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What Do We Know About Underachievement in Mathematics? A Review Based on SCOPUS and WOS

Çiğdem ÇALIŞKAN TORAMAN[a] *

[a] *Ministry of National Education, Edremit Science and Arts Center, Balıkesir 10300, Türkiye*

Abstract

Underachievement refers to the inability of individuals with demonstrated potential to achieve success at a level consistent with their capacity. Although underachievement in mathematics has been discussed in many studies and many different forms, there are no bibliometric studies conducted on this topic. This study aims to examine the current state and development of research in underachievement in mathematics based on the data available in the SCOPUS and Web of Science (WoS). To do this, a bibliometric approach was adopted to map the literature on using the metadata from the SCOPUS and WoS between 1971 and 2024 in terms of the distribution of the articles by year of publication and average citation status, the most productive journals about underachievement in mathematics and number of citations, the most cited articles and authors, top countries in which the articles were cited most, the authors who have produced the most articles on underachievement in mathematics, their publications and corresponding author(s)' countries, and the trend of words associated with underachievement in the articles. The main contribution of this study is the quantitative methodological design for examining the evolution of research conducted on underachievement in mathematics. We believe that this study provides a comprehensive review of the studies on underachievement in mathematics and provides interesting insights about the development of the field for future research.

Keywords: Mathematics, Underachievement, Student, Bibliometric Study, Literature Mapping

1. Introduction

Mathematics is an activity aimed at describing and thus understanding the world in ways that can guide and enhance our actions in life. With its high level of abstraction and unparalleled power of generalization, mathematical narratives are considered a universal tool that can be applied to all aspects of life. In fact, mathematics has made extraordinary and long-lasting contributions to the welfare of humanity. Although mathematics primarily deals with the universe of abstract objects, it has provided narratives that enable individuals to effectively address the realities of life and

* Corresponding author: Çiğdem ÇALIŞKAN TORAMAN. ORCID ID.: https://orcid.org/0000-0002-5862-628X
E-mail address: tiencigdem5@hotmail.com

environment. Therefore, it is not surprising that mathematics is regarded as indispensable in human life (Sfard, 2014). Today, developed countries are the ones that make the most extensive use of mathematics, or nations and individuals who integrate mathematics into their daily lives tend to achieve greater success (Göker, 1993). Mathematics is the scientific discipline that examines the properties of abstract entities such as numbers, quantities, geometric shapes, expressions, and operations, as well as the relationships between them, by using logical methods (Tuncer, 1995). It deals with concepts abstracted from objective reality to better understand and shape it, focusing on these concepts and the interrelationships between them, utilizing "logic" as its primary method. Formulas and symbols are merely tools or the language of mathematics. Consequently, mathematics serves as an abstract systematization of the methods we use in art, law, and life in general (Tepedelenlioğlu, 1995). Mathematics facilitates our understanding of the world, guiding our problem-solving and logical reasoning processes, which teaches us to explain and create a meaning of the world and human life, generate new ideas on various subjects, provide evidence, and interpret these phenomena through logical reasoning, which makes mathematics an inherently abstract phenomenon.

Mathematics has a critical role in learners' educational process as it encourages individuals to question, research, and think critically, helping them navigate complex situations. Mathematical thinking is a highly intricate activity that has been extensively studied in the related literature. Using mathematical thinking in problem-solving is one of the primary yet most challenging goals of teaching mathematics. The ultimate objective of instruction is for students to independently conduct mathematical investigations and determine where the mathematics they have learned can be applied in real-life scenarios. As mathematician Paul Halmos (1980) stated, problem-solving is "the heart of mathematics." While educators worldwide, particularly with gifted students, have achieved significant success in this regard, there remains a considerable need to help more students gain a deeper understanding of what it means to engage in mathematical thinking and use mathematics in their daily and professional lives. Mathematical thinking supports science, technology, and economy. Governments increasingly recognize that a nation's economic prosperity is bolstered by strong levels of "mathematical literacy" (PISA, 2006) among its population. Mathematical literacy is the ability to use mathematics in everyday life, work, and advanced education. Thus, PISA assessments present students with problems set in real-life contexts. The framework used by PISA demonstrates that mathematical literacy encompasses many components of mathematical thinking, such as critical reasoning, modeling, and establishing connections between ideas. It is evident, then, that mathematical thinking is of great importance, as it equips students with the ability to use mathematics, making it a significant outcome of school education.

Underachievement refers to individuals with certain abilities or potential failing to achieve success in line with their capacity in relation to program objectives (Demirel,

2020; Matthews & McBee, 2007). Donald et al. (2006) define academic underachievement as performing below potential, while Reis and McCoach (2000) describe it as a discrepancy between ability and performance. Decision-makers concerned with underachievement often focus on groups of students who fail to reach their potential at a given time. Given the high societal expectations of mathematics, the underachievement of learners is unacceptable, and educators must take measures to address this issue. Academic underachievement is a concern not only for gifted students but also across all ability levels (Esther Chere & Hlalele, 2014). It involves the knowledge and skills acquired from courses offered in an educational settings, evaluated by educators based on students' grades (Carter & Good, 1973). This concern may relate to specific social classes, genders, ethnic groups, or individuals from disadvantaged backgrounds (West & Pennell, 2003).

