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Research trends on early algebra in the middle school: A combined bibliometric and meta-analysis review

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Abstract

The aims of this study is to analyze publications on early algebra in middle schools to contribute to the development of related literature. A total of 234 articles on early algebra published in various Scopus databases between 2013 and 2024 were retrieved and analyzed through a bibliometric analysis approach and 19 articles through a Comprehensive Meta Analysis (CMA). The results showed fluctuating trends in research related to early algebra in middle schools. The surge in publications using VOSviewer and RStudio from 2013 to 2024 did not align with a corresponding increase in average citations, contributing to a stagnation in the average citation per year. The noticeable upward trend in the volume of publications on early algebra since the beginning of 2013 indicates a dynamic and evolving research landscape in this field. This consistency suggests a widespread and sustained interest in early algebra research beyond the confines of a single country, further emphasizing its global relevance and significance. Integrating multimedia technology into early algebra instruction significantly enhances student learning outcomes. Moreover, access to technology and enhanced learning resources through technology integration can play a more crucial role in improving the effectiveness of early algebra learning in countries with lower income levels.

Keywords: comprehensive meta analysis; bibliometric analysis; early algebra; meta analysis; middle school; Rstudio; VOSviewer

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Introduction

Algebraic concepts emerged during the 19th century, and their eventual integration into undergraduate curricula took place in the 20th century (Stout et al., 1871; Mumford et al., 1981; Feferman et al., 2002; Macdonald et al, 2011; Stout, 2021; Bingham & Krzanowski, 2022). However, ongoing discussions in academic literature increasingly emphasize the drawbacks of separating the teaching of arithmetic and early algebra (Carraher et al., 2006; Warren, 2004; Welder, 2012). This segregation tends to impede students on their journey from concrete to abstract realms (Kieran et al., 2016). Consequently, early algebra holds paramount significance as it nurtures the ability to discern mathematical relationships, surpassing the constraints of isolated arithmetic operations (Lins & Kaput, 2004; Malisani & Spagnolo, 2009; Blanton & Kaput, 2011).

Algebra plays a pivotal role in achieving success in advanced mathematics, holding significant importance in resolving problems frequently encountered and addressed through early algebra (Knuth et al., 2016; Lee et al., 2018; Apawu et al., 2018). In a broader context, Kaput introduced two fundamental aspects crucial for fostering algebraic thinking in the early grades: the ability to generalize and symbolize mathematical relationships (Kaput & Schorr, 2008). Consequently, students focus on scrutinizing connections between quantities and articulating their regularities (Carraher et al., 2008; Cañadas et al., 2016; Schifter, 2017). This study specifically underscores early algebra, where the primary mathematical focus is on functions.

The profound import of algebra in fostering success in advanced mathematics cannot be overstated (Stephens & Ribeiro, 2012). Both in the practical exigencies of everyday life and the demands of the professional sphere, early algebra occupies a pivotal role in resolving complex issues that invariably necessitate an algebraic approach (Lins, 2004; Schifter, 2009; Fonger, Nicole et al., 2015). To articulate it more broadly, as supposed by Kaput (2008), algebraic thinking in the formative years of education is predicated upon two fundamental pillars: the capacity for generalization and the art of symbolizing mathematical relationships. Accordingly, students are enjoined to scrutinize the interplay between quantities and articulate their regularities (Tuominen, 2018; Panorkou, 2020). In a more specific context, this investigation underscores the primacy of early algebra, wherein the concept of a mathematical function assumes a central position (Carraher et al., 2008; Thomas & Tall, 1988)

Furthermore, over the past decade, there has been a noticeable absence of scholarly discussions regarding the bibliometric analysis of early algebra in middle-school settings (Veith et al., 2023). Bibliometrics, a statistical method used to assess and quantify the proliferation of publications within specific research domains (Fellnhofer, 2019; Khodabandelou et al., 2019; Maggio et al., 2022; Maharana & Sethi, 2013; Roy & Basak, 2013), has recently gained increased favor due to its ability to mitigate subjectivity and associated biases (Jiang et al., 2019). Moreover, bibliometric analysis has demonstrated its efficacy as an indispensable tool for examining research phenomena and advancements across various academic spheres (Raan, 2003; Oliveira, 2019). It plays a pivotal role in providing an updated perspective on the parameters and trends that define scholarly inquiries (Dutta & Sataloff, 2019; Origgi &

Ramello, 2015; Slowe, 2018). These studies collectively establish a crucial groundwork for crafting research methodologies aimed at guiding students towards acquiring mathematical knowledge accurately and with epistemic understanding (Dasari et al., 2024).

Thus, this study was conducted to map the outcomes of article publications through bibliometric analysis, utilizing data extracted from Scopus and processed using VOSviewer and RStudio software. The objective of this research is to contribute substantially to the intellectual community by offering insights for researchers to consider, particularly in the context of formulating research themes, with a specific focus on early algebra within secondary education. However, meta-analysis is utilized to bolster the findings of bibliometric analysis.

Numerous research reports have delved into the realm of early algebra. In an investigation conducted by Nurmawanti & Sulandra (2020) on algebra, their research outcomes affirm the usefulness of these studies in formulating pedagogical strategies aimed at nurturing students' early algebraic cognitive abilities. Recent findings further highlight a significant correlation between mathematics and the early algebraic domain, suggesting that within the realm of primary education, students demonstrate signs of informal engagement with early algebraic concepts (Febriandi et al., 2023). Moreover, it is evident that research focused on understanding early algebraic cognition is relatively scarce, emphasizing the pressing need for such inquiries (Jones, 2012; Ralston, 2013). This is crucial, considering that children are evidently acquiring an innate understanding of early algebra (Gabbay & Mulligan, 2009).

In the context of mathematical education, there are several areas that have garnered significant attention, notably encompassing early algebra, mathematical proof, calculus, technological applications, geometry, and modelling (Cai et al., 2014; Julius et al., 2021; Reyes et al., 2019). There exists a critical juncture in the curriculum wherein the introduction of early algebra might render simple concepts complex, yet the omission of early algebra instruction will inevitably render the mastery of intricate concepts an insurmountable challenge (Carraher et al., 2006; Tall & Thomas, 1991).

Taking all of these aspects into consideration, the overarching aim of this study resides in the examination of the patterns within the sphere of early algebra in middle-school education, a pursuit realized through the lens of bibliometric analysis. For this purpose, the study endeavors to address the following inquiries:

1. What is the distribution of academic articles concerning early algebra distributed across different years?
2. What is the distribution of academic articles concerning early algebra distributed across different sources?
3. What is the distribution of academic articles concerning early algebra distributed across different countries?
4. What are the mostly occurring keywords found in articles concerning early algebra, and how do these keywords evolve over time?

Theoretical review

The concept of early algebra

The conceptualization and development of early algebra originated in the United States. In its early stages, algebra was viewed as incompatible with arithmetic (Maharana & Sethi, 2013). Algebra frequently includes the process of generalizing mathematical procedures, and it increasingly deals with unknown numbers as it becomes more complicated (Sibgatullin et al., 2022). The prevailing pedagogical approach dictated that students should first master arithmetic before delving into the realm of algebra (Adamuz-Povedano et al., 2021; Banerjee, 2011). This sequential approach, contingent upon a solid foundation in arithmetic (Carraher & Schliemann, 2019). However, this approach frequently leaves students ill-prepared for the cognitive transition from the tangible to the abstract (Anderson, 2000). When simplifying algebraic expressions, learners frequently encounter challenges related to both the structural and operational aspects of their knowledge (Dhlamini, 2023).

On the contrary, algebra inherently involves exploring relationships between unknown variables and the empirical data embedded in a given problem (MacGregor, 1995). It progresses through a series of relatively automatic manipulations of these variables, ultimately leading to the elucidation of a solution (Wahyuni et al., 2022). As an academic discipline, algebra is distinctly characterized by its emphasis on the intricate interplay between quantities, supported by a flexible symbolic language that reveals unique semantic nuances (Tabak, 2004; Radford, 2008). Moreover, these symbols, often resembling one another, play a crucial role in supporting the cognitive transition from arithmetic to algebra, facilitating the development of algebraic thought even in the early stages of this transition (Hernandez-Martinez et al., 2011).

The introduction of early algebraic instruction typically takes place in the seventh grade, corresponding to the middle school phase of education (Mukhni et al., 2021). Challenges with algebraic concepts can emerge as early as elementary school and persist into middle school (Ketterlin-Geller et al., 2019; Wahyuni et al., 2020). Information from the 2015 National Assessment of Educational Progress (NAEP) in mathematics (National Center for Education Statistics, 2015) reveals disparities in algebraic performance among students in 4th and 8th grades, belonging to diverse subgroups in the United States. This inequality has the potential to perpetuate differences in academic achievement. However, In Indonesia, the proficiency in algebra holds significant importance (Jupri & Drijvers, 2014). According to the Trends in International Mathematics and Science Study (TIMSS) 2007, Indonesian students demonstrated poor performance in the TIMSS 2007 study. Specifically, Indonesian average score in algebra was 405, significantly lower than the international average of 500 (Gonzales et al., 2008). Furthermore, Indonesian students' scores in algebra were notably inferior to those of students from other Southeast Asian countries. For instance, students from Thailand, Malaysia, and Singapore achieved average scores of 433, 454, and 579, respectively, with corresponding rankings of 29th, 20th, and 3rd. Globally, students encounter challenges when learning algebra (Booth 1988; Drijvers 2003; Herscovics & Linchevski 1994; Warren 2003).

Early algebra is a branch of mathematics exploring the realms of letters and symbols, employing predefined rules for manipulating these symbolic elements (Esteve et al., 2008; Van Amerom, 2003). In this educational framework, students are expected to grasp the fundamental notions, symbols, and structures inherent in algebraic learning (Jupri & Sispiyati, 2020). Furthermore, acquiring proficiency in algebra serves as a crucial gateway to future educational and vocational success, as it lays the foundation for students to explore and pursue studies in any academic discipline during their college journey (Wilder, 2013; Snipes & Finkelstein, 2014; Kim, 2015). In the context of middle school education, students are conventionally exposed to various mathematical representations as a means of assimilating algebraic concepts (Ross & Wilson, 2012).

