this might affect the results of the study. Therefore, the same results can be concluded for the current study.

In addition, highlighting some parts of the curriculum by including some topics more than others depicts their importance. This is in support of the time-on-task theory. Basically, the time-on-task theory, formulated by John B. Carroll in the 1960s, proposes that the real amount of time a learner spends on participating in learning activities directly relates or influences the comprehended and achieved learning results of the student (Carroll, 1989). Carroll's model of school learning postulates that learning is a function of the time spent on learning relative to time needed to learn. This theory has been supported by empirical research that shows that increased time spent on engagement enhances learning outcomes. Consequently, the greater the weight given to a topic in the curriculum, the more time spent on it, leading to better comprehension. Thus, focused time and efforts spent on topics prioritized for study within the curriculum can explain the variance observed in mathematics achievement according to mathematics vocabulary types.

Studies that worked on specific mathematics vocabulary to specific mathematics skills are present in the reviewed literature (Ufer and Bochnik, 2020; Stevens *et al.*, 2024). For example, Stevens *et al.* (2024) conducted a study about word problem-solving and concluded that word problem vocabulary knowledge explains the variance in word problem-solving ability. No specific grouping of mathematics achievement was studied in the current study because the results announced also are not reachable by the

participants in the LGS exam. Therefore, conducting such an analysis was not feasible. However, exploring that directional relationship could offer a more comprehensive understanding and illuminate more significant connections.

Overall, this study investigated the relationship between mathematics vocabulary and mathematics achievement. Findings showed that after controlling reading comprehension, processing speed, working memory, and non-verbal reasoning, mathematics vocabulary has uniquely contributed to mathematics achievement. Vocabulary related to numbers, operations, and algebra was more important to mathematics achievement than other types of mathematics vocabulary.

5.3. Implications

The findings of the current study suggest some educational implications. Given that the majority of the participants in this study were identified as low-achieving in mathematics, the findings underscore the importance of targeted instructional strategies that prioritize the development of mathematics vocabulary. The data revealed that these students struggle significantly with mathematical concepts. This suggests that a strong grasp of mathematics vocabulary could be a key factor in improving their overall performance. By focusing on vocabulary enhancement, educators can help bridge the gap between students' understanding and their ability to apply mathematical concepts effectively. Such interventions could potentially mitigate some of the challenges faced by low-achieving students, enabling them to engage more confidently with the subject matter. This is especially critical in light of the high-stake testing environments where vocabulary plays a crucial role in both comprehension and problem-solving. Therefore, reinforcing mathematics vocabulary might not only support students in mastering the content but also build a stronger foundation for future learning and achievement.

Moreover, the results may offer valuable insights for curriculum developers. According to task-on-test theory (Carroll, 1989), aligning the curriculum with desired outcomes could potentially support the enhancement of mathematics vocabulary knowledge. Critical areas in the curriculum might be emphasized based on the importance of mathematics vocabulary knowledge. In 2024, a new curriculum for middle school mathematics was announced, to be implemented in the following years, starting with fifth graders in the academic year 2024-2025. Future research can explore the role of math vocabulary in the revised curriculum (MoNE, 2024e). Nevertheless, it will take time to thoroughly evaluate the impact of the new curriculum on students' math abilities.

The current study's other finding that reading comprehension predicted mathematics achievement aligns with previous research exploring the relationship between language skills and mathematics achievement (Grimm, 2008; Fuchs *et al.*, 2015; Peng *et al.*, 2020; Ünal *et al.*, 2023). This suggests that effective reading comprehension strategies may positively influence students' mathematical achievement. Therefore, teachers might consider using interdisciplinary approaches that connect language skills with mathematical concepts.

In addition to reading comprehension, the results indicated that mathematics vocabulary is a significant predictor of mathematics achievement, consistent with the reviewed literature (Forsyth and Powell, 2017; Powel *et al.*, 2017; Powell and Nelson, 2017; Peng and Lin, 2019; Lin *et al.*, 2021). Teachers implementing the curriculum may need to consider the potential influence of mathematics vocabulary on mathematics achievement. Studies on fifth-grade students suggest that explicit instruction on mathematics vocabulary and terms can enhance mathematics vocabulary performance (Powell and Driver, 2014). Consequently, teachers might design their lessons to improve students' mathematics vocabulary abilities and consider professional development courses on effective strategies for doing so.