For some psychologists, educational achievement is the inconsistency between a child's measured intelligence quotient (IQ) and their score on an educational test, with IQ identified as the primary factor in educational failure (Plewis, 1991). However, this view faces criticism because IQ tests are designed to measure mental ability or potential rather than achievement or attainment. Sociologists argue that some student groups from disadvantaged backgrounds or specific ethnic groups fail regardless of their IQ (West & Pennell, 2003). A clearer and less controversial definition might be "relatively low-achieving groups," as noted by Plewis (1991).

A review of the literature reveals a study by Esther Chere and Hlalele (2014) examining the concept of underachievement. Esther Chere and Hlalele's study is a literature review focused on general research about underachievement. However, the present study specifically emphasizes the concepts of mathematics and underachievement. Therefore, this study aims to illustrate the literature map and development of research on mathematics and underachievement based on the Web of Science (WoS) and SCOPUS indices.

2. Method

This study is a bibliometric analysis focusing on research related to mathematics and underachievement. Bibliometrics is a type of research conducted to evaluate literature in a specific scientific field. It has been widely applied across all areas of science (Andrés, 2009). The term bibliometrics was first introduced by Pritchard in 1969 (Andrés, 2009). In the literature, the term scientometrics is also frequently used alongside bibliometrics (Korkmaz & Toraman, 2024). Scientometrics refers to the process of analyzing science, often represented by communication within a network of publications characterized by keywords and citations (Sooryamoorthy, 2021; Szántó-Várnagy et al., 2014).

2.1. Data Creation Process

The dataset for this study was constructed based on Clarivate's Web of Science (WoS) and Elsevier's SCOPUS indexing. WoS and SCOPUS are databases frequently utilized in bibliometric and scientometrics studies (Mongeon & Paul-Hus, 2016). For this study, research on mathematics and underachievement was compiled following the steps illustrated in Figure 1.

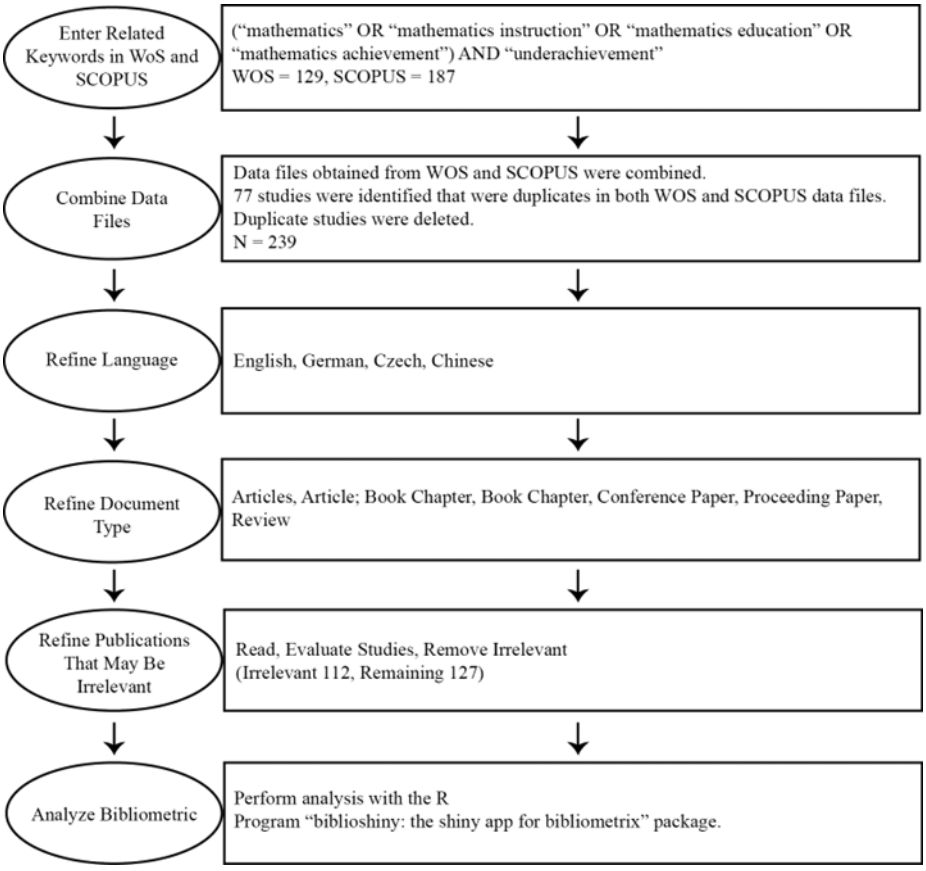

Figure 1. Data creation process

By applying these steps, the dataset for analysis comprised 127 studies related to mathematics and underachievement.