Kaput (2000) articulated that addressing algebraic problems involves four key objectives: (1) instilling a level of coherence, depth, and effectiveness often absent in K-8 mathematics education; (2) enhancing, if not entirely eliminating, the most detrimental and alienating aspects of current high school algebra courses—namely, their belated, disjointed, cursory, and superficial nature; (3) democratizing access to influential mathematical concepts, reshaping algebra from an inadvertent source of inequality into an intentional tool for mathematical empowerment; and (4) establishing the conceptual and institutional capacity needed to make space in the secondary curriculum for the new mathematics demanded by the 21st century, unburdened by the entrenched 19th century high school curriculum. Kaput further elucidated that two fundamental tenets lie at the core of algebra, including:

Table 1. Fundamental elements and strands

The Two Fundamental Elements
A. Algebra functions as the systematic representation of overarching patterns and limitations.
B. Algebra operates as the utilization of syntax-driven logic and procedures for manipulating generalizations conveyed through established symbolic systems.
Fundamental Elements A & B are Embodied in Three Strands
A. Algebra is the exploration of abstract structures and systems divorced from concrete calculations and connections, encompassing those that emerge within the domain of arithmetic (algebra as a form of generalized arithmetic) as well as those rooted in quantitative reasoning.
B. Algebra constitutes the investigation of functions, relationships, and concurrent changes.
C. Algebra encompasses the utilization of an array of modeling languages, both within and beyond the realm of mathematics

The state of research and its evolution over the past

The discourse on early algebra has garnered considerable attention in academic circles, driven by extensive research spanning multiple decades. In the 1980s, investigations into early algebra and learning predominantly focused on scrutinizing students' errors and the constraints influencing their learning processes, placing a specific emphasis on developmental hurdles (Van Amerom, 2002). Early algebra at the middle school level often proves to be a formidable challenge in terms of mathematical comprehension (Van Amerom, 2003). However, understanding early algebra at the middle school level is often difficult because its concepts require a transition from arithmetic thinking to more abstract thinking, where students must grasp the relationships between variables and engage in problem-solving symbolically (Cai et al., 2015). This aligns with the stages of cognitive development proposed by Piaget (1970), where students in the age range of 12-13 years (middle schools) are still in the cognitive transition from the concrete operational stage to the formal operational stage. During this transition, they are developing the ability to think more abstractly and systematically, but they do not yet have fully mastered these comprehensions. Consequently, the abstract nature of early algebra concepts, which require understanding variables and symbolic problem-solving, can pose difficulties for students who are still in the midst of this cognitive transition.

Within the realm of learning early algebra, students frequently confront substantial obstacles, particularly when engaging with the manipulation of algebraic expressions (Jupri et al., 2014; Saputro et al., 2018). According to Noto, Pramuditya, and Handayani (2020), Indonesian middle school students encounter challenges in learning due to their insufficient grasp of mathematical concepts associated with algebraic expressions, resulting in an epistemological obstacle. Sidik, Suryadi & Turmudi (2021) stated that the challenges students face when solving given problems encompass converting narrative problems into mathematical statements, utilizing the concept of place value, performing addition and subtraction calculations, and struggling due to the limited range of questions available which can be categorized into three types of obstacle, namely, ontogenic, epistemological, and didactical obstacles. This is in line with Utami & Prabawanto (2023) which stated that the didactical obstacle were identified in understanding the equal sign, variable, and mathematization. Epistemological obstacles were observed in comprehending the equal sign, variable, algebraic expression, and algebraic operation. In other side, ontogenic challenges were detected specifically in understanding the equal sign. However, the ontogenic, epistemological, and didactical obstacles in the learning process can hinder the development of a more profound understanding of algebraic concepts (Lange et al., 2014; Booth, 2017). The origins of students' struggles in early algebra can be traced to fundamental concepts associated with algebraic expressions and the operational procedures entailed in algebraic manipulations (Malihatuddarojah & Prahmana, 2019; Pramesti & Retnawati, 2019).

Over the years, early algebra has consistently held a prominent position within the realm of research in mathematics education (Pincheira & Alsina, 2021; Radford, 2018). Recently, there has been a growing interest in research related to early algebra (Vergel, 2015). In a study conducted by Gökçe & Guner (2021), the researchers delved into articles within the context of mathematics education using the Web of Science database. In their investigation, Gokce and Guner performed searches using terms such as "mathematics education," "maths education," or "math education" within the titles and keywords of the articles. In the initial phase of their analysis, their primary focus was on tracking patterns in the quantity of articles related to mathematics education. Gökçe & Guner (2021) conducted a study examining articles related to mathematics education in the Web of Science (WoS) database over a forty-year period. Their search included terms such as "mathematics education," "maths education," or "math education" in both the title and keyword sections of the articles. The research aimed to analyze trends in the number of articles related to mathematics education. The results stated a rising trend in the number of articles over the years. Figure 1 provides data concerning the information in the number of articles from 1980 to 2019.

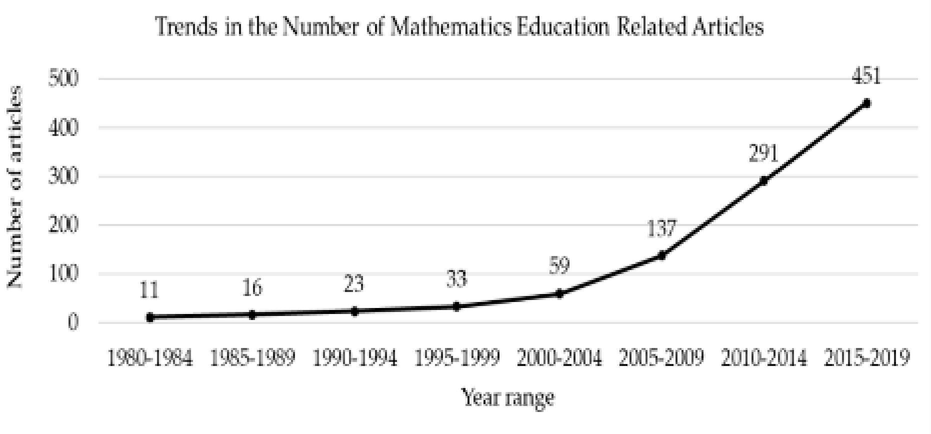

Figure 1. Trends in the number of mathematics education related articles between 1980 and 2019 (Gökçe & Guner, 2021)

Figure 1 illustrates that the growth rates of publications between 1980 and 1999 were relatively modest, but during each five-year interval from 2000 to 2014, the number of publications nearly doubled. This figure highlights a discernible upward trend in the volume of articles over the years. Notably, MathSciNet (MSN) features a distinctive attribute in the form of the Mathematics Subject Classification (MSC). This comprehensive classification system encompasses an extensive array of over 60 distinct mathematical subjects, each of which can further be subdivided into a multitude of sub-subjects. In the MSN database, each published work is meticulously cataloged under a primary subject category or, in some instances, under a primary subject along with several associated secondary subjects. This rigorous classification system plays a crucial role in the precise organization and retrieval of mathematical literature, ensuring that researchers can effectively access relevant resources in their specific areas of interest.

Figure 2 presents data on the quantity of yearly new indexed mathematics publications across eight subjects over two decades. Overall, the publication rates in analytic areas, applications to the sciences, early algebraic areas, computer science and information theory, as well as probability and statistics, witnessed a substantial increase from 2000 to 2019. In contrast, the geometric areas, logic, set theories, and other subjects maintained a relatively stable rate, hovering slightly below 5000 articles per year.

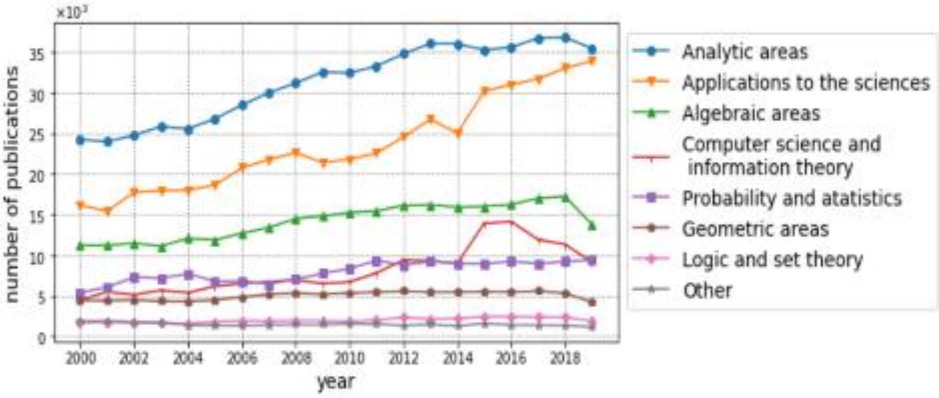

Figure 2. Yearly new indexed mathematics publication (8 subjects) based on MSC (2020)

Analytic areas, which was the highest percentage of publication subjects in 2000, constituting nearly 25.000 publications, saw a rise slightly over 35.000 publications, which was the highest proportion in 2019. Followed by applications to the science and early algebraic areas, which was the second and the third highest publication subjects, respectively. In stark contrast, logic and set theories was the second lowest of publication subjects in two decades, accounting for just under 2500 articles every year. However, publications rate about early algebraic areas experienced a dramatically increase between 2000 and 2018, but had a noticeable decrease in 2019.

Research related to mapping bibliometric analysis of early algebra in middle-school has not been carried out in the last 10 years. Based on mathematical content area in early algebra mentioned above, in this research, researcher will focus to determine the research topics, especially by thinking about early algebra in secondary schools.

Methods

Research design

In this study, a bibliometric and meta-analysis were employed to examine articles related to early algebra in the Scopus database. Bibliometrics, functioning as a scholarly discipline, involves the systematic evaluation of information extracted from the bibliographic elements of scientific publications, utilizing quantitative analyses and statistical procedures (Lazarides et al., 2023). This method provides an opportunity for a methodical and quantitative appraisal of the body of literature, thereby enhancing the depth of understanding regarding the research landscape associated with early algebra (Zan, 2019). To ensure the validity of the bibliometric method in creating scientific conclusions, researchers carefully select the sources of data used in bibliometric analysis. This includes ensuring that the data sources used are relevant and reliable. However, researchers limit the analysis to articles indexed in databases such as Scopus, selecting articles in quartile 1 to quartile 4. Furthermore, researchers choose to only analyze published articles, excluding other document types such as conference proceedings or book reviews. This is done to ensure that the data used in the analysis is of consistent quality and relevance to the research objectives. To ensure the novelty of the research, the data collected is from publications within the last decade. By limiting the data sources to relevant and high-quality articles, and focusing the analysis on appropriate document types, researchers can enhance the validity of their bibliometric analysis and ensure that the scientific conclusions drawn are reliable.

