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The Relationship Between Reading and Mathematics Achievement: Findings from Meta-Analysis

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Abstract

This meta-analysis study aims to analyse the findings of quantitative studies examining the relationship between reading skills and mathematics achievement. Articles discussing the relationship between reading skills and mathematics achievement in the education field constitute this study's data source. Data from 13 studies and 397882 students were combined. The Difference in Standardized Means was used to calculate the effect size in the meta-analysis. Quantitative data such as correlation, t-value, p-value, mean, standard deviation and sample size were obtained from each study. Inter-coder reliability was ensured by receiving a 92% agreement rate with two independent coders. Meta-analysis was performed with Comprehensive Meta-Analysis software, and both fixed and random effects models were examined. Heterogeneity in effect sizes was determined by Q and I2 analyses. Publication bias was tested with four different methods. The results underline a strong link between reading and math achievement. However, the data analysis reveals heterogeneity, suggesting a potential complexity in this relationship and that the influence of various factors may vary. The study found no statistically significant differences between subgroups. Moderators such as education level, geographical location and type of research did not significantly affect the relationship between reading and math achievement. This suggests that the relationship between reading and math achievement is generally consistent across different groups. This meta-analysis of the relationship between reading and math achievement has critical educational practice and policy implications.

Keywords: Reading, Mathematics, Achievement, Meta-analysis

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Okumak ve Matematik Başarısı Arasındaki İlişki: Meta Analizden Bulgular

Özet

Bu meta-analiz çalışması, okuma becerileri ile matematik başarısı arasındaki ilişkiyi inceleyen nicel araştırmaların bulgularını analiz etmeyi amaçlamaktadır. Eğitim alanında okuma becerileri ile matematik başarısı arasındaki ilişkiyi inceleyen makaleler bu çalışmanın veri kaynağını oluşturmaktadır. Toplam 13 çalışma ve 397882 öğrenciden elde edilen veriler birleştirilmiştir. Meta analizde etki büyüklüğünü hesaplamak için Standartlaştırılmış Ortalamalardaki Fark kullanılmıştır. Her çalışmadan korelasyon, t-değeri, p-değeri, ortalama, standart sapma ve örneklem büyüklüğü gibi nicel veriler elde edilmiştir. İki bağımsız kodlayıcı ile %92 uyum oranı elde edilerek kodlayıcılar arası güvenilirlik sağlanmıştır. Meta-analiz Comprehensive Meta-Analysis yazılımı ile gerçekleştirilmiş ve hem sabit hem de rastgele etkiler modelleri incelenmiştir. Etki büyüklüklerindeki heterojenlik Q ve I2 analizleri ile belirlenmiştir. Yayın yanlılığı dört farklı yöntemle test edilmiştir. Sonuçlar, okuma ve matematik başarısı arasında güçlü bir bağlantı olduğunun altını çizmektedir. Bununla birlikte, veri analizi heterojenliği ortaya koyarak bu ilişkide potansiyel bir karmaşıklığa ve çeşitli faktörlerin etkisinin değişebileceğine işaret etmektedir. Analiz, alt gruplar arasında istatistiksel olarak anlamlı farklılıklar bulmamıştır. Eğitim seviyesi, coğrafi konum ve araştırma türü gibi moderatörler okuma ve matematik başarısı arasındaki ilişkiyi önemli ölçüde etkilememiştir. Bu da okuma ve matematik başarısı arasındaki ilişkinin farklı gruplar arasında genel olarak tutarlı olduğunu göstermektedir. Okuma ve matematik başarısı arasındaki ilişkinin bu meta-analizi, önemli eğitim uygulamaları ve politika çıkarımlarına sahiptir.

Anahtar Kelimeler: Okuma, Matematik, Başarı, Meta-analiz

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1. Introduction

Reading and mathematics skills are determining factors in individuals' academic achievement. Understanding and analysing the relationship between these two domains is a complex problem educators and researchers face. However, in recent years, the impact of reading skills on students' mathematics performance has become an essential topic of discussion among educational researchers and policymakers. This topic is of particular importance as it has significant implications for curriculum design, instructional strategies, and student assessment in both reading and mathematics (Ertürk Kara, 2019; Karakuş Aktan et al., 2021; Pala & Sağlam, 2019).