2.2. Data Analysis

The data were analyzed using R 4.2.3 (R Core Team, 2023) with the RStudio 2023.06.0 version and the "bibliometrix" package (Aria & Cuccurullo, 2017). This package, which operates in the R program, directs users to a web page via the R-Shiny interface, where

analyses are performed. The study described the time range of the included research, the number of studies, the annual growth trends, the number of authors, citation statistics, the average number of publications per year, and the average number of citations per study. Key sources and the most frequently cited works were identified. From the perspective of authorship, the most prominent authors related to mathematics and underachievement, highly cited authors, their affiliated institutions, and the countries where the research was conducted were examined. Additionally, the countries with the most citations in the context of mathematics and underachievement were analyzed. The study also explored frequently used words, a word cloud representation (word clusters), yearly trends and frequency of keywords in documents, trending topics, and a network analysis showing proximity and distance in the usage of words.

3. Results

3.1. The Annual Production and Average Citation Status of Publications on Mathematics and Underachievement Studies

The annual changes and citation status of publications on mathematics and underachievement was examined. A total of 127 articles on mathematics and underachievement were identified from WoS and SCOPUS databases, spanning from 1971 to 2024. The year-to-year numerical changes in the publications are presented in Figure 2.

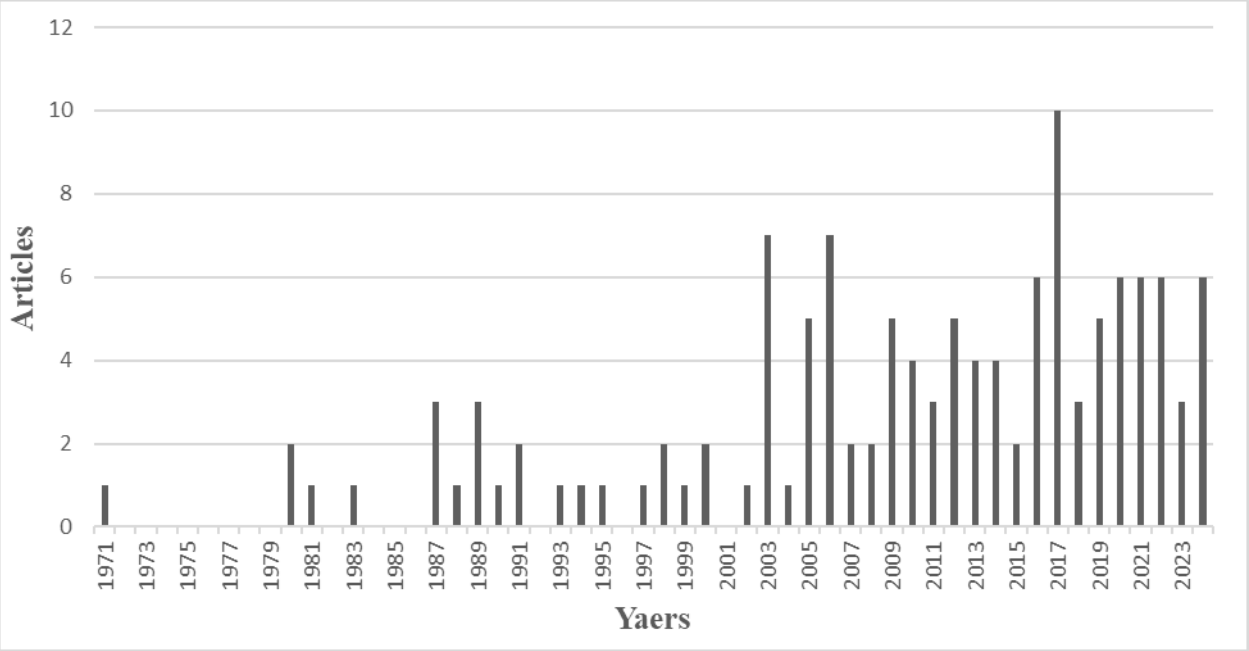

Figure 2. Yearly Changes in Publications on Mathematics and Underachievement

The publications on mathematics and underachievement began in 1971 with one publication. No publications were found between 1972 and 1979. A similar lack of publications is observed from 1980 to 2002. However, since 2003, a noticeable increase has occurred. The years with the highest number of publications were 2003, 2005, 2006, 2009, 2012, 2016, 2017, 2019, 2020, 2021, 2022, and 2024. As of November 2024, a total of 127 publications have been made. The changes in yearly publications on mathematics and underachievement and their average annual citation count are shown in Figure 3.