Research trends can be analyzed with the help of bibliometrics (Donthu et al., 2021, Karampelas, 2023). Bibliometric analysis was chosen as a method to conduct a rigorous statistical evaluation of scholarly articles with the primary objective of elucidating prevailing trends within the realm of mathematics education research (Ali, 2018; Julius et al., 2021). This was achieved through a meticulous examination of keyword co-occurrence. By scrutinizing the interrelationships and patterns of keywords within the literature, the research aimed to unveil significant thematic and directional underpinnings in the field of mathematics education (Cheng et al., 2014; Durmaz, 2023). This approach directs the study from a micro focus to a macro focus, affording the researcher the chance to explore the dynamics of the field from a more expansive and comprehensive vantage point (Moorhead, 1981; Zupic & Čater, 2015). The research design of the study covers the exploration, visualization, identification and verification phases that offers a pathway that spans from the initial exploration of pertinent articles to the subsequent characterization of clusters formed by terms, predicated on their frequency of occurrence.

Meta analysis is utilized to bolster the findings of bibliometric analysis. Meta-analysis refers to a statistical technique used to combine and analyze data from multiple independent studies on a particular topic to draw overall conclusions. It allows researchers to synthesize the results of various studies, providing a more comprehensive understanding of the subject matter than any single study could provide on its own. In the context of academic research, bibliometric analysis involves the quantitative analysis of bibliographic data, such as publication patterns, citation counts, and authorship trends within a specific field or discipline. By incorporating meta-analysis alongside bibliometric analysis, researchers can strengthen their findings by systematically reviewing and integrating the results of multiple studies, thus enhancing the robustness and reliability of their conclusions.

Data collection

Scopus database has been chosen as the primary source of documents in this research. This is due to three reasons: first, Scopus adheres to a uniform and steadfast criterion when selecting documents for incorporation into its index (Baas et al., 2020; Kähler, 2010). Second, it encompasses a broader spectrum of documents suitable for comprehensive reviews of research within the domains of education and the social sciences (Hallinger & Chatpinyakoop, 2019). Third, Scopus includes more open access content (Miguel, 2011; Reeves et al., 2017). However, all the articles in Scopus database were published between 2013 and 2024. Finally, 234 articles acquired for subsequent analysis. Comprehensive information regarding the exploration phase can be found in Table 2.

Table 2. Summary of the Investigation Criteria

Criteria	Descriptions
Data source	Scopus
Search terms	Algebra OR "early algebra", AND "middle school" OR "junior high school" OR "secondary school"
Publication periods	2013 to 2024
Document type	Article
Language	English

This research followed the procedures provided in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA). There are four stages guided by PRISMA, namely, identification, screening, eligibility, and inclusion (Suparman et al., 2021). Figure 3 provides a PRISMA diagram.

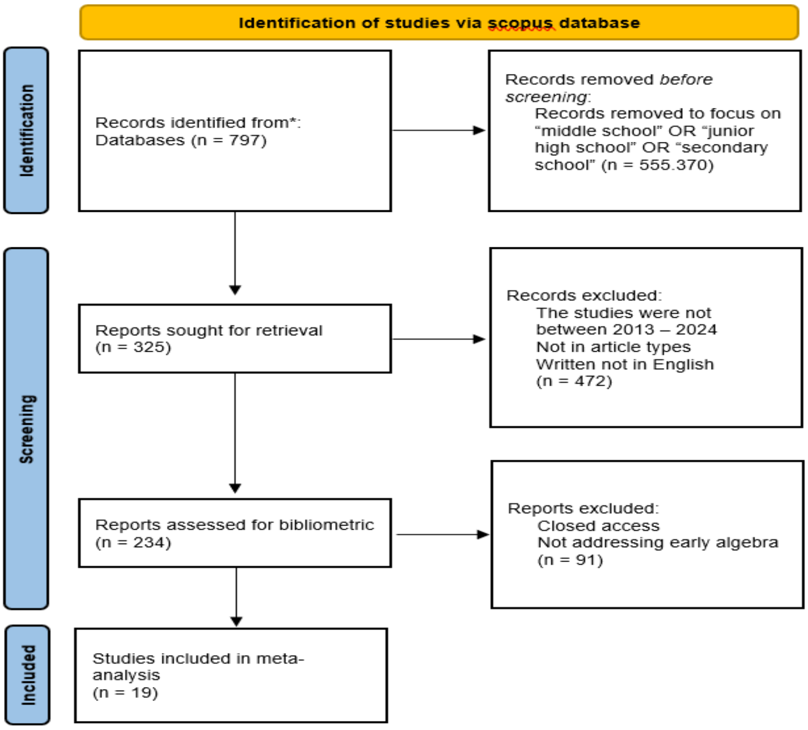

Figure 3. A flow diagram of PRISMA

Data analysis

To offer statistical insights into the most prevalent elements, connections between elements, and item clusters through bibliometric analysis, VOSviewer and RStudio software were employed. This software facilitates the creation of bibliometric maps, including network maps that elucidate the interconnections between items and organize them into clusters based on the robustness of these connections (Eck & Waltman, 2009; Nandiyanto et al., 2021; Waltman et al., 2010). Additionally, it enables the generation of overlay maps, which employ a color spectrum to depict variations over time, and density maps that visually represent the frequency of occurrence of items associated with keywords prominently featured in publications (Gökçe & Güner, 2022). Following to the criteria established within the framework of this study, the data from 234 articles sourced from the Scopus database were imported into VOSviewer and RStudio software. Subsequently, essential bibliometric analyses were conducted, leading to the generation of visual maps.

From the perspective of meta-analysis, the data analysis for this study was performed using the Comprehensive Meta-Analysis (CMA) software. The analysis employed Hedges' formulas to evaluate the effect size of incorporating the technology on students' achievements in algebra.

$$Hedges's\ g = \frac{X_1 + X_2}{S_{Pooled}}$$

The obtained of Effect Size (ES) can be classified into five categories, as outlined by Thalheimer and Cook (2002), as illustrated in Table 3.

Table 3. The categorization of effect size

Range of Effect Size (ES)	Interpretation
$-0.15 \leq ES < 0.15$	Ignored
$0.15 \leq ES < 0.40$	Low
$0.40 \leq ES < 0.75$	Medium
$0.75 \leq ES < 1.10$	High
$1.10 \leq ES < 1.45$	Very High
$ES \geq 1.45$	Very Good

Results

In this section of the paper, the findings of descriptive and evaluative analyses are presented. Specifically, the paper outlines results pertaining to bibliographic coupling of the sources, co-occurrences of author keywords, bibliographic coupling of countries, and bibliographic coupling of publications. These results were obtained through the utilization of specialized software tools such as VOSviewer, Rstudio, and CMA.

Distribution of publications by years

Figure 4 illustrates the distribution of publication, the average citations per article and the average citation per year related to early algebra between 2013 and 2024 at a 11-year interval. It is noticeable that the publication output saw a positive trend with the publication output in 2022 showing the most significant rise. Looking at the starting year, the publication output accounted for 16 articles, which was the third lowest quantity of publications in the last 11 years. Over the next half decade, the distribution of publications related to early algebra showed a slight decreasing trend. In stark contrast, in the next year in 2019, the publication rate increased significantly by approximately 11 articles. This made the year 2019 the year with the highest publication rate in the last decade. Finally, by the year 2023, the publication rate stayed around 26 articles. Until January 2024, there is only one article related to early algebra in middle schools.

On the other hand, the average citation per article related to early algebra saw a dramatic decrease from year to year. At its peak, in 2023, there were only an average of 3 citations per article related to early algebra. With regard to the first research question, the increase in the number of publications from 2013 to 2024, however, was not accompanied by a corresponding increase in average citations. It also impacted the average citation of articles per year, which exhibited a stagnant trend, remaining just below 3 citations annually until the present.