Educational achievement is a multifaceted concept encompassing various aspects of a student's academic performance. It is often measured by basic skills such as reading and mathematics. Reading, for instance, is not confined to language and literature courses but permeates other disciplines, including mathematics (Snow & Sweet, 2003). Mathematics achievement, on the other hand, reflects students' ability to think analytically, solve problems, and make logical inferences (National Mathematics Advisory Panel, 2008). The intricate relationship between these two essential skills has long been a fascinating and challenging area of educational research.

Reading skill involves students' understanding, interpreting and evaluating written materials. This skill directly affects students' access to information, learning processes and academic achievement (Guthrie & Wigfield, 2000). Students with high reading skills are more successful in various disciplines (Cunningham & Stanovich, 1997). Reading also plays a vital role in understanding and solving mathematical problems. In particular, word problems require students to use their reading skills to understand and apply mathematical concepts (Vilenius-Tuohimaa et. al., 2008). Mathematics is a fundamental discipline that develops students' analytical and logical thinking skills. Mathematical achievement predicts students' future academic and professional success (Geary, 2011). Students who excel in mathematics often have better problem-solving skills and scientific thinking abilities (Rittle-Johnson & Schneider, 2015). However, mathematical success is broader than numerical abilities; linguistic skills also play an essential role. Students must have strong reading skills to correctly understand and solve mathematical problems (LeFevre et al., 2010).

The relationship between reading skills and mathematics achievement has been extensively studied in educational research, and the findings have significant practical implications. The strong relationship between these two skills provides essential insights into how reading skills can positively influence mathematics performance. Research consistently shows that students with higher reading skills excel in mathematics (Purpura et. al., 2011). Particularly in word problems, reading comprehension skills are crucial for correctly understanding and solving the problem (Fuchs et al., 2006).

Although studies examining the relationship between reading and mathematics are usually conducted as correlational studies, such studies have some limitations. Although correlational studies help determine the relationship between two variables, they may need to provide more information about the generalizability and consistency of these relationships (Salkind, 2010). The findings of a single study may need to be consistent with other studies due to sample size, methodological differences, or contextual factors (Cooper, 2010). This can make assessing the relationship between reading and mathematics difficult.

The purpose of this meta-analysis was not just to review the existing literature examining the relationship between reading and mathematics achievement but also to provide a robust assessment of the strength and consistency of this link. The meta-analysis method, which combines data from different studies, ensures the validity and generalizability of our conclusions (Borenstein et. al., 2009). This study aims to contribute significantly to developing reading and mathematics education strategies for educators and policymakers.

1.1. Reading Skills and Mathematics Achievement

Reading skills can directly affect students' ability to understand and solve math problems. Research shows that students with higher reading skills understand and solve math problems better (Smith & Johnson, 2019).

Studies examining the impact of reading skills on mathematics performance can generally be categorised under two main headings: reading comprehension and vocabulary knowledge. Reading comprehension helps students correctly interpret math problems and develop solution strategies (Fuchs et al., 2019). For example, a study by O'Reilly and McNamara (2007) showed that improved reading comprehension skills increase students' capacity to solve math problems.

Vocabulary knowledge also has a significant impact on math performance. Familiarity with math terms helps students understand problems more quickly and accurately (Hiebert & LeFevre, 2017). Moreover, improving reading skills enables students to better understand mathematical terms and concepts, positively affecting their problem-solving skills (Kintsch & Greeno, 1985).

In conclusion, the findings in the literature demonstrate the direct and indirect effects of reading skills on mathematics performance. This underscores the importance of improving reading skills for language learning and overall academic achievement (Booth & Thomas, 2020; Smith, 2021). These insights provide a clear roadmap for educators and policymakers, empowering them to implement effective strategies that can significantly enhance students' competencies in both reading and mathematics.

Reading skills can directly affect students' ability to understand and solve math problems. Research shows that students with higher reading skills understand and solve math problems better (Smith & Johnson, 2019). Studies examining the impact of reading skills on mathematics performance can generally be categorised under two main headings: reading comprehension and vocabulary knowledge. Reading comprehension helps students correctly interpret math problems and develop solution strategies (Fuchs et al., 2019). For example, a study by O'Reilly and McNamara (2007) showed that improved reading comprehension skills increase students' capacity to solve math problems. Students with high reading comprehension skills can analyse problems better and develop more effective strategies in the solution process.