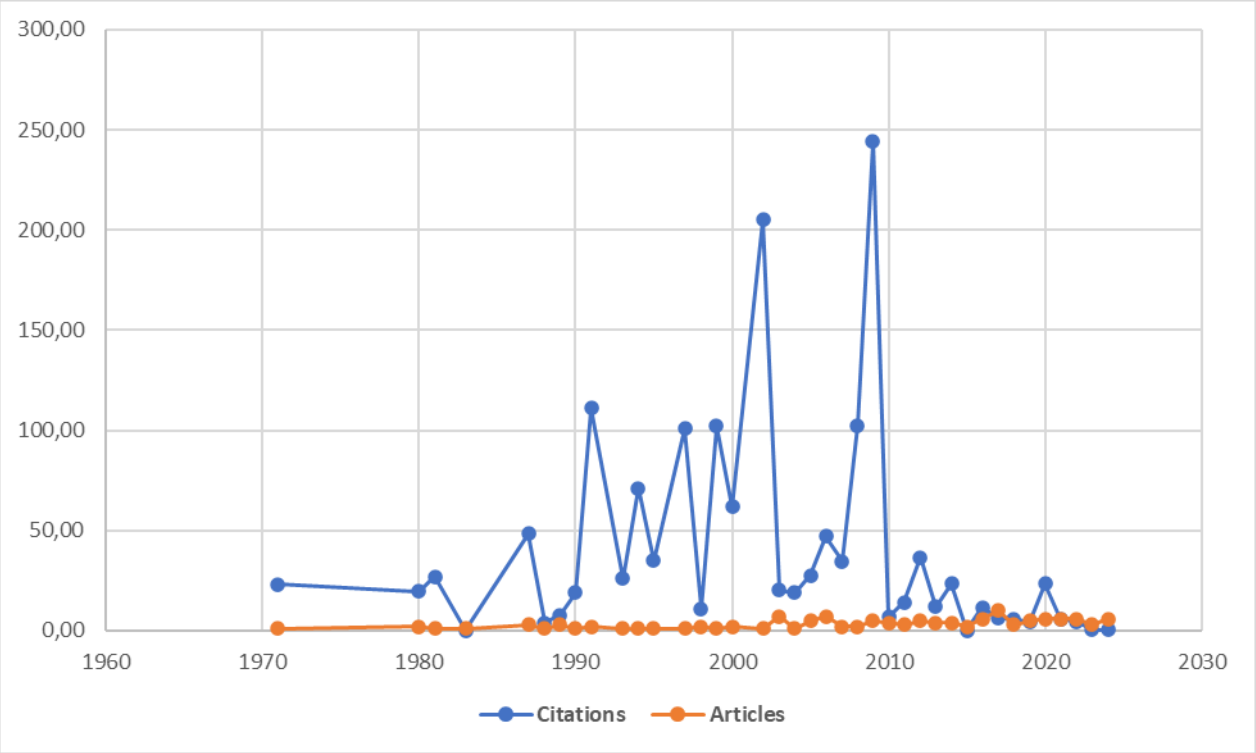

Figure 3. Yearly Changes in Publications on Mathematics and Underachievement and Changes in Their Annual Average Citation Count

The data presented in Figure 3 reveals that an average of 32.17 citations were made per publication. The highest citations were made in 2009 (244 citations), 2002 (205 citations), 1991 (111 citations), 1999 and 2008 (102 citations), and 1997 (101 citations). In the last decade, a decrease in citations for publications on mathematics and underachievement has been observed.

3.2. Journals Publishing the Most Articles on Mathematics and Underachievement

A total of 127 publications on mathematics and underachievement are present in WoS and SCOPUS, published across 112 different journals. The journals that published the most articles on mathematics and underachievement are presented in Table 1.

Table 1. Leading Journals Publishing Articles on Mathematics and Underachievement

Journal	Document*
Gifted Child Quarterly	3
Learning and Individual Differences	3
British Journal of Educational Psychology	2
Ceskoslovenska Psychologie	2
Educational Studies in Mathematics	2
Gender and Education	2
International Journal of Mathematical Education in Science and Technology	2
Journal of Abnormal Child Psychology	2
Journal of Child Neurology	2
Journal of Educational Research	2
Journal of School Psychology	2
Research in Developmental Disabilities	2
Teachers College Record	2

*The journals with two or more publications on mathematics and underachievement are listed as of November 2024.

The journals that accept articles on mathematics and underachievement include those in giftedness, special education, pediatric neurology, five psychology, educational psychology or individual differences. This data suggests that the topic is of interest to special education, psychology, and educators.

3.3. Most Cited Publications, Authors, and Countries on Mathematics and Underachievement

Another finding was about the most cited articles and their authors. The most influential and cited publications on research related to mathematics and underachievement are presented in Table 2.

Table 2. Most Cited Publications on Mathematics and Underachievement

Title	Journal	Authors	Year	Citations*
Meta-Analysis of Neurobehavioral Outcomes in Very Preterm and/or Very Low Birth Weight Children. https://doi.org/10.1542/peds.2008-2816	Pediatrics	Aarnoudse-Moens, C. S. H., et al.	2009	1165
Academic Underachievement and Attention-Deficit/Hyperactivity Disorder: The Negative Impact of Symptom Severity on School Performance. https://doi.org/10.1016/S0022-4405(02)00100-0	Journal of School Psychology	Barryi T. D., et al.	2002	205
Academic Achievement Over 8 Years Among Children Who Met Modified Criteria for Attention-deficit/Hyperactivity Disorder at 4–6 Years of Age. https://doi.org/10.1007/s10802-007-9186-4	Journal of Abnormal Child Psychology	Massettii G. M., et al.	2008	202
The Relationship of Young Children's Motor Skills to Later School Achievement. https://dx.doi.org/10.1353/mpq.2006.0033	Merrill-Palmer Quarterly	Son, S., & Meisels, S. J.	2006	149
Attention Deficit Disorder Without Hyperactivity: A Distinct Behavioral and Neurocognitive Syndrome. https://doi.org/10.1177/0883073891006001s05	Journal of Child Neurology	Hynd, G. W., et al.	1991	122
Fostering Parental Support for Children's Mathematical Development: An Intervention with Head Start Families. https://doi.org/10.1207/s15566935eed1105_7	Early Education and Development	Starkey, P., & Klein, A.	2000	120
Academic Achievement (chapter). In: Educating English Language Learners: A Synthesis of Research Evidence. https://doi.org/10.1017/CBO9780511499913.006	Cambridge University Press	Borsato, G., et al.	2006	111
The Cognitive and Academic Profiles of Reading and Mathematics Learning Disabilities. https://doi.org/10.1177/0022219410393012	Journal of Learning Disabilities	Compton, D. L., et al.	2012	102
School Mobility and Achievement:	Journal of	Temple,	199	102