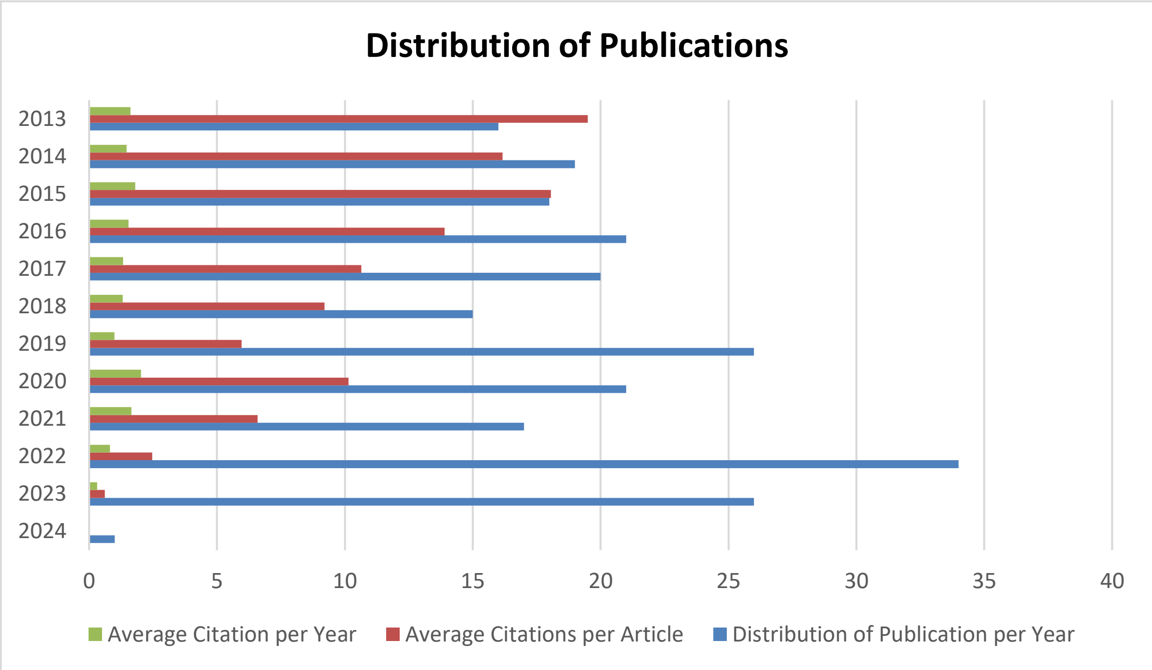

Figure 4. Distribution and average of publications related to early algebra

The declining trend in scholarly publications from year to year raises concerns about its potential impact on students' learning outcomes in early algebraic concepts. First, a decrease in scholarly publications have significant implications for educators and students, limiting access to up-to-date materials and research findings (Engel et al., 2015). Like a domino effects, the dwindling number of scholarly publications can trigger a cascade of consequences for both educators and students, ranging from limited access to current materials and research findings to potential stagnation in teaching practices and compromised learning outcomes in early algebraic concepts. Second, the availability of scholarly publications informs the quality of instruction in educational settings. A decline in publications indicate a decrease in research-based practices and innovative approaches to teaching early algebra (Novotná & Hošpesová, 2014). This could potentially impact the effectiveness of instruction and students' ability to grasp key concepts. Third, scientific research serves as a source of inspiration for innovation in teaching. When the number of scientific publications decreases, teachers' ability to adopt new and effective teaching approaches in teaching early algebraic concepts to students potentially to be hindered. This can result in students facing difficulties in understanding the material deeply and sustainably, and it can reduce their motivation in learning (Cusi & Malara, 2015). Table 4 provide the results of the moderator variable based on publication year.

Table 4. Moderator variable based on publication years

Publication year	N	Effect Size	Test of Null (Two Tailed)		Heterogenity		
			Z-value	P-value	Q_b	Df (Q)	P-value
2015 – 2019	14	0.57	6.04	0.00	0.05	1	0.81
2020 - 2024	5	0.53	2.98	0.00			

Based on the results of the meta-analysis, it was revealed that the characteristics of the study years were divided into two groups: 2015 - 2019 and 2020 - 2024. There is a modest correlation in the effect size values of 0.53 (medium effect) in research conducted during 2020–2024 and 0.57 (medium effect) in studies conducted during 2015–2019. However, the influence of publication year only has a moderate effect on enhancing student achievement in early algebra. The moderate correlations of 0.53 and 0.57 between effect sizes for the two time periods suggest some consistency in the impact of research on student achievement in early algebra across a decade. This indicates that, between the two periods, there are also notable similarities in how research outcomes influence student outcomes. As a consequence, educators and policymakers can use this finding to inform decisions about the relevance and applicability of research findings to their current educational contexts. It highlights the importance of considering a broad range of research across different time periods rather than focusing solely on the most recent studies.

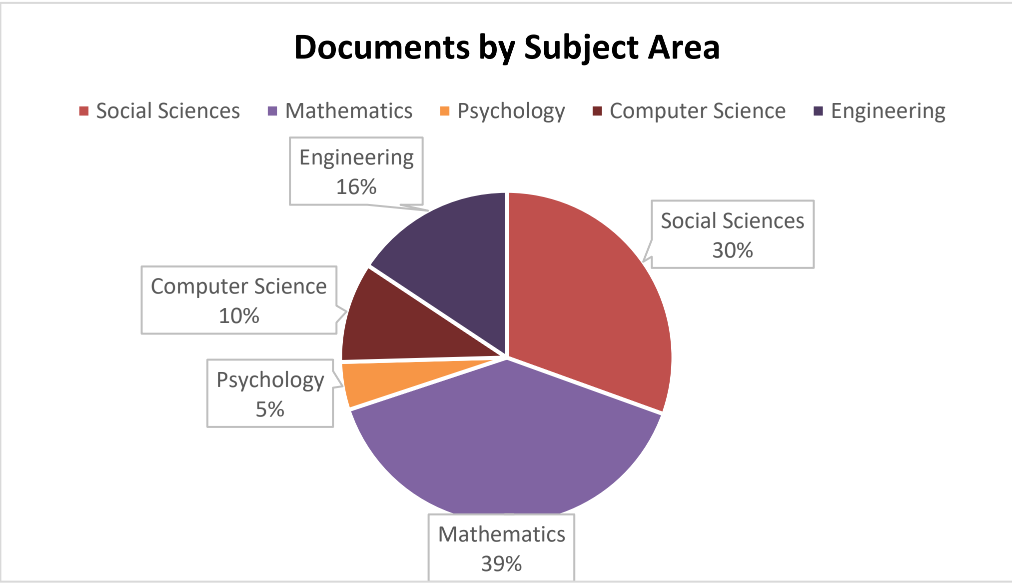

Figure 5. Subject areas related to early algebra

The published articles come from various subject areas. As evident in Figure 5, the majority of publications originate from researchers in the fields of mathematics and social science. Additionally, a substantial number of articles come from the disciplines of engineering, computer science, and psychology. It can be asserted that there is a widespread interest across diverse fields in the realm of early algebra education in secondary schools. This is in line with Prendergast & O'Donoghue (2010), which stated that there is a growing interest in early algebra education in secondary schools, with a focus on improving teaching methods to engage students. Research within the realm of psychology has provided insight into the cognitive mechanisms underpinning algebraic reasoning. Studies indicate that various abilities associated with spatial visualization, causal reasoning, qualitative analysis, and verbal reasoning are fundamental to this cognitive process (Chimoni & Pitta-Pantazi, 2017). Moreover, algebra is a crucial element of computer science, finds application across diverse domains including scientific computing, mathematical physics, and quantum computing (Ganzha et al., 2012). In engineering, engineers frequently use algebraic techniques to model and analyze complex systems, solve equations, design structures, optimize processes, and interpret data (Corrochano & Sobczyk, 2001). This reflects a multifaceted engagement with the subject matter, underscoring the interdisciplinary nature of the research landscape.

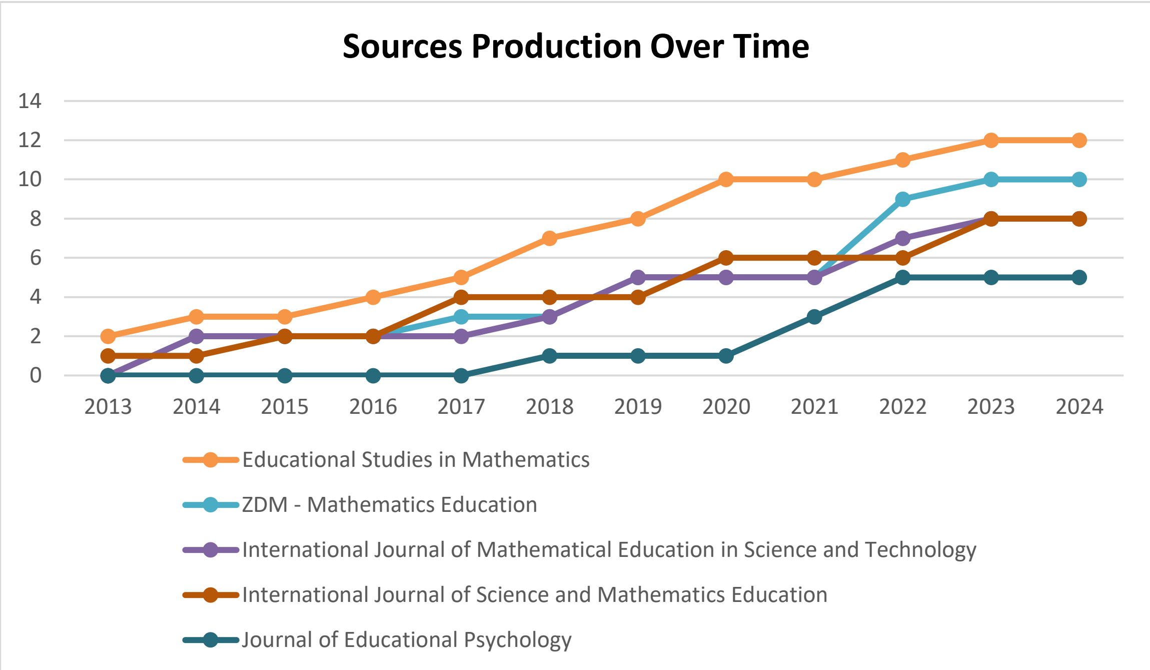

Figure 6. Sources production related to early algebra

With regard to the second research question, it is notable that Educational Studies in Mathematics and ZDM – Mathematics Education emerge as two significant journals, contributing to a total of 133 sources. Clearly, there has been a discernible upward trend in the volume of publications on early algebra from these primary five journals since the beginning of 2013. This points towards the evolving landscape of research in the field of early algebra. However, the increasing volume of publications on early algebra indicates a growing interest in understanding algebraic concepts introduced at an earlier stage in mathematics education (Kılıç, 2014). Furthermore, the growing body of research on early algebra can provide valuable insights into effective pedagogical practices for teaching algebraic concepts to students at an earlier stage. Educators can leverage this research to refine their instructional approaches and design more effective learning experiences for students (Weinert & Corte, 2001). These significant journals can help researcher to identify key concepts and developmental milestones in early algebra which can enable educators to identify students who may be struggling with algebraic reasoning at an early stage (Schifter et al., 2009).

Distribution of publications by country

The distribution of publications on early algebra is evident across various countries worldwide. However, the research trend in algebra appears to be relatively high in the continents of America and Asia compared to other continents. In Southeast Asia, nearly all countries have published articles related to algebra, such as Indonesia, the Philippines, Malaysia, and Thailand. Figure 7 depicts the average scientific output categorized by geographic characteristics.