Vocabulary knowledge also has a significant impact on math performance. Familiarity with math terms helps students understand problems more quickly and accurately (Hiebert & LeFevre, 2017). Moreover, developing reading skills enables students to better understand mathematical terms and concepts, positively affecting their problem-solving skills (Kintsch & Greeno, 1985). In particular, understanding the terms and symbols used in mathematical language plays a critical role in problem-solving. In this context, reading skills are fundamental for students to understand and apply mathematical concepts.

Reading skills also contribute to the development of critical thinking and analytical skills. Critical thinking supports the logical reasoning processes for solving mathematical problems (Booth & Thomas, 2020). As students learn to evaluate texts critically, they can develop a deeper understanding of mathematical concepts. This suggests that reading skills contribute to text analysis and the strengthening of mathematical thought processes. Moreover, reading skills also enhance interaction with other disciplines. For example, understanding scientific and technical texts can help connect mathematical concepts to real-world applications (Smith, 2021). This improves students' ability to use mathematical thinking in various contexts.

Strong reading skills reduce students' cognitive load when solving math problems. When they understand the text part of the problem with less effort, students can focus more of their mental resources on the problem-solving process (Sweller et. al., 2011). This suggests that improving reading skills is essential in enhancing students' overall academic performance. Thus, this interrelationship between reading skills and mathematics achievement requires educators to adopt holistic approaches to increase students' competencies in both domains.

Regarding educational strategies, educators play a crucial role in creating integrated educational programs that develop reading and mathematics skills together. Such programs not only strengthen students in both areas but also highlight the integral role of educators in their learning journey (Booth & Thomas, 2020). Educators should teach specific reading strategies to students, empowering them to tackle math problems effectively. These strategies include underlining important information, taking notes, and summarising texts (Fuchs et al., 2019). Educators should encourage students to learn and actively use mathematical terms in mathematics lessons. Activities and games can significantly improve vocabulary knowledge (Hiebert & LeFevre, 2017).

This study is of significant importance as it aims to analyse the findings obtained from quantitative studies in the literature on the relationship between reading skills and mathematics achievement. The following questions were sought to be answered, highlighting the relevance and significance of this research.

1. Does reading skill affect mathematics achievement?
2. Does the effect of reading skills on mathematics achievement differ according to moderator variables?

2. Method

The method of this research is meta-analysis. Meta-analysis can be defined as statistical synthesis and interpretation based on the quantitative findings of different studies on the same subject (Cumming, 2012; Ellis, 2012; Petticrew & Roberts, 2006). In this meta-analyzed study, the data obtained from the students were accessed. Publication bias analyses were conducted within the scope of reliability studies. Predetermined analysis procedures statistically processed these data, and the results were synthesised.

2.1. Selecting and coding the data (studies)

In the meta-analysis, articles on the relationship between reading skills and mathematics achievement in the field of education are the data source of this study. These were excluded from the scope. Because they did not undergo a severe peer review. The keywords “reading”, “mathematics”, and “achievement” were used in the search. EBSCO and Google academic search engines were used, and many databases were accessed. As a result of the search, 1690 studies that met the inclusion criteria from 2013 to 2024 (April) were reached. Of these studies, 13 were included in the meta-analysis because they met the inclusion criteria. Data from 13 studies and 397882 students were combined. The inclusion procedure is shown in the PRISMA flowchart below (Figure 1).

Studies to be included in the meta-analysis;