Longitudinal Findings From an Urban Cohort. https://doi.org/10.1016/S0022-4405(99)00026-6	School Psychology	J. A. & Reynolds, A. J.	9	
Reclaiming School Mathematics: The girls fight back. https://doi.org/10.1080/09540259721268	Gender and Education	Boaler, J.	1997	101
We Can't Change What We Don't Recognize: Understanding the Special Needs of Gifted Females. https://doi.org/10.1177/001698628703100208	Gifted Child Quarterly	Reis, S. M.	1987	100
The Student Motivation Scale: Further Testing of an Instrument that Measures School Students' Motivation. https://doi.org/10.1177/000494410304700107	Australian Journal of Education	Martin, A. J.	2003	93
When Do Girls Prefer Football to Fashion? An analysis of female underachievement in relation to 'realistic' mathematic contexts. https://doi.org/10.1080/0141192940200504	British Educational Research Journal	Boaler, J.	1994	71
Emotional experiences during test taking: Does cognitive ability make a difference? https://doi.org/10.1016/j.lindif.2006.12.002	Learning and Individual Differences	Goetz, T., et al.	2007	62
Academic Outcomes of School-Aged Children Born Preterm: A Systematic Review and Meta-analysis. https://doi.org/10.1001/jamanetworkopen.2020.2027	JAMA Netw Open	McBryde M., et al.	2020	61
Poverty, inequality and mathematics performance: the case of South Africa's post-apartheid context. https://doi.org/10.1007/s11858-013-0566-7	ZDM Mathematics Education	Graven, M. H.	2014	50
Curriculum and Assessment Considerations for Young Children from Culturally, Linguistically, and Economically Diverse Backgrounds. https://doi.org/10.1002/pits.20115	Psychol. Schs.	Espinosa, L.M.	2005	50

*The studies cited by 50 or more publications on mathematics and underachievement as of November 2024 have been highlighted

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Table 2 shows the most influential publications on research related to mathematics and underachievement based on the number of citations. Upon examining the cited publications, it was determined that the research focused on topics such as neurobehavioral outcomes in children born with low birth weight, academic achievement and underachievement in individuals with ADHD, children's motor skills and school performance, parental support in mathematical development, cognitive and academic profiles of individuals with disabilities, gender-related disadvantages in mathematics, giftedness, student motivation, poverty, inequality, and mathematics performance. These publications were mostly published between 1987 and 2020 in journals related to psychology, pediatric neurology, special education, early childhood education, gifted education, and education and mathematics. The countries with the most influential publications on mathematics and underachievement are shown in Figure 4.

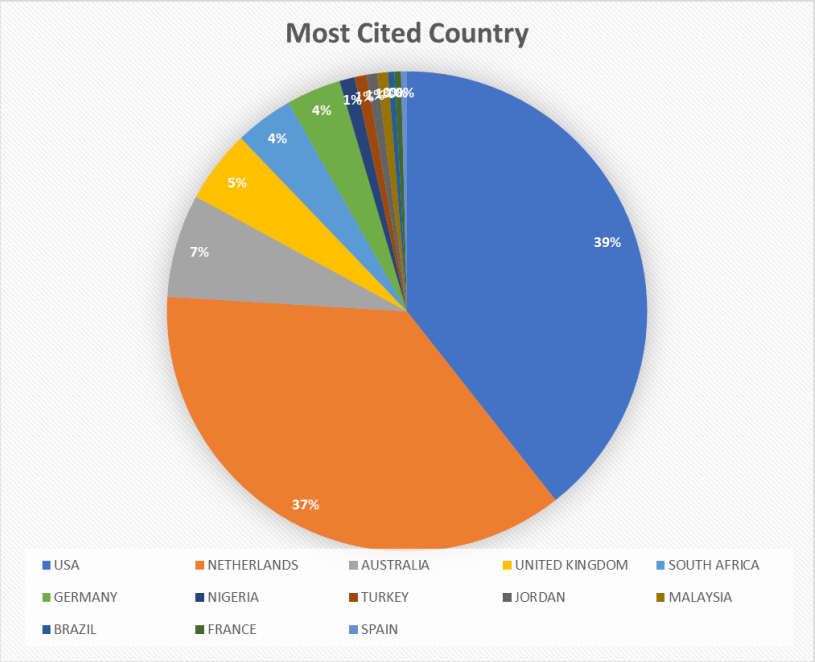

Figure 4. Most influential countries in mathematics and underachievement publications based on the number of citations

The USA leads the countries with the most citations. Other countries with the high frequency of citations include the Netherlands, Australia, the United Kingdom, South Africa, and Germany.