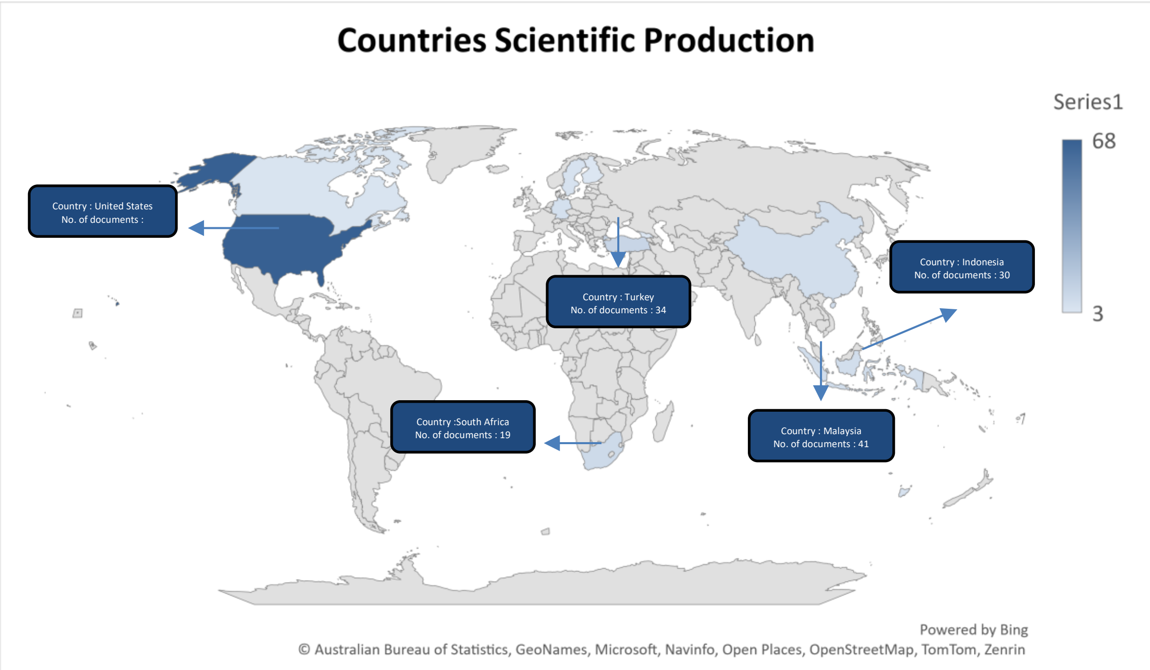

Figure 7. Countries scientific production related to early algebra

In the context of the global distribution of articles on early algebra, it is evident that the USA, Malaysia, and Turkiye hold crucial positions in the field of algebraic studies, collectively representing 604 authors, as illustrated in Figure 7. In 2024, these countries significantly contributed to the literature with 302, 41, and 34 articles, respectively. With regard to the third research question, with the exception of the USA, there is a noticeable consistent trend in the publication volume of early algebra-related articles from the top five countries since the beginning of 2013. Figure 8, provides additional insights into the synthesis of publications involving multiple countries.

Figure 8. Co-authorship network related to early algebra

Co-authorship relationships among countries were analyzed by constructing a network. In this network, individual countries are depicted as circle nodes, and collaborations between two countries are represented by edges connecting the respective nodes.

Table 5. Moderator variable based on region

Region	N	Effect Size	Test of Null (Two Tailed)		Heterogenity		
			Z-value	P-value	Q_b	Df (Q)	P-value
Africa	4	0.98	3.93	0.00	6.25	4	0.18
America	3	0.37	1.27	0.20			
Asia	9	0.50	4.68	0.00			
Europe	3	0.43	2.02	0.04			

There are variations in the effectiveness of early algebra instruction across different regions. Early algebra exhibits the lowest effect size in the Americas compared to other regions, standing at 0.37 (indicating a low effect). Meanwhile, early algebra instruction in Europe and Asia consecutively demonstrates moderate effect sizes of 0.43 and 0.50, respectively. This aligns with Utami's findings (2022). These disparities arise because early algebra is specifically designed to introduce algebraic concepts to elementary school students and has been incorporated into the curricula of several advanced countries such as the United States, Spain, and Japan (NCTM, 2000; Pinto & Cañadas, 2021; Watanabe, 2011).

On the other hand, early algebra learning integrated with technology seems to be a highly effective strategy in Africa, as highlighted by the results of the meta-analysis with an effect size of 0.98 (high effect). This indicates that the use of technology in early algebra education in the region has a significant impact on improving student achievement. This interpretation suggests that the use of technology may help overcome some of the challenges that may be encountered in the education context in Africa. Technology serves as a tool to aid humans in their activities (Apsari et al., 2020). Technology can open access to limited educational resources, facilitate more interactive and engaging learning, and increase student engagement in the learning process. Thus, integrating technology into early algebra learning in Africa can be an effective step towards enhancing students' understanding and achievement in this subject. Moreover, research in Asia, specifically in Indonesia has shown the positive impact of technology-rich interventions on early algebra learning. Jupri et al (2015) found that the use of digital technology, such as applets and ICT-based teaching sequences, improved students' conceptual understanding and procedural skills in initial algebra. Kolko (2002) underscore the complex interplay of access to technology, digital literacy, cultural attitudes, and supporting infrastructure in shaping the effectiveness of technology integration in diverse, developing countries, as seen in the case of Uzbekistan.. Research conducted by Pilet et al (2013) in Europe has recognized the capacity of technology to aid in customizing instruction, boosting student involvement, and elevating academic achievements. In America, Rhine et al (2015) and Alsaeed (2017) both emphasize the potential of technology to support algebra instruction, with Rhine specifically highlighting the use of technology to enhance preservice teachers' understanding of students' algebraic thinking.

Co-occurences of the author keywords

The analysis of visualization mapping in this study was conducted using three schemes: network visualization, overlay visualization, and density visualization. This visual representation serves to clarify the relationships between terms by depicting networks or lines, highlighting the associations between one term and another.

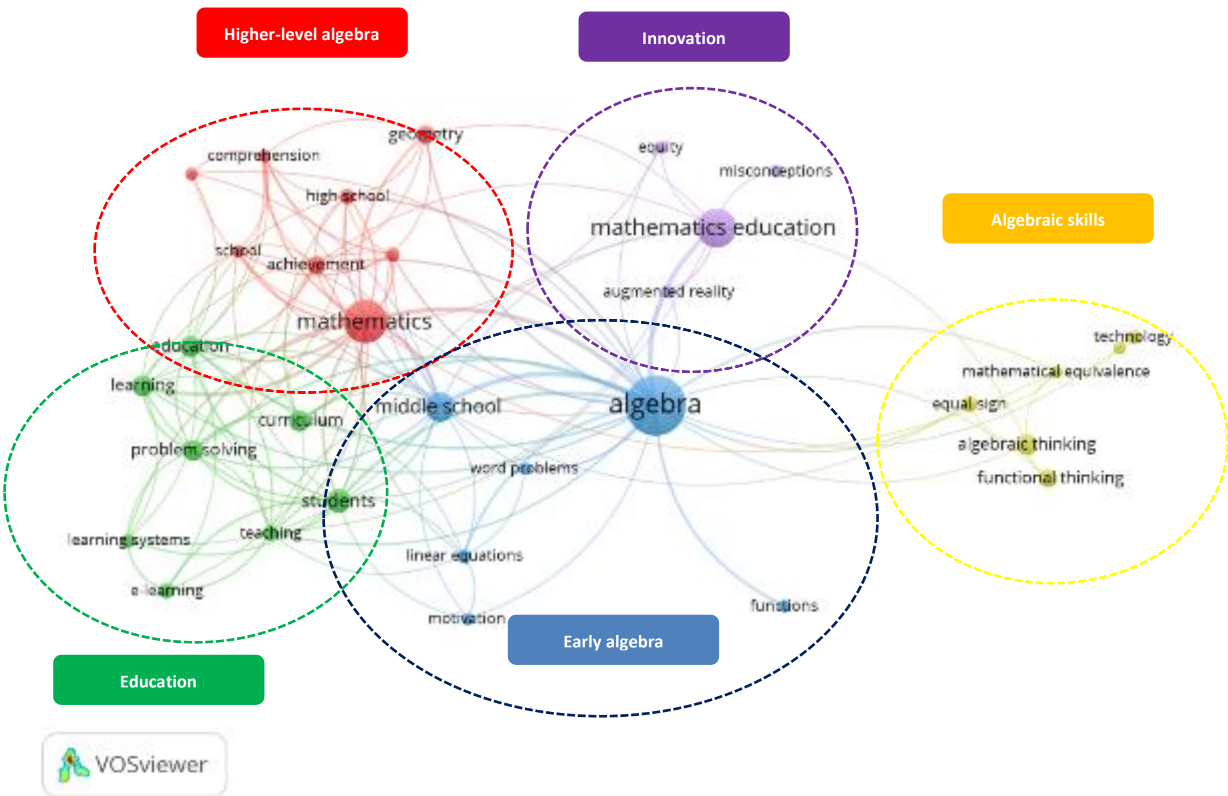

Figure 9. Co-occurrences of author keywords (network visualization)

In network visualization, the connections between terms are shown as connections or lines that link one term to another. The diameter of the circle shows the frequency of the keyword (Khafizofa et al., 2024). As shown in Figure 9, some circles have different colours, circle sizes, and labels that are connected by a line. The size of the labelled circle shows a positive correlation with the appearance of the term in the title and abstract. The utilization of VOSviewer and RStudio applications effectively facilitated the mapping of numerous articles, simplifying the task of researchers in streamlining their articles based on specific criteria. From these results, 32 items related to early algebra in middle schools were selected which were divided into 5 clusters, including: (1) Higher-level algebra; (2) Education; (3) Early algebra; (4) Algebraic skills, and (5) Innovation. The analysis yielded five clusters for the keywords. In each cluster, the most frequently co-occurring keywords are prominently displayed, interconnected within the network.