5.4. Limitations

The findings of the study must be interpreted in light of several limitations. Firstly, the study was conducted at a single state school, encompassing only eight eighth-grade classes during the 2023-2024 academic year. With a total of 108 participants out of 220 eligible students, the sample size was deemed insufficient to make generalizations about all eighth-grade students in Turkey. Upon conducting a descriptive analysis of the data, it became evident that the sample did not adequately reflect the school's overall performance, as the mean scores in the LGS exam were higher than those of the sample. Also, while the study did not initially aim to focus on low-achieving students, the discovery that this group formed the majority of the sample provides valuable insights but also presents a limitation in terms of generalizability. Future research endeavors should address this limitation by involving a larger and more diverse sample from multiple schools, thereby yielding more representative and generalizable results.

The tests were specifically created to be administered online in order to accommodate time constraints and to ensure that a greater number of students could participate. However, it is important to acknowledge that online data collection methods carry a risk of malfunction, even when participants have been well-informed about the process. Therefore, future research studies should explore alternative approaches to data collection for assessing cognitive skills and compare the results to determine any variations in the analysis.

Another limitation to consider is the analysis of LGS exam scores, as participant responses to incorrect or unanswered questions are not specified in the results. The reliability scores of the test were not announced by the MoNE, thus remaining unreported in the study. However, it is assumed that the test needs to demonstrate reliability, given its selective nature. Nonetheless, using the LGS exam for achievement scores is also a strength, as it is a valid exam established by the MoNE.

Lastly, the MVT was a test prepared by Ünal *et al.* It contained some questions that the participants had not encountered before. Therefore, the test could be modified to align with the curriculum outcomes. However, this was not an option due to time limitations in the current study. While preparing and testing a test before applying it is valuable, this process requires time, which the current study lacked.

5.5. Suggestions for Future Studies

Future studies should explore the relationship between different types of mathematics vocabulary and various mathematics skills. This can provide deeper insights and inform targeted instructional strategies to address specific learning needs. The studies mentioned the relationship between specific vocabulary and a specific mathematics ability mostly involved English-speaking participants or non-Turkish samples (Powell and Driver, 2014; Peng and Lin, 2019; Reinhold *et al.*, 2020). Therefore, investigating the same connections among Turkish-speaking participants can lead to a better comprehension of variations stemming from cultural differences.

Furthermore, future studies can utilize broader vocabulary tests that cover essential mathematics vocabulary, as this study lacks comprehension and only measured the vocabulary mostly specified with the eighth grade. Implementing targeted achievement tests, specifically tailored to evaluate students' mathematical abilities, could help to gain deeper insights into the relationship between mathematics vocabulary and achievement. Additionally, types of mathematics ability, for instance, problem solving and arithmetic and their relation with types of mathematics vocabulary, is an important aspect to be investigated for Turkish students. This could provide a more comprehensive understanding of students' strengths and areas needing improvement, ultimately contributing to a more effective educational approach.

Finally, as the current study is correlational in nature intervention studies could be utilized to investigate the causal relationship between mathematics vocabulary and mathematics achievement.

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APPENDIX A: MATHEMATICS VOCABULARY TEST

Mathematics Vocabulary Test (Ünal *et al.*, 2021)

Table A.1. Mathematics vocabulary test.

Aşağıdaki örnek soruları öğretmeninizle birlikte cevaplandırınız.
Aşağıda üç soru tipi verilmiştir.
1. soruda verilen tanıma uygun kavramı seçmeniz gerekmektedir.
2. soruda verilen kavrama en uygun olan tanımı seçmeniz gerekmektedir.
3. soruda boşluğa gelebilecek en uygun olan kavramı seçmeniz gerekmektedir.
Örnekler:
1. Bir çemberin etrafında bir tur atıldığında alınan yoldur. A) Çemberin çevresi B) Çemberin alanı C) Çemberin çapı D) Çemberin merkezi
2. Çap; A) Bir çemberin merkezinden geçen ve çemberi beş eşit parçaya bölen doğru parçasıdır. B) Bir çemberin çevresinden geçen ve çemberi iki eşit parçaya bölen doğru parçasıdır. C) Bir çemberin merkezinden geçen ve çemberi iki eşit parçaya bölen doğru parçasıdır. D) Bir çemberin çevresinden geçen ve çemberi beş eşit parçaya bölen doğru parçasıdır.
3. İki sayının oranını sayıları ..... bulunur. A) Toplayarak B) Çıkararak C) Bölerek D) Çarparak

Table A.1 Mathematics vocabulary test. (cont.)