3.4. Authors and Countries Producing the Most Publications on Mathematics and Underachievement

The most prolific authors in publications related to mathematics and underachievement, based on WoS and SCOPUS, have been identified. Two authors, Jo Boaler and Benjamin Lahey, each have three publications on this topic.

Professor Jo Boaler is a faculty member at Stanford University's Graduate School of Education. Boaler's research focuses on how different teaching approaches affect student learning, using mathematics to promote a growth mindset, and how to foster equality in mathematics classrooms. The researcher has been particularly focused on supporting teachers to create more equitable and effective learning environments. Additionally, Boaler explored the importance of data science and its integration into other school subjects.

The countries that produced the most publications on mathematics and underachievement were shown in Figure 5.

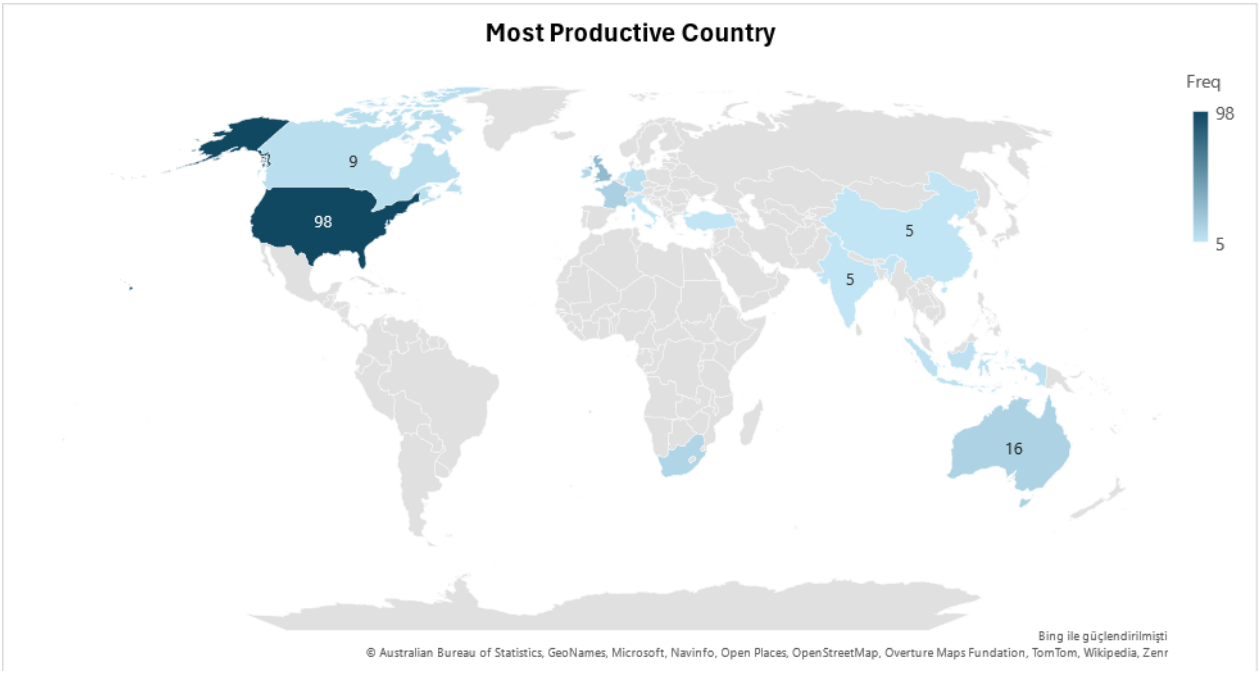

Figure 5. Countries producing the most publications on mathematics and underachievement

The countries producing the most publications on mathematics and underachievement are as follows: 98 publications from the USA, 30 from the United Kingdom, 17 from France, 16 from Australia, 14 from South Africa, 12 from Ireland, 9 from Canada, 9 from Germany, 7 from Indonesia, and 6 from the Netherlands.

3.5. Word Network and Trend in Publications on Mathematics and Underachievement

The bibliographic data from WoS and SCOPUS regarding the research on mathematics and underachievement reveals the frequency of co-occurrence of words used in these studies. The results are shown in Figure 6.

Figure 6. Frequency of co-occurring words in mathematics and underachievement publications

As shown in Figure 6, the most frequently co-occurring words in publications on mathematics and underachievement are: children (N=18), achievement (N=15), performance (N=14), students (N=13), education (N=8), mathematics (N=8), school (N=8), academic-achievement (N=7), motivation (N=7), individual-differences (N=6), difficulties (N=5), learning-disabilities (N=5), metaanalysis (N=5), and underachievement (N=5). The trend of these co-occurring words over time is shown in Figure 7.