Table 6. Moderator variable based on types of technology

Types of Technology	N	Effect Size	Test of Null (Two Tailed)		Heterogenity		
			Z-value	P-value	Q_b	Df (Q)	P-value
Animated learning	2	0.24	1.43	0.15	9.32	5	0.09
Computer	1	0.49	1.75	0.08			
E-learning	4	0.48	4.16	0.00			
Geogebra	6	0.58	4.04	0.00			
Learning videos	3	0.29	2.51	0.01			
Multimedia	3	1.15	3.76	0.00			

Based on the analysis using CMA, early algebra learning integrated with multimedia technology exhibits a remarkably high effect size of 1.15 compared to other types of technology. This implies that integrating multimedia technology into early algebra instruction significantly enhances student learning outcomes. The effect size of 1.15 indicates that the effective use of multimedia technology strengthens understanding of early algebraic concepts and improves students' mathematical skills very efficiently. Incorporating multimedia technology into early algebra instruction provides a more interactive, visual, and engaging learning experience for students, facilitating better internalization of mathematical concepts. Consequently, these findings strongly support adopting a learning approach that utilizes multimedia technology as an effective strategy to enhance student achievement in early algebra.

One way to measure technological development in a country is based on the Global Innovation Index (GII). This index aims to measure the level of innovation and innovative competitiveness in various countries worldwide. The GII uses various indicators to evaluate a country's innovation capability, including investment in research and development, output of scientific research, number of patents and scientific publications, availability of skilled human resources, information technology infrastructure, and various other factors related to the innovation ecosystem. The goal of the GII is to provide insights into the strengths and weaknesses of innovation and technology in a country, thus providing guidance for government policies, businesses, and other stakeholders in enhancing their innovative capacity and economic competitiveness.

Table 7. Moderator variable based on GII

GII	N	Effect Size	Test of Null (Two Tailed)		Heterogenity		
			Z-value	P-value	Q_b	Df (Q)	P-value
High-income	5	0.35	3.14	0.00	4.81	4	0.30
Lower-income	13	0.70	5.37	0.00			
Upper-income	1	0.35	1.31	0.18			

Based on the analysis using CMA, it appears that the integration of technology in early algebra learning is highly effective when applied in countries with lower income levels (GII lower income). The effect size for GII lower income is 0.70 (medium effect), compared to countries with higher or lower GII levels, each having an effect size of 0.35. This implies that the integration of technology in early algebra learning tends to have a more significant impact in countries with lower middle-income (GII lower income) compared to those with higher incomes (higher or lower GII levels). The higher effect size in GII lower income (0.70) suggests that the use of technology in early algebra learning has a greater or more effective impact in countries with lower economic status.

This finding may indicate that access to technology and enhanced learning resources through technology integration can play a more crucial role in improving the effectiveness of early algebra learning in countries with lower income levels. This could be attributed to the fact that technology can serve as a more efficient and affordable means to provide learning materials and support student interaction with the material in countries with limited traditional resources. Countries with lower levels of technology may face greater challenges in achieving progress in education and economic development. Therefore, they may be more open to adopting technology in education as an effort to catch up and improve educational outcomes. These countries may also have a high level of curiosity and motivation to learn new technologies as a means to enhance their progress. Innovation in educational technology can be an attraction for these countries to improve the quality and accessibility of education. In countries with lower levels of technology, there may be more support or incentives to introduce technology in education as a way to overcome existing physical and human resource limitations.

As depicted in Figure 10, various circles exhibit distinct colors, sizes, and interconnected labels by lines. The graph indicates that darker colors correspond to less frequent publications, while brighter colors are indicative of emerging research trends. In the realm of bibliometrics related to early algebra in middle schools, the analysis uncovered a network of interconnected concepts. The central theme of algebra involves a deep exploration of equality, mathematics education, arithmetic, and the application of these concepts at an advanced educational level. Furthermore, the correlation with topics like fractions, curriculum, and linear equations demonstrates the intricate and pertinent aspects of teaching early algebra in middle schools. The research outcomes shed light on the pivotal role of students, teaching methodologies, and motivational factors in comprehending early algebra, offering a comprehensive understanding of crucial elements within the academic literature.

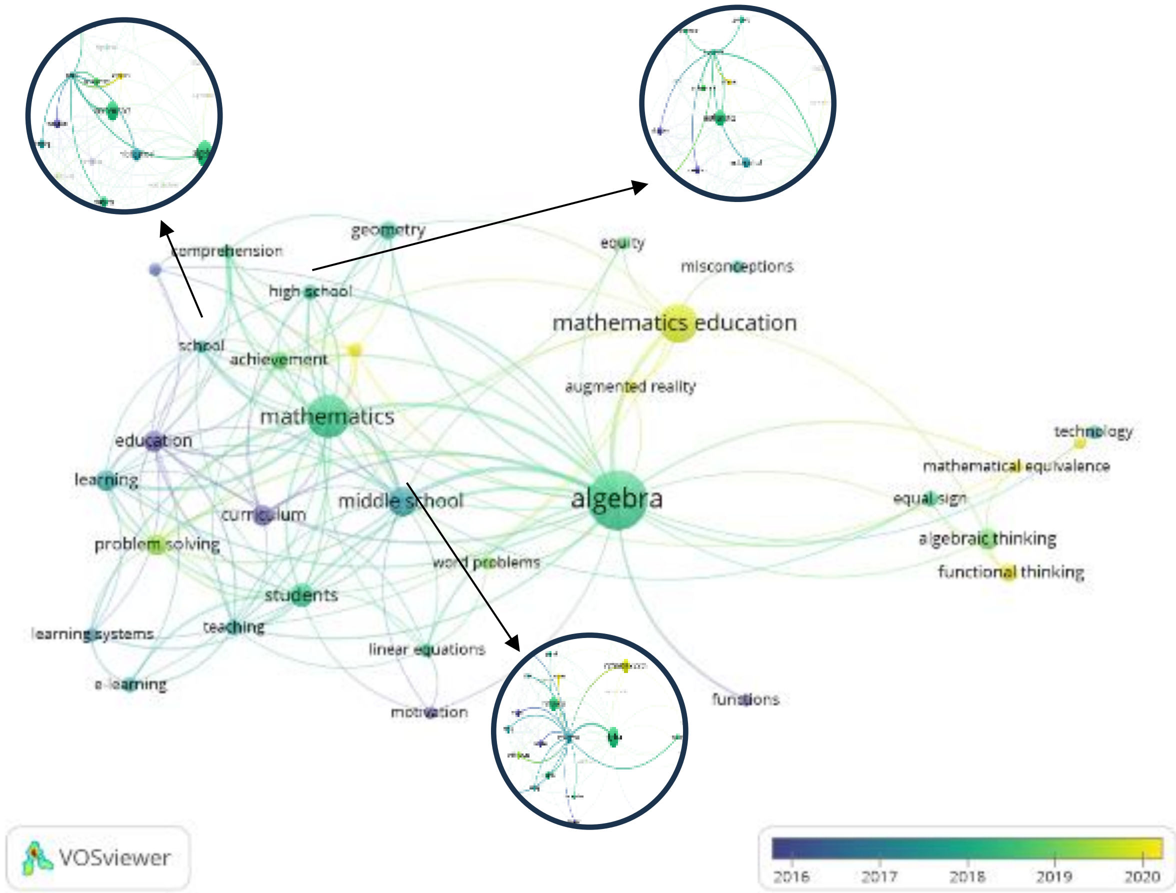

Figure 10. Co-occurrences of author keywords (overlay visualization)

Based on the analysis using CMA, it was found that algebra learning at the elementary and middle school levels has a significant impact, with effect sizes of 0.44 and 0.55 respectively, indicating a moderate level. However, algebra learning at these levels has a lower impact on students with disabilities or those not attending school, with effect sizes of 0.38 and 0.26 respectively. A surprise emerged when examining the results at the high school level, where algebra learning had a very large impact on student achievement, with an effect size reaching 0.77.

Table 8. Moderator variable based on school levels

School levels	N	Effect Size	Test of Null (Two Tailed)		Heterogenity		
			Z-value	P-value	Q_b	Df (Q)	P-value
Disabilities (not attending school)	1	0.38	1.92	0.05	4.85	4	0.30
Primary school	3	0.44	2.13	0.03			
Junior high school	6	0.55	3.67	0.00			
Senior high school	7	0.77	4.37	0.00			
University	2	0.26	1.59	0.11			

According to Piaget, students in the age range of 13 years are still in the transitional stage between concrete operational and formal operational stages, which is one of the factors contributing to why the effect size of algebra learning at the middle school level tends to be moderate.

With regard to the fourth research question, the keywords (Figure 10) that emerged most (Figure 11) were Mathematics, Students, Human, Child, Learning and Algebra.

Figure 11. The most frequent keywords

Discussion

The findings of this research indicate that in the last decade, research on early algebra has continued to experience a positive increase in the number of publications. However, the increase in the number of publications from 2013 to 2024 was not accompanied by a corresponding increase in average citations. Consequently, this has impacted the average citation of articles per year. However, the influence of publication year only has a moderate effect on enhancing student achievement in early algebra. This limitation arises because early algebra is designed to introduce algebraic concepts to elementary school students and has been implemented in the curriculum in some developed countries such as the United States, Spain, and Japan (NCTM, 2000; Pinto & Cañadas, 2021; Watanabe, 2011). However, in some countries such as Indonesia and Malaysia, early algebra learning is not yet included in the elementary school curriculum, so the main challenges in learning early algebra often arise when students are already in junior high school.

Piaget's model of cognitive development, as discussed in Shayer et al (1976), Stern (2005), Wulach (1977), and Day (1981), suggests that children aged 12-13 are transitioning from concrete operational to formal operational thinking. Shayer's study found that only one-fifth of children in this age group demonstrated formal operational thought, indicating a significant shift in cognitive development. Therefore, it is crucial to begin introducing basic algebraic concepts to students at this stage from the outset (Kieran, 2004). In this transitional period, students start to exhibit more abstract and hypothetical thinking, making it an opportune time to introduce foundational algebraic principles. By incorporating early exposure to algebraic concepts, teachers can better nurture the development of their cognitive abilities, preparing them for the more advanced problem-solving skills required in the formal operational stage and employ algebraic techniques to solve even the simplest problems that could have been more effectively addressed using arithmetic methods (Usman, 2015).

Further research on the topics of augmented reality, mathematics education, functional thinking, technology, mathematical equivalence, and arithmetic holds great potential for investigation as they have been hot research topics in the last three years.