1) İki tam sayının oranı şeklinde yazılamayan sayılardır. A) Rasyonel sayılar B) Doğal sayıları C) Kare köklü sayılar D) İrrasyonel sayılar
2) Rasyonel sayılar ve irrasyonel sayıların birleşimidir. A) Tam sayılar B) Kare köklü sayılar C) Gerçek sayılar D) Doğal sayılar
3) Bir üslü ifadede, kendisiyle tekrarlı çarpılan sayıdır. A) Taban B) Kuvvet (üs) C) Tam kare sayı D) Kare köklü sayı
4) Tam kare sayılar; A) Bir irrasyonel sayının karesi şeklinde yazılan sayılardır. B) Bir tam sayının karekökü şeklinde yazılan sayılardır. C) Bir tam sayının karesi şeklinde yazılan sayılardır. D) Bir irrasyonel sayının karekökü şeklinde yazılan sayılardır.
5) Sayıların kendileriyle tekrarlı çarpımlarının kısaca gösterimidir. Taban ve kuvvet (üs) kullanılarak ifade edilir. A) Kuvvet (üs) B) Kare köklü sayı C) Taban D) Üslü sayı
6) Kare köklü ifade; A) $<$ Sembolü kullanılarak yazılan ifadelerdir. B) $\surd$ Sembolü kullanılarak yazılan ifadelerdir. C) $\neq$ Sembolü kullanılarak yazılan ifadelerdir. D) $\geq$ Sembolü kullanılarak yazılan ifadelerdir.

Table A.1 Mathematics vocabulary test. (cont.)

7) $1 \leq c < 10$ ve n bir tamsayı iken c x 10^n şeklinde yazılan gösterim biçimidir. A) Bilimsel gösterim B) Kare köklü gösterim C) Rasyonel gösterim D) Cebirsel gösterim
8) m bir sayı olmak üzere, herhangi bir n sayısının $m^2 = n$ şeklinde yazılmasıdır. A) Bilimsel gösterim B) Karekök alma C) Kuvvet (üs) D) Taban
9) a, b ve c gerçek sayılar, $a \neq 0$ ve $b \neq 0$ olmak üzere, ax + by + c = 0 şeklinde yazılabilen denklemlerdir. A) 2 bilinmeyenli doğrusal olmayan denklemin tanımı B) 3 bilinmeyenli doğrusal olmayan denklemin tanımı C) 3 bilinmeyenli doğrusal denklemin tanımı D) 2 bilinmeyenli doğrusal denklemin tanımı
10) m eğim ve by ekseninin kesim noktası olmak üzere, doğrusal denklemlerin $y = mx + b$ şeklinde ifade edilmesidir. A) Eğim B) Doğrusal olmayan denklem formu C) Y ekseni kesim noktası formu D) Eğim kesim noktası
11) Tanım kümesinin her elemanını değer kümesinin yalnız ve yalnız bir tek elemanına eşleştiği bağıntıdır. A) Fonksiyon B) Sabit terim C) Denklem D) Benzer terim
12) Cebirsel ifadelerde değişkeni çarpan sayılar. A) Sabit terim B) Benzer terim C) Katsayı D) Denklem

Table A.1 Mathematics vocabulary test. (cont.)