- Studies published between 2013-2024 (April),

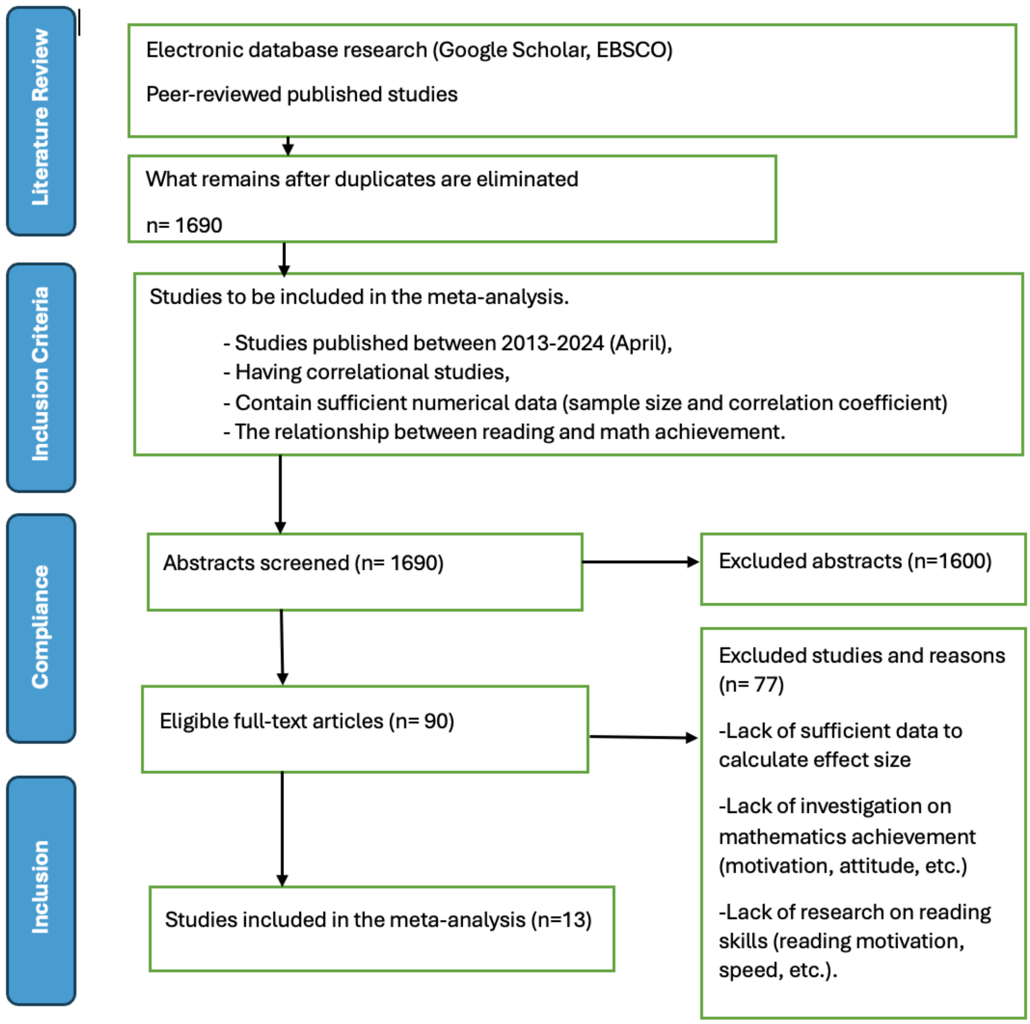
- Having correlational studies,

- Contain sufficient numerical data (sample size and correlation coefficient)

- It should be about the relationship between reading and math achievement.

Figure 1

PRISMA Flowchart



2.2. Coding the Studies, Reliability of the Coding Process

This study used the Difference in Standardized Means to calculate the effect size in meta-analysis. Quantitative data such as r, t, p values, mean and standard deviation values and sample size were obtained from each study to calculate the Difference in Standardized Means and reach possible moderators. Inter-coder reliability was ensured with two independent coders. According to the Cohen Kappa reliability analysis, an excellent agreement was observed with a rate of 0.92.

2.3. Meta-Analysis Procedure and Publication Bias

This study calculated effect size with Comprehensive Meta-Analysis (Version 2.0) software. Calculations were made in fixed and random effects models. However, random effects model is recommended for meta-analysis studies in social sciences (Cumming, 2012). Heterogeneity of effect sizes was determined by Q and I2 analysis. Publication bias was tested using four methods: Classic fail-safe N Egger Regression Test, Berg and Mazumdar Rank Correlation.

3. Result

3.1. Publication Bias Findings

Table 1

Results of Reliability Tests Representing the Probability of Publication Bias

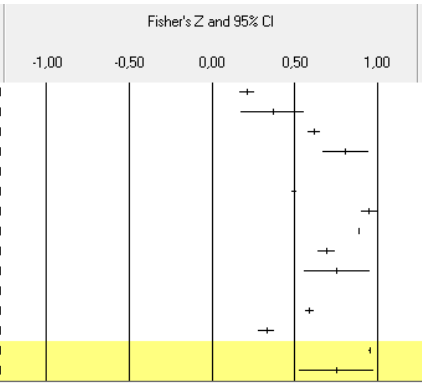
Classic fail-safe N	**Egger's test**	**Berg & Mazumdar Rank Correlation test**
p = 0.000	p = 0.37	p = 0.123
We need to find 7749 non-significant studies for the p-value to exceed 0.05.	Since p> 0.05, it can be said that there is no publication bias.	Since p> 0.05, it can be said that there is no publication bias.