Conclusion

This paper serves as a comprehensive overview of the field of early algebra, examining both the information available and the controversies surrounding it. To delve into the issues within the field of early algebra, researchers utilize bibliometric analysis and meta-analysis. Bibliometric analysis allows for an examination of how the field of early algebra has evolved over time, while meta-analysis enables the compilation and analysis of findings from various empirical studies to explore differences, similarities, and contradictions within early algebra. Consequently, this research provides a comprehensive overview of early algebra in the middle grade, while identifying areas that may require further research or may be contentious within the existing literature.

Examining the global landscape, research trends in algebra show a relatively high level of activity in the continents of America and Asia compared to other continents. This geographical distribution hints at regional variations in the emphasis and exploration of early algebra in secondary education. The noticeable upward trend in the volume of publications on early algebra since the beginning of 2013 indicates a dynamic and evolving research landscape in this field. Interestingly, except for the USA, there is a consistent trend in the publication volume of early algebra-related articles across various regions since the same period. This consistency suggests a widespread and sustained interest in early algebra research beyond the confines of a single country, further emphasizing its global relevance and significance. However, the findings suggest that there are variations in the effectiveness of early algebra instruction across different regions. Thus, integrating technology into early algebra learning in Africa can be an effective step towards enhancing students' understanding and achievement in this subject. Integrating multimedia technology into early algebra instruction significantly enhances student learning outcomes. Moreover, access to technology and enhanced learning resources through technology integration can play a more crucial role in improving the effectiveness of early algebra learning in countries with lower income levels.

In summary, the observed disparity between the increase in publications and the relatively stagnant citation rates underscores the need for a nuanced evaluation of the impact and visibility of early algebra research. The identified clusters and global trends shed light on the diverse and evolving nature of research in early algebra education, offering valuable insights for researchers, educators, and policymakers alike.

While this bibliometric analysis provides valuable insights into the trends and dynamics of early algebra research in secondary schools, it is important to acknowledge certain limitations that may affect the interpretation of the findings. Firstly, this study solely examines early algebra learning in secondary schools. Future research could delve into trends in advanced algebra research spanning from upper secondary to university levels. Secondly, future research could conduct more studies and training in early algebra learning integrated with technology in countries with low Global Innovation Index, particularly in the African continent. Third, early algebra learning integrated with multimedia technology exhibits a remarkably high effect compared to other types of technology. However, future research could explore what types of multimedia that can improve learning in algerba. There are several suggestions for future research, such as conduct more in-depth analyses specific to each continent or region to uncover localized trends, challenges, and opportunities in early algebra research. Undertake longitudinal studies to track the evolution of early algebra research over an extended period, and providing a more comprehensive understanding of its trends and potential shift

Conflicts of Interest

The authors declare no conflict of interest regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancies, have been completed by the authors.

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Author Contributions

Dilham Fardian: Conceptualization, writing - original draft, formal analysis, editing, and visualization; **Didi Suryadi:** Validation, supervision; **Sufyani Prabawanto:** Validation and supervision; **Silfia Hayuningrat:** Resources, data curration.

References

Adamuz-Povedano, N., Fernández-Ahumada, E., Teresa García-Pérez, M., & Montejo-Gámez, J. (2021). Developing number sense: An approach to initiate algebraic thinking in primary education. *Mathematics*, *9*(5), 1–25. https://doi.org/10.3390/math9050518

Afonso, D., & Mc Auliffe, S. (2019). Children's Capacity for Algebraic Thinking in the Early Grades. *African Journal of Research in Mathematics, Science and Technology Education*, *23*(2), 219–232. https://doi.org/10.1080/18117295.2019.1661661

Ali, Ö. (2018). Bibliometric analysis of the studies in the field of mathematics education. *Educational Research and Reviews*, *13*(22), 723–734. https://doi.org/10.5897/err2018.3603

Alsaeed, M. S. (2017). Using the internet in teaching algebra to middle school students: A study of teacher perspectives and attitudes. *Contemporary Issues in Education Research (CIER)*, *10*(2), 121-136.

Anderson, J. R. (2000). *Learning and memory: An integrated approach*. John Wiley & Sons

Inc.
Apawu, J., Owusu-Ansah, N. A., & Akayuure, P. (2018). A study on the algebraic working processes of senior high school students in Ghana. *European Journal of Science and Mathematics Education*, *6*(2), 62-68.
Apsari, R. A., Sripatmi, S., Maulyda, M. A., & Salsabila, N. H. (2020). Pembelajaran matematika dengan media obrolan kelompok multi-arah sebagai alternatif kelas jarak jauh [Math learning with multi-directional group chat media as an alternative to remote classrooms]. *Jurnal Elemen*, *6*(2), 318-332.
Baas, J., Schotten, M., Plume, A., Côté, G., & Karimi, R. (2020). Scopus as a curated, high-quality bibliometric data source for academic research in quantitative science studies. *Quantitative Science Studies*, *1*(1), 377–386. https://doi.org/10.1162/qss_a_00019
Banerjee, R. (2011). Is arithmetic useful for the teaching and learning of algebra? *Contemporary Education Dialogue*, *8*(2), 137–159. https://doi.org/10.1177/097318491100800202
Bingham, N. H., & Krzanowski, W. J. (2022). Linear algebra and multivariate analysis in statistics: development and interconnections in the twentieth century. *British Journal for the History of Mathematics*, *37*(1), 43-63. https://doi.org/10.1080/26375451.2022.2045811
Blanton, M. L., & Kaput, J. J. (2011). *Functional thinking as a route into algebra in the elementary grades. In Early algebraization: A global dialogue from multiple perspectives* (pp. 5-23). Springer Berlin Heidelberg. https://doi.org/ 10.1007/BF02655895.
Booth, J. L., McGinn, K. M., Barbieri, C., & Young, L. K. (2017). *Misconceptions and learning algebra, and the rest is just algebra*, 63-78.
Booth, L. R. (1988). *Children's difficulties in beginning algebra. In A.F. Coxford (Ed.), The ideas of algebra, K–12(1988 Yearbook)* (pp. 20–32). National Council of Teachers of Mathematics
Cai, J., Ding, M., & Wang, T. (2014). How do exemplary Chinese and U.S. mathematics teachers view instructional coherence? *Educational Studies in Mathematics*, *85*(2), 265–280. https://doi.org/10.1007/s10649-013-9513-3
Cai, J., Lew, H. C., Morris, A., Moyer, J. C., Fong Ng, S., & Schmittau, J. (2005). The development of students' algebraic thinking in earlier grades: A cross-cultural comparative perspective. *Zentralblatt für Didaktik der Mathematik*, *37*, 5-15.
Cañadas, M. C., Brizuela, B. M., & Blanton, M. (2016). Second graders articulating ideas about linear functional relationships. *Journal of Mathematical Behavior*, *41*, 87–103. https://doi.org/10.1016/j.jmathb.2015.10.004
Carraher, D. W., Martinez, M. V, & Schliemann, A. D. (2008). Early algebra and mathematical generalization. *ZDM - International Journal on Mathematics Education*, *40*(1), 3–22. https://doi.org/10.1007/s11858-007-0067-7
Carraher, D. W., & Schliemann, A. D. (2019). Early algebraic thinking and the US mathematics standards for grades K to 5. *Infancia y Aprendizaje*, *42*(3), 479–522. https://doi.org/10.1080/02103702.2019.1638570
Carraher, D. W., Schliemann, A. D., Brizuela, B. M., & Earnest, D. (2006). Arithmetic and algebra in early mathematics education. *Journal for Research in Mathematics Education*, *37*(2), 87–115. https://doi.org/10.2307/30034843.
Cheng, B., Ioannou, I., & Serafeim, G. (2014). Corporate social responsibility and access to finance. *Strategic Management Journal*, *35*(1), 1–23. https://doi.org/10.1002/smj.2131
Chimoni, M., & Pitta-Pantazi, D. (2017). Parsing the notion of algebraic thinking within a cognitive perspective. *Educational Psychology*, *37*(10), 1186-1205.
Corrochano, E. B., & Sobczyk, G. (2001). *Geometric algebra with applications in science and engineering*. Springer Science & Business Media.

Cusi, A., & Malara, N. A. (2015). *Which algebraic learning can a teacher promote when her teaching does not focus on interpretative processes?.* In Proceedings of the Ninth Congress of the European Society for Research in Mathematics Education (pp. 405-411).

Dasari, D., Muhammad, I, & Juandi, D. (2024). Crafting math minds: Abibliometric odyssey into innovative didactical designs for learning (2006-2023). *Jurnal Elemen, 10*(1), 181-198.

Day, M. C. (1981). Thinking at Piaget's Stage of Formal Operations. *Educational Leadership, 39*(1), 44-45.

De Oliveira, O. J., da Silva, F. F., Juliani, F., Barbosa, L. C. F. M., & Nunhes, T. V. (2019). *Bibliometric method for mapping the state-of-the-art and identifying research gaps and trends in literature: An essential instrument to support the development of scientific projects. In Scientometrics recent advances*. IntechOpen. https://doi.org/10.5772/intechopen.85856

Dhlamini, Z. B. (2023). The structural and operational complementarity: Grade nine learners' pitfalls and gains of simplifying algebraic expressions. *EURASIA Journal of Mathematics, Science and Technology Education, 19*(10), em2344. https://doi.org/10.29333/ejmste/13653

Donthu, N., Kumar, S., Mukherjee, D., Pandey, N., & Lim, W. M. (2021). How to conduct a bibliometric analysis: An overview and guidelines. *Journal of business research, 133*, 285-296. https://doi.org/10.1016/j.jbusres.2021.04.070.

Drijvers, P. H. M. (2003). *Learning algebra in a computer algebra environment: Design research on the understanding of the concept of parameter* [Unpublished Dissertation]. Utrecht: CD-B Press

Dunne, E., & Hulek, K. (2020). Mathematics subject classification 2020. *Not. Am. Math. Soc, 67*(3), 410-411.

Durmaz, B. (2023). The use of literary elements in teaching mathematics: A bibliometric analysis. *Journal of Teacher Education and Lifelong Learning, 5*(1), 152–172. https://doi.org/10.51535/tell.1232736

Dutta, M., & Sataloff, R. T. (2019). The importance of scholarly reviews in medical literature. *Ear, Nose and Throat Journal*, *98*(5), 251–252. https://doi.org/10.1177/0145561319827725

Eck, N. J. V., & Waltman, L. (2009). How to normalize cooccurrence data? An analysis of some well-known similarity measures. *Journal of the American society for information science and technology, 60*(8), 1635-1651. https://doi.org/10.1002/asi.21075

Engel, L. C., Banks, D., Patterson, J., & Stehle, S. (2015). *Research related to the International Baccalaureate*.