13) Sabit terim; A) Cebirsel ifadelerde değişkeni çarpan sayılar. B) Değişkenleri ve değişkenlerinin üsleri aynı olan terimler. C) Cebirsel ifadede değişken içermeyen bir terimdir. D) Bir cebirsel ifadede yer alan harfli ifadeler.
14) Benzer terimler; A) Değişken içermeyen bir terimler. B) Katsayıları aynı olan terimler. C) Sabit terimleri ve değişkenleri aynı olan terimler. D) Değişkenleri ve değişkenlerinin üsleri aynı olan terimler.
15) Bir cebirsel ifadede yer alan harfli ifadeler. A) Sabit terim B) Değişken C) Katsayı D) Denklem
16) Terim; A) Bir cebirsel ifadeyi oluşturan toplananların veya çıkarılanların her biridir. B) Bir cebirsel ifadeyi oluşturan bölünen sayıların her biridir. C) Bir cebirsel ifadeyi oluşturan bölünen veya çarpılanların her biridir. D) Bir cebirsel ifadeyi oluşturan çarpılanların her biridir.
17) Sayısal ifadeler; A) Sadece rakam, değişken ve işlemlerden oluşan matematiksel ifadelerdir. B) Sadece işlem ve sayılardan oluşan matematiksel ifadelerdir. C) Sadece rakamlardan ve değişkenlerden oluşan matematiksel ifadelerdir. D) Sadece işlemden oluşan matematiksel ifadelerdir.
18) Rakam, değişken ve işlemlerden oluşan matematiksel ifadelerdir. A) Cebirsel ifadeler B) Sayısal ifadeler C) Üslü ifadeler D) Kare köklü ifadeler

Table A.1 Mathematics vocabulary test. (cont.)

19) Dikey uzunluk; A) İki noktadan geçen dikey doğrudur B) Koordinat düzleminde x eksenini kesen dikey doğrudur C) Birbirine paralel yatay iki doğruyu kesen dikey doğrudur D) Bir doğru üzerinde, iki nokta arasındaki dikey değişimdir.
20) Yatay uzunluk; A) Bir doğru üzerinde, iki nokta arasındaki yatay değişimdir. B) İki noktadan geçen yatay doğrudur. C) Koordinat düzleminde y eksenini kesen yatay doğrudur. D) Birbirine paralel yatay iki doğruyu kesen dik doğrudur.
21) Eğim; A) Dikey uzunluğun yatak uzunlukla orantısıdır. B) Dikey uzunluğun yatay uzunluğa oranıdır. C) Yatay uzunluğun dikey uzunlukla orantısıdır. D) Yatay uzunluğun dikey uzunluğa oranıdır.
22) Bir şekli genişletirken, genişletmek için kullanılan referans noktasıdır. A) Genişletme doğrusu B) Genişletme açısı C) Genişletme merkezi D) Genişletme figürü
23) Dönme merkezi; A) Bir şekli döndürürken, döndürmek için kullanılan referans çizgisidir. B) Bir şekli döndürürken, döndürmek için kullanılan referans açısıdır. C) Bir şekli döndürürken, döndürmek için kullanılan referans kenarıdır. D) Bir şekli döndürürken, döndürmek için kullanılan referans noktasıdır.

Table A.1 Mathematics vocabulary test. (cont.)

24) Bir şeklin sabit bir noktaya göre büyültülüp küçültülmesidir. A) Dönme B) Genişletme/daraltma C) Öteleme D) Dönüşüm
25) Yansıma; A) Bir şeklin bir eksen boyunca görüntüsünün eksenin diğer tarafında oluşmasıdır. B) Bir şeklin her noktasının aynı yönde ve eşit miktarda hareket ettirilmesidir. C) Bir şeklin bir nokta etrafında büyültülüp küçültülmesidir. D) Bir şeklin bulunduğu konumda veya büyüklüğünde yapılan değişiklikle yeni bir şeklin oluşturulmasıdır.
26) Bir şeklin her noktasının aynı yönde ve eşit miktarda hareket ettirilmesidir. A) Dönüşüm B) Öteleme C) Yansıma D) Ötelemeli yansıma
27) Dönme; A) Bir şeklin bir eksen boyunca görüntüsünün eksenin diğer tarafında oluşmasıdır. B) Bir şeklin her noktasının aynı yönde ve eşit miktarda hareket ettirilmesidir. C) Bir şeklin bir nokta etrafında büyültülüp küçültülmesidir. D) Bir şeklin bulunduğu konumda veya büyüklüğünde yapılan değişiklikle yeni bir şeklin oluşturulmasıdır.

Table A.1 Mathematics vocabulary test. (cont.)