In meta-analyses, the possibility of publication bias cannot be ignored. The aim is to reach a general conclusion by combining the results of many different studies. Conducting publication bias analyses is a critical step in meta-analyses. This process can provide a different perspective from the reality in the literature, potentially preventing the dissemination of incorrect conclusions. Ensure the results are objective and reliable (Rothstein et al., 2005). According to Table 1, the Orwin Protected N Number, a statistical measure used to estimate the number of studies needed to change a meta-analysis finding, is 7749. This number is approximately 546 times more than 13 studies. However, 13 studies are all the studies that could be reached according to the inclusion criteria among the studies conducted in Turkey for this research question. The fact that it was impossible to get 7749 studies other than these shows no publication bias in this meta-analysis. The fact that the results of Egger's test (p = 0.37) and Rank Correlation test (Begg's test, p = 0.123), which are other publication bias tests, were not significant, were accepted as other indicators that there was no publication bias in this meta-analysis study.

Table 2

Standardized effect sizes included

Model	Study name	Outcome	Statistics for each study						
			Fisher's Z	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value
	Habók et.	Ortaokul	0,215	0,022	0,000	0,172	0,259	9,737	0,000
	Hassinger-D	Okuloncesi	0,369	0,098	0,010	0,177	0,561	3,762	0,000
	Shin et. al.,	İlkokul	0,618	0,020	0,000	0,579	0,657	31,006	0,000
	Ten Braak	Okuloncesi	0,811	0,071	0,005	0,672	0,949	11,466	0,000
	Adelson et.	Lise	1,510	0,005	0,000	1,501	1,520	308,524	0,000
	Barnard-Bra	İlkokul	0,497	0,007	0,000	0,484	0,511	72,761	0,000
	Schöber et,.	Ortaokul	0,950	0,025	0,001	0,901	1,000	37,948	0,000
	Masci, et.	Ortaokul	0,891	0,002	0,000	0,887	0,895	419,452	0,000
	Watts et.	İlkokul	0,693	0,027	0,001	0,640	0,746	25,553	0,000
	Chu et. al.,	Okuloncesi	0,758	0,102	0,010	0,559	0,957	7,467	0,000
	Zhu, 2022	Ortaokul	1,528	0,009	0,000	1,510	1,545	167,715	0,000
	You et. al.,	Ortaokul	0,590	0,013	0,000	0,565	0,615	46,558	0,000
	Korpershoe	Lise	0,332	0,024	0,001	0,285	0,379	13,870	0,000
Fixed			0,955	0,002	0,000	0,951	0,958	533,858	0,000
Random			0,753	0,115	0,013	0,527	0,979	6,529	0,000



When Table 2 is examined, it is seen that the standardised effect sizes in 13 studies are between 0.215 and 1.528. There is no statistically significant difference in all studies. The studies have confidence intervals ranging between 0.007 and 0.102.

Table 3

Average effect size

Model	Average Effect Size (EB)							Heterogeneity		
	k	ES	S.H.	Lower limit	Upper limit	Z	P	Q	sd	p
Fixed	13	0.955	0.002	0.951	0.958	533.858	0.000	252.255	2	0.000
Random	13	0.753	0.115	0.527	0.979	6.529	0.000			

Average Effect Size Value d=0.20 for small effect; d=0.40 for medium effect; d=0.60 for significant impact (Hattie, 2008).*

According to the data in the studies included in the meta-analysis, the effect size (in terms of Pearson r) was calculated as .955 according to the fixed effect model and .753 according to the random effects model. When the data were subjected to a heterogeneity test, the Q(sd=12) statistic value was calculated as 252.255 ($p<0.01$). The fact that the Q value obtained exceeds the value read from the chi-square table at I2 degrees of freedom and .05 confidence level (sd I2, X2 (.05) = 21.026) indicates that the data are heterogeneous. Another method used to determine heterogeneity is calculating the I2 percentile value. The I2 value calculated from the data is 99.95%. This value indicates a high level of heterogeneity. The estimated average effect size value indicates a significant effect according to Hattie's (2008) classification.