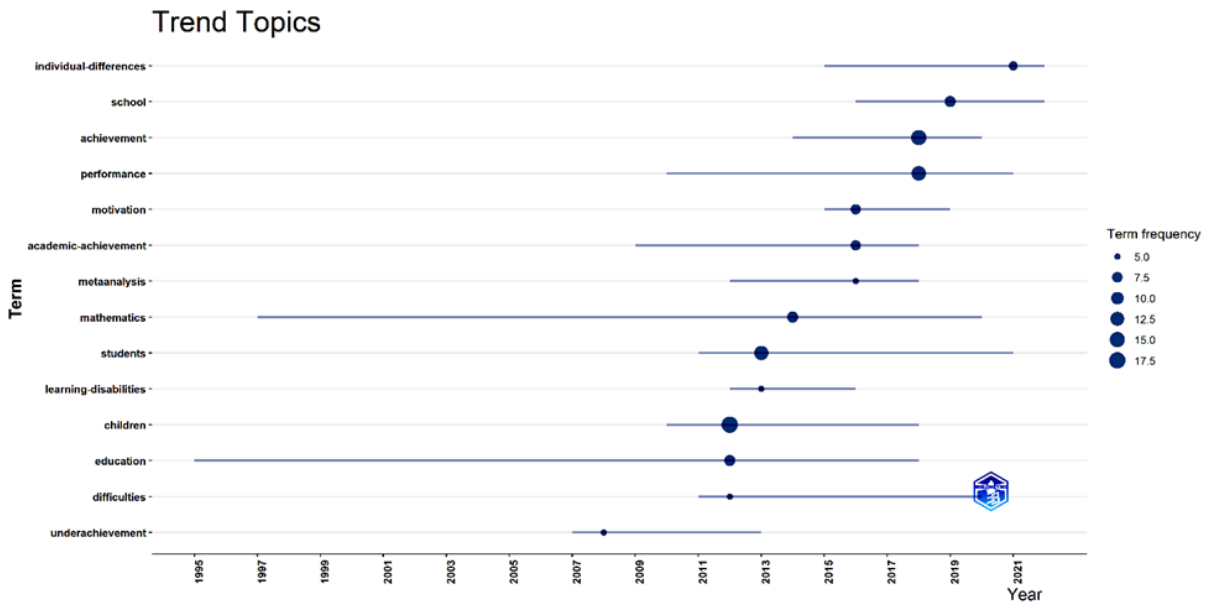

Figure 7. Trend of Keywords in Mathematics and Underachievement Publications

- From 1995 to 2014, underachievement, children, education, difficulties, students, learning-disabilities, and mathematics were frequently used.
- From 2015 to 2022, academic-achievement, motivation, meta-analysis, achievement, performance, school, and individual-differences were frequently used.

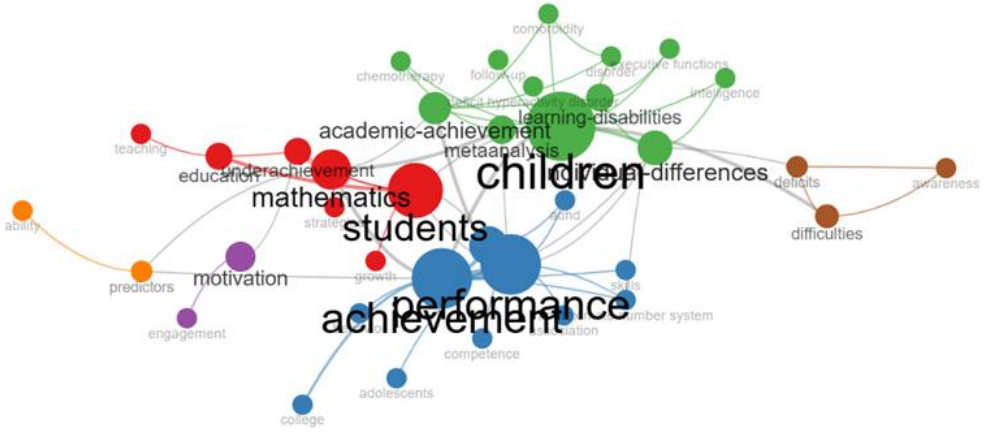

Figure 8. Co-occurrence network of words in mathematics and underachievement publications