28) Bir şekil saat yönünde veya saat yönünün tersi yönünde 180 ° döndürüldüğünde aynı şekil elde ediliyorsa bu şekil . . . . . ne sahiptir. A) Açı simetrisi B) Dönme simetrisi C) Yansıma simetrisi D) Merkez simetrisi
29) Dönüşüm; A) Bir şeklin bir eksen boyunca görüntüsünün eksenin diğer tarafında oluşmasıdır. B) Bir şeklin her noktasının aynı yönde ve eşit miktarda hareket ettirilmesidir. C) Bir şeklin bir nokta etrafında büyültülüp küçültülmesidir. D) Bir şeklin bulunduğu konumda veya büyüklüğünde yapılan değişiklikle yeni bir şeklin oluşturulmasıdır.
30) Yöndeş açı; A) İki doğrunun bir kesenle oluşturduğu açılardan kesenin aynı tarafında ve biri içte, diğeri dışta olan açılar. B) İki doğrunun bir kesenle oluşturduğu açılardan kesenin aynı tarafında ve ikisi de dışta olan açılar. C) İki doğrunun bir kesenle oluşturduğu açılardan kesenin aynı tarafında ve ikisi de içte olan açılar. D) İki doğrunun bir kesenle oluşturduğu açılardan kesenin zıt tarafında ve biri içte, diğeri dışta olan açılar.
31) İki geometrik şekilde birbirleriyle aynı yöne bakan açı veya kenar çiftleridir. A) Bütünler açılar/kenarlar B) Karşılıklı noktalar C) Karşılıklı açılar/kenarlar D) Tümler açılar/kenarlar

Table A.1 Mathematics vocabulary test. (cont.)

32) Karşılıklı açılarının ölçüleri eşit ve karşılıklı kenarlarının uzunlukları birbiriyle orantılı olan şekillerdir. A) Karşılıklı şekiller B) Simetrik şekiller C) Benzer şekiller D) Karşılıklı kenarlar
33) Kesen; A) Paralel olan iki doğrunun arasındaki uzaklıktır. B) Bir açıyı kesen doğrudur. C) Paralel olan veya paralel olmayan iki doğrunun her biriyle farklı bir noktada kesişen üçüncü bir doğrudur. D) Paralel olmayan iki doğrunun birbiriyle kesişme noktasıdır.
34) Bir grafikteki serpilmiş şekilde bulunan bütün noktalara olabilecek en yakın mesafeden çizilen doğru. A) Ölçek B) En iyi uyan doğru C) Kesen D) Simetri doğrusu
35) Koordinat düzleminde bir noktayı göstermek için kullanılan (x,y) sayı çiftidir. İlk sayı x koordinatı, ikinci sayı y koordinatıdır. A) Koordinat ekseni B) Benzer ikili C) Koordinat düzlemi D) Sıralı ikili
36) Bir koordinat düzleminde sıralı ikilileri gösteren grafik. Her ikili grafikte birer nokta olarak gösterilmiştir. A) Saçılım grafiği B) Daire grafiği C) Kesen D) Simetri doğrusu

APPENDIX B: CONSENT FORM TEMPLATE

T.C.
BOĞAZİÇİ ÜNİVERSİTESİ
FEN BİLİMLERİ VE MÜHENDİSLİK ALANLARI
İNSAN ARAŞTIRMALARI ETİK KURULU
KATILIMCI BİLGİ ve ONAM FORMU

Araştırmayı destekleyen kurum: -
Araştırmanın adı: Investigating the Relation Between Mathematics Vocabulary Knowledge and Mathematics Performance Among Eighth Graders (Sekizinci Sınıf Öğrencilerinin Matematik Kelime Bilgisi ile Matematik Performansları Arasındaki İlişkinin İncelenmesi)
Proje Yürütücüsü/Araştırmacının adı: Doç. Dr. Serkan Özel
Adresi: Eğitim Teknolojileri Binası ET-412 Kuzey Kampüs Boğaziçi Üniversitesi Bebek/İstanbul
E-mail adresi: ozels@bogazici.edu.tr
Telefonu: 0-212-359-6592

Sayın Veli,

Boğaziçi Üniversitesi Matematik ve Fen Bilimleri Bölümü öğretim üyesi Dr. Serkan Özel "Sekizinci Sınıf Öğrencilerinin Matematik Kelime Bilgisi Türleri ile Matematik Performansları Arasındaki İlişkinin İncelenmesi" adı altında bilimsel bir araştırma projesi yürütmektedir. Bu çalışmanın amacı, sekizinci sınıf öğrencilerinin matematik kelime bilgileri ile matematik başarısı arasındaki ilişkiyi incelemektir. Matematik başarısı literatürde çeşitli bilişsel yetenekler ile ilişkilendirilmiştir. Bu sebepten

araştırmaya katılan öğrencilerin matematik kelime bilgisi yanında sözcük dağarcığı, okuduğunu anlama, bilişsel yetenekler olan karar hızı, işler bellek ve muhakeme yeteneklerini ölçmeyi amaçlayan testler uygulanacaktır. Matematik kelime bilgisinin matematik başarısı üzerindeki etkilerini ölçmeyi amaçlayan bu araştırmaya katılmak üzere çocuğunuzu davet ediyoruz. Kararınızdan önce araştırma hakkında sizi bilgilendirmek istiyoruz.