Table 4

Analog ANOVA (Level of Education)

	Average Effect Size (ES)								Heterogeneity		
	Category	k	ES	S.H.	Lower limit	Upper limit	Z	P	Q	sd	p
Level of Education	Kindergarten	2	0.601	0.061	0.481	0.721	9.820	0.000	1.860	3	0.602
	Primary School	3	0.921	0.589	-0.234	2.076	1.563	0.118			
	Middle School	3	0.650	0.137	0.382	0.919	4.744	0.000			
	High School	5	0.835	0.175	0.492	1.179	4.766	0.000			

According to the mixed effects model, the chi-square value was 3 with 7.815 degrees of freedom, and the p-value was 0.602. In this case, there is no statistically significant difference between the subgroups. It is necessary to use the mixed-effects model and report accordingly since the analyses in which we investigated the source of variance between groups were conducted. The education level variable was analysed, and the findings of the analogue ANOVA analyses are presented in Table 4. The average effect size and confidence interval values in Table 4 are reported by converting them into Pearson correlation units.

Table 5

Analog ANOVA (Continent)

	Average Effect Size (ES)								Heterogeneity		
	Category	k	ES	S.H.	Lower limit	Upper limit	Z	P	Q	sd	p
Continent	America	6	0.742	0.276	0.201	1.283	2.689	0.007	0.749	2	0.688
	Asia	2	1.059	0.469	0.140	1.977	2.259	0.024			
	Europe	5	0.639	0.164	0.318	0.960	3.898	0.000			

According to the mixed effects model, the chi-square value was 2 with 5.991 degrees of freedom, and the p-value was 0.688. In this case, there is no statistically significant difference between the subgroups. It is necessary to use the mixed-effects model and report accordingly since we are conducting analyses to investigate the source of variance between groups. The continent variable was analysed, and the findings of the analogue ANOVA analyses are presented in Table 5. The average effect size and confidence interval values in Table 5 are reported by converting them into Pearson correlation units.

Table 6

Analog ANOVA (Type of Research)

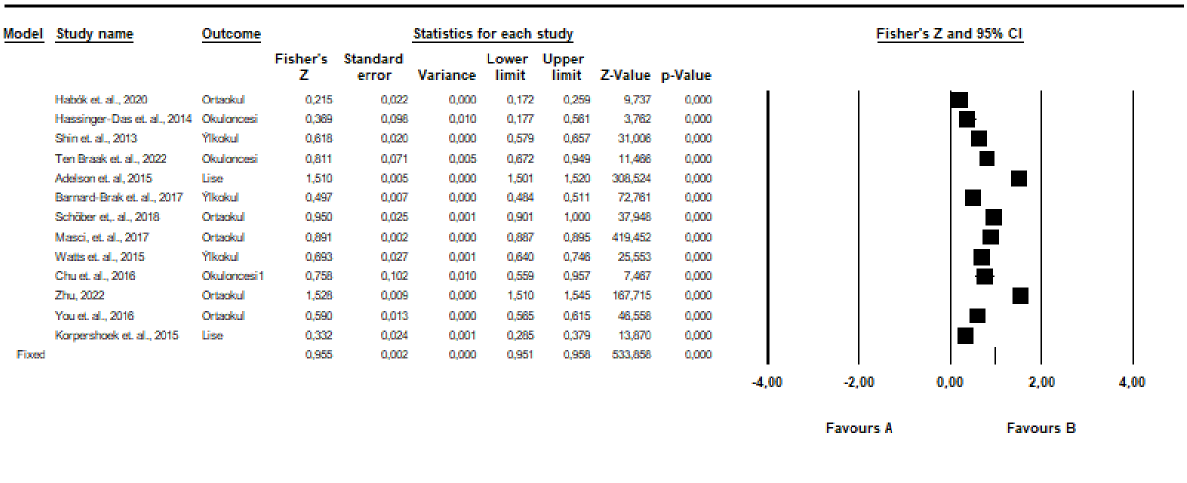
	Average Effect Size (ES)								Heterogeneity		
	Category	k	ES	S.H.	Lower limit	Upper limit	Z	P	Q	sd	p
Type of Research	Longitudinal	6	0.682	0.111	0.464	0.900	6.135	0.000	0.345	1	0.557
	Cross-sectional	7	0.812	0.191	0.438	1.186	4.252	0.000			

According to the mixed effects model, the chi-square value was 1 with 3.841 degrees of freedom, and the p-value was 0.557. In this case, there is no statistically significant difference between the subgroups. It is necessary to use the mixed-effects model and report accordingly since the analysis in which we investigated the source of variance between groups was conducted. The research type variable was analysed, and the findings of the analogue ANOVA analyses are presented in Table 6. The average effect size and confidence interval values in Table 6 are reported by converting them into Pearson correlation units.