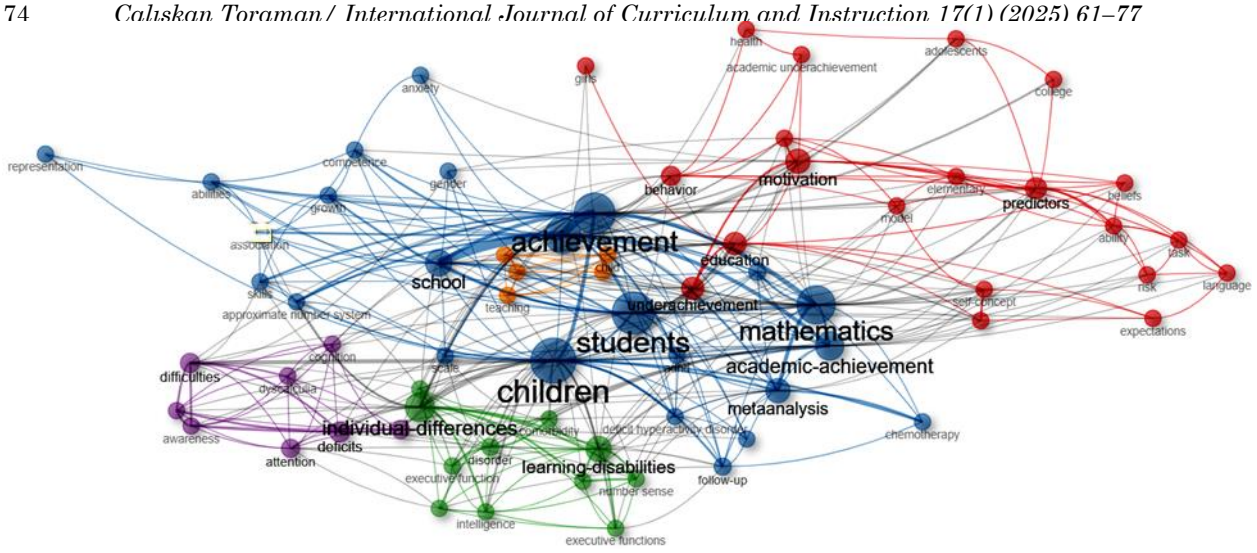

Figure 9. Thematic network of words in mathematics and underachievement publications

The co-occurrence network reveals six clusters:

- The first cluster includes words such as students, education, mathematics, underachievement, growth, strategies, and teaching.
- The second cluster includes words such as achievement, performance, school, adolescents, behavior, skills, approximate number system, association, college, and competence.
- The third cluster includes words such as children, academic-achievement, individual-differences, learning-disabilities, meta-analysis, deficit hyperactivity disorder, disorder, executive functions, follow-up, intelligence, chemotherapy, and comorbidity.
- The fourth cluster includes words such as motivation and engagement.
- The fifth cluster includes words such as predictors and ability.
- The sixth cluster includes words such as difficulties, deficits, and awareness.

In the thematic network, the following groupings are observed:

- Words such as education, motivation, underachievement, adolescents, behavior, predictors, beliefs, engagement, self-concept, ability, academic underachievement, college, elementary, expectations, girls, health, language, model, parental involvement, risk, and task are often used together.
- Words such as achievement, performance, students, mathematics, school, academic achievement, meta-analysis, growth, skills, deficit hyperactivity disorder, follow-up, gender, strategies, abilities, anxiety, approximate number system, association, chemotherapy, competence, failure, representation, and scale are grouped together.

- Words such as individual-differences, learning-disabilities, disorder, executive functions, intelligence, comorbidity, corpus-callosum, executive function, impairment, number sense, and short-term are grouped together.
- Words such as difficulties, deficits, disability, attention, and awareness are often found together.
- Words such as teaching, article and human are often used together.

When the frequency of word use, word trends over time, co-occurrence of concepts, and thematic networks of concepts are evaluated together, it is evident that the topics of mathematics and underachievement attract the interest of the fields of education, psychology, special education, and health. The concepts primarily approached the topic from the perspective of special education, difficulties, and learning disabilities. Over time, the focus has shifted toward individual differences, motivation, and student engagement. Underachievement can be explained as a barrier or linked to learning disabilities, but it can also be observed in typically developing students. In this context, the alignment of the topic with concepts such as individual differences, motivation, and student engagement over time can be considered a logical evolution. Additionally, parallel to the increase in publications, meta-analysis research has also gained attention. Concept networks have reflected this progression.

4. Discussion and Conclusions

It can be concluded that the topics of mathematics and underachievement attract attention from the fields of education, psychology, special education, and health. Initially, the concepts related to these topics were addressed primarily through the lenses of special education, difficulties, and learning disabilities. Over time, the focus has evolved towards individual differences, motivation, and student engagement. Underachievement can be explained as a barrier or linked to learning disabilities, but it can also be observed in typically developing students. In this context, the alignment of the topic with concepts such as individual differences, motivation, and student engagement over time reflects a logical evolution.

Findings also showed that underachievement may result from factors such as low motivation, personality-related causes, family-related issues, school and teacher-related factors, and low academic self-efficacy. According to Reis and McCoach (2000), factors like school environment, motivation, peer pressure, and family setting significantly impact individual success. For gifted individuals, inappropriate educational environments that fail to meet their needs are among the causes of underachievement (Schultz, 2002). Understanding the indicators and causes of underachievement is crucial for addressing it effectively. Some of these causes include low self-regulatory or

metacognitive skills, low motivation, low academic self-concept, and negative emotions toward educators and educational institutions (Callahan & Plucker, 2008).

A research project found that teachers perceive some students as underachieving and that these perceptions systematically vary by age, gender, and ethnicity (Tizard et al., 1988). Similarly, Baker et al. (1998) noted the existence of models in the literature aimed at identifying the causes of underachievement. These models suggest that individual, familial, and school-related factors contribute to underachievement. Among individual factors, underachievement is often linked to motivational or behavioral characteristics. Family-related factors emphasize the influence of relationships within the family. From this perspective, underachievement may arise from a lack of sufficient support from the family. The family perspective highlights the absence of a structured, supportive environment for fostering success and the inadequacies of parents in this regard. School-related factors draw attention to the mismatch between the student's needs and the school environment. Misalignments between pedagogical approaches and children's learning styles, or the failure to provide students with opportunities and encouragement to express their abilities, may further contribute to underachievement.

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