Bu bilgileri okuduktan sonra araştırmaya katılmak isterseniz lütfen aşağıdaki bağlantıdaki onam formunu doldurunuz.

Onam Formu Bağlantısı: ....

Araştırmaya katılımcı olma kriterimiz, çocuğunuzun 8. sınıf öğrencisi olmasıdır. Bu kriter sağlandığı takdirde velisinin onayı olan her öğrenci çalışmaya katılabilmektedir.

Araştırmaya katılmayı kabul ettiğiniz takdirde, öğrenciniz bilişsel düşünme becerisi, problem çözme becerisi ve öz-yeterlilik ve motivasyon testlerini çözecektir. Öğrencinin çalışmaya katılması tamamen isteğe bağlıdır. Sizden ücret talep etmiyoruz ve size herhangi bir ödeme yapmayacağız. İstediğiniz zaman çalışmaya katılmaktan vazgeçebilirsiniz. Bu durumda öğrencinin test formları imha edilecektir.

Yapmak istediğimiz araştırmanın öğrencilere risk getirmesi beklenmemektedir. Aynı zamanda çalışmanın öğrencilere bir yarar getirip getirmeyeceği konusunda size söz veremeyiz.

Araştırmanın ileride matematik eğitimi müfredatı geliştirmede yarar sağlaması muhtemeldir.

Değerlendirme verileri çocuğunuza atadığımız bir kod numarası aracılığı ile toplanacaktır. Bu şekilde, çocuğunuza ve size ait kişisel bilgiler koruma altına alınacaktır.

Bu araştırmaya katılmak tamamen isteğe bağlıdır. Katıldığınız takdirde çalışmanın herhangi bir aşamasında herhangi bir sebep göstermeden onayınızı çekme hakkına da sahipsiniz. Araştırma projesi hakkında ek bilgi almak istediğiniz takdirde lütfen Boğaziçi Üniversitesi Matematik ve Fen Bilimleri Eğitimi Bölümü Öğretim Üyesi Doç. Dr. Serkan Özel ile temasa geçiniz (Telefon: 0- 212- 359- 65 92, e-posta: ozels@bogazici.edu.tr, Adres: Boğaziçi Üniversitesi, Eğitim Fakültesi ET 412, 34342 Bebek, İstanbul). Araştırmayla ilgili haklarınız konusunda Boğaziçi Üniversitesi Fen Bilimleri ve Mühendislik Alanları İnsan Araştırmaları Etik Kurulu'na (fminarek @ boun. edu. tr) danışabilirsiniz.

Ben, (katılımcının velisinin adı) ....., yukarıdaki metni okudum ve çocuğumun katılması istenen çalışmanın kapsamını ve amacını, gönüllü olarak üzerime düşen sorumlulukları tamamen anladım. Çalışma hakkında soru sorma imkânı buldum. Bu çalışmayı istediğim zaman ve herhangi bir neden belirtmek zorunda kalmadan bırakabileceğimi ve bıraktığım takdirde herhangi bir ters tutum ile karşılaşmayacağımı anladım. Bu koşullarda söz konusu araştırmaya kendi isteğimle, hiçbir baskı ve zorlama olmaksızın katılmayı kabul ediyorum. Formun bir örneğini aldım / almak istemiyorum (bu durumda araştırmacı bu kopyayı saklar).

Katılımcının Adı-Soyadı: .....
İmzası: .....
Adresi (varsa Telefon No, Faks No): .....
Tarih (gün/ay/yıl): . . . /...../.....
Katılımcının Velisinin Adı-Soyadı: .....
İmzası: .....
Tarih (gün/ay/yıl): ...../...../.....
Araştırmacının Adı-Soyadı: .....
İmzası: .....
Tarih (gün/ay/yıl): . . . /...../.....