The forest plot showing the distribution of the effect size values of the studies within the scope of the research according to the random effects model is given in Graph 1.

Graph 1

Forest Graph



Graph 1 shows that the result is statistically significant according to the random effects model (d = 0.955 [-0.215; 1.528] p = 0.000) and a substantial effect according to Cohen.

4. Discussion and Conclusion

This meta-analysis delves into the relationship between reading and math achievement. The findings underscore a robust connection between the two. However, the data analysis reveals heterogeneity, suggesting a potential complexity in this relationship, with the influence of various factors possibly varying.

On the other hand, no statistically significant differences were found in the analysis between subgroups. Moderators such as educational level, geographical location, and research type did not significantly affect the relationship between reading and mathematics achievement. This suggests that the relationship between reading and math achievement is generally consistent across different groups.

The study broadly evaluates the relationship between reading and mathematics achievement and reveals a strong and consistent link between these two skill areas. The findings align with the results of similar studies in the literature. For example, Vukovic and Siegel (2010) reported that students with reading difficulties also had math difficulties. Similarly, in their meta-analysis, Nelson and Harwood (2011) showed that students with learning disabilities significantly lagged behind their peers in reading and math achievement. These findings indicate that reading and math skills are closely interrelated.

In addition, a review study by Raghubar, Barnes, and Hecht (2010) focuses on the cognitive mechanisms that explain the relationship between reading and mathematics. According to this study, verbal-linguistic skills (e.g., vocabulary and language comprehension) are essential in developing mathematical problem-solving and computational skills. Therefore, the cognitive processes linking reading and mathematics achievement should be examined more deeply. These processes may include transferring language skills to mathematical problem-solving, using reading comprehension strategies in mathematical texts, and integrating verbal and non-verbal information in mathematical tasks. On the other hand, the heterogeneity observed in this meta-analysis suggests that the relationship between reading and mathematics achievement may be complex and multifaceted. Various demographic, socio-cultural and instructional factors may affect this relationship. For example, students' differences, such as age, gender, socioeconomic status, the school district, teachers' qualifications, and instructional methods, may shape the link between reading and mathematics achievement.

This meta-analysis confirms a strong and consistent relationship between reading and mathematics achievement. However, further exploration of the cognitive mechanisms and contextual factors underpinning this relationship is required. Educators and researchers must adopt holistic approaches to foster students' development of both reading and mathematics skills. The heterogeneity between studies and subgroups also signals the need for more research to comprehend the relationship between reading and math achievement fully.

These findings on how reading and mathematics skills influence each other should be seen as important information that can guide the development of teaching approaches and curricula and better unlock students' academic potential.

4.1. Implications of Research

The results of this meta-analysis have important implications for educational practice and policy. First, emphasising the solid and consistent relationship between reading and mathematics achievement shows that educators must holistically support these two skill areas. Reading and mathematics skills should be considered to influence each other mutually, and curricula and interventions should be designed to cover both areas.

Second, a deeper examination of the cognitive mechanisms underlying the relationship between reading and mathematics achievement may contribute to developing instructional methods. For example, understanding the impact of verbal-linguistic skills on mathematical problem-solving may allow for the design of more effective interventions to identify and address students' difficulties in both reading and mathematics.

Furthermore, examining the role of various individual and contextual factors in this relationship may allow the development of interventions specific to student profiles and learning environments. Thus, more sensitive approaches can be adapted to the needs of students with different demographic, socioeconomic and cultural characteristics.

4.2. Limitations and Suggestion

Some limitations of this study and suggestions for future research are presented below:

- The meta-analysis method of the study could not fully explain the heterogeneity arising from the methodological differences of the individual studies. In the future, more comprehensive studies using qualitative research methods may contribute to a deeper understanding of the relationship between reading and mathematics achievement.

- In the current study, moderator analyses were limited, and the role of student-, teacher-, and school-level factors needed to be adequately examined. Considering these contextual variables in future research is essential, as they can significantly influence reading and mathematics achievement.

- The study's cross-sectional design did not allow for examining the developmental relationship between reading and math skills. The urgency and importance of conducting longitudinal studies to reveal the dynamic changes in the interaction between these two skill areas over time cannot be emphasised enough.

- The study needed to adequately discuss the cognitive processes underlying the relationship between reading and math achievement. Future research should address the impact of language skills on math performance in more detail, specifically focusing on the role of vocabulary acquisition and comprehension in mathematical problem-solving.

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