Esteve, J., Brunet, P., & Vinacua, A. (2008). Piecewise algebraic surface computation and smoothing from a discrete model. *Computer Aided Geometric Design, 25*(6), 357–372. https://doi.org/10.1016/j.cagd.2007.09.005

Febriandi, R., Herman, T., Turmudi, T., Farokhah, L., Abidin, Z., Alman, A., & Supriyadi, E. (2023). Research on algebraic thinking in elementary school is reduced: A bibliometric analysis. *Journal of Engineering Science and Technology*, *18*(3), 97–104.

Feferman, R., Levin, S., Blatman, D., Javinsky, S., Greene, R., Ring, D., & Blatt, W. (2002). as defined 6^ the boundaries they existed 1867-1917.

Fellnhofer, K. (2019). Toward a taxonomy of entrepreneurship education research literature: A bibliometric mapping and visualization. *Educational Research Review, 27*(January), 28–55. https://doi.org/10.1016/j.edurev.2018.10.002

Fonger, Nicole, L., Stephens, A., Blanton, M., & Knuth, E. (2015). A learning progressions approach to. *Proceedings of the 37th Annual Meeting of the North American Chapter of the International Group for the Psychology of Mathematics Education, July 2015*, 201–

204.

Gabbay, M. J., & Mulligan, D. P. (2009, August). *Universal algebra over lambda-terms and nominal terms: the connection in logic between nominal techniques and higher-order variables*. In Proceedings of the Fourth International Workshop on Logical Frameworks and Meta-Languages: Theory and Practice (pp. 64-73). https://doi.org/10.1145/1577824.1577835

Ganzha, V. G., Mayr, E. W., & Vorozhtsov, E. V. (Eds.). (2012). *Computer algebra in scientific computing CASC 2001*. Proceedings of the Fourth International Workshop on Computer Algebra in Scientific Computing, Konstanz, Sept. 22-26, 2001. Springer Science & Business Media.

Gökçe, S., & Guner, P. (2021). Forty years of mathematics education: 1980-2019. *International Journal of Education in Mathematics*. https://doi.org/10.46328/ijemst.1361

Gökçe, S., & Güner, P. (2022). Dynamics of GeoGebra ecosystem in mathematics education. *Education and Information Technologies*, *27*(4), 5301–5323. https://doi.org/10.1007/s10639-021-10836-1

Gonzales, P., Williams, T., Jocelyn, L., Roey, S., Kastberg, D., & Brenwald, S. (2008). *Highlights from TIMSS 2007: Mathematics and science achievement of U.S. fourth-and eighth-grade students in an international context (NCES 2009–001 Revised).* National Center for Education Statistics, Institute of Education Sciences, US Department of Education.

Hallinger, P., & Chatpinyakoop, C. (2019). A bibliometric review of research on higher education for sustainable development, 1998-2018. *Sustainability (Switzerland)*, *11*(8). https://doi.org/10.3390/su11082401

Hernandez-Martinez, P., Williams, J., Black, L., Davis, P., Pampaka, M., & Wake, G. (2011). Students’ views on their transition from school to college mathematics: Rethinking “transition” as an issue of identity. *Research in Mathematics Education*, *13*(2), 119–130. https://doi.org/10.1080/14794802.2011.585824

Herscovics, N., & Linchevski, L. (1994). A cognitive gap between arithmetic and algebra. *Educational Studies in Mathematics*, *27*(1), 59–78.

Jiang, Y., Ritchie, B. W., & Benckendorff, P. (2019). Bibliometric visualisation: an application in tourism crisis and disaster management research. *Current Issues in Tourism*, *22*(16), 1925–1957. https://doi.org/10.1080/13683500.2017.1408574

Jones, A., Morris, S. A., & Pearson, K. R. (2012). *Abstract algebra and famous impossibilities*. Springer Science & Business Media.

Julius, R., Halim, M. S. A., Hadi, N. A., Alias, A. N., Khalid, M. H. M., Mahfodz, Z., & Ramli, F. F. (2021). Bibliometric analysis of research in mathematics education using Scopus database. *Eurasia Journal of Mathematics, Science and Technology Education*, *17*(12). https://doi.org/10.29333/EJMSTE/11329

Jupri, A., Drijvers, P., & van den Heuvel-Panhuizen, M. (2014). Difficulties in initial algebra learning in Indonesia. *Mathematics Education Research Journal*, *26*(4), 683–710. https://doi.org/10.1007/s13394-013-0097-0

Jupri, A., Drijvers, P., & van den Heuvel-Panhuizen, M. (2015). Improving grade 7 students’ achievement in initial algebra through a technology-based intervention. *Digital Experiences in Mathematics Education, 1*, 28-58.

Jupri, A., & Sispiyati, R. (2020). Students’ algebraic proficiency from the perspective of symbol sense. *Indonesian Journal of Science and Technology*, *5*(1), 86–94. https://doi.org/10.17509/ijost.v5i1.23102

Kähler, O. (2010). Combining peer review and metrics to assess journals for inclusion in Scopus. *Learned Publishing*, *23*(4), 336–346. https://doi.org/10.1087/20100411

Kaput, J. J. (2000). *Transforming algebra from an engine of inequity to an engine of* *mathematical power by" algebrafying" the K-12 curriculum*. US Department of Education, Office of Educational Research and Improvement, Educational Resources Information Center.

Kaput, J. J., & Schorr, R. (2008). Changing representational infrastructures changes most everything: The case of simcalc, algebra and calculus. *Research on Technology and the Teaching and Learning of Mathematics: Cases and Perspectives, 2,* 1–46. http://www.kaputcenter.umassd.edu/downloads/simcalc/cc1/library/changinginfrastruct.pdf

Karampelas, K. (2023). Examining the relationship between TPACK and STEAM through a bibliometric study. *European Journal of Science and Mathematics Education*, *11*(3), 488–498. https://doi.org/10.30935/scimath/12981

Ketterlin-Geller, L. R., Shivraj, P., Basaraba, D., & Schielack, J. (2019). Universal screening for algebra readiness in middle school: Why, what, and does it work? *Investigations in Mathematics Learning*, *11*(2), 120–133. https://doi.org/10.1080/19477503.2017.1401033

Khafizova, A. A., Zhdanov, S. P., Beltyukova, O. V., Lapidus, N. I., Grebenshchikova, L. Y., & Lushchik, I. V. (2024). A bibliometric analysis covering the relevant literature on science anxiety over two decades. *Eurasia Journal of Mathematics, Science and Technology Education, 20*(3), em2411. https://doi.org/10.29333/ejmste/14283

Khodabandelou, R., Aleebrahim, N., Amoozegar, A., & Mehran, G. (2019). Revisiting three decades of educational research in Iran: A bibliometric analysis. *Iranian Journal of Comparative Education*, *2*(1), 1–21. https://doi.org/10.22034/ijce.2019.187779.1002

Kieran, C., Pang, J. S., Schifter, D., & Ng, S. F. (2016). *Early algebra: Research into its nature, its learning, its teaching*. library.oapen.org. https://library.oapen.org/bitstream/handle/20.500.12657/27822/1002183.pdf

Kılıç, H. (2014). The impetus for teaching algebra in the early grades. *Edu 7: Yeditepe Üniversitesi Eğitim Fakültesi Dergisi, 3*(5), 48-71.

Kim, J., Kim, J., DesJardins, S. L., & McCall, B. P. (2015). Completing algebra II in high school: Does it increase college access and success?. *The Journal of Higher Education, 86*(4), 628-662. https://doi.org/10.1080/00221546.2015.11777377.

Knuth, E., Stephens, A., Blanton, M., & Gardiner, A. (2016). Build an early foundation for algebra success. *Phi Delta Kappan, 97*(6), 65–68. https://doi.org/10.1177/0031721716636877

Kolko, B. E. (2002). *International it implementation projects: Policy and cultural considerations*. In Proceedings. IEEE International Professional Communication Conference (pp. 352-359). IEEE.

Lange, K. E., Booth, J. L., & Newton, K. J. (2014). Learning algebra from worked examples. *The Mathematics Teacher, 107*(7), 534-540. https://doi.org/10.5951/mathteacher.107.7.0534

Lazarides, M. K., Lazaridou, I.-Z., & Papanas, N. (2023). Bibliometric analysis: Bridging informatics with science. *The International Journal of Lower Extremity Wounds,* 153473462311535. https://doi.org/10.1177/15347346231153538

Lee, K., Ng, S. F., & Bull, R. (2018). Learning and solving algebra word problems: The roles of relational skills, arithmetic, and executive functioning. *Developmental psychology, 54*(9), 1758. https://doi.org/10.1037/dev0000561.

Lee, O. J., Ju, H. W., Khang, G., Sun, P. P., & ... (2016). An experimental burn wound-healing study of non-thermal atmospheric pressure microplasma jet arrays. *Journal of Tissue …*. https://doi.org/10.1002/term.2074

Lins, R., & Kaput, J. (2004). *The early development of algebraic reasoning: The current state of the field.* The Future of the Teaching and Learning of Algebra The 12 th ICMI Study,

45-70.
MacDonald, A., Davies, N., Dockett, S., & Perry, B. (2012). *Early childhood mathematics education*. In Research in mathematics education in Australasia 2008-2011 (pp. 167-192). Brill.
MacGregor, M., & Stacey, K. (1995). The effect of different approaches to algebra on students' perceptions of functional relationships. *Mathematics Education Research Journal*, *7*(1), 69-85. https://doi.org/10.1007/BF03217276
Maggio, L. A., Ninkov, A., Frank, J. R., Costello, J. A., & Artino, A. R. (2022). Delineating the field of medical education: Bibliometric research approach(es). *Medical Education*, *56*(4), 387–394. https://doi.org/10.1111/medu.14677
Maharana, R. K., & Sethi, B. B. (2013). A bibliometric analysis of the research output of Sambalpur university's publication in ISI web of science during 2007-11. *Library Philosophy and Practice*, *2013*(April), 1–14.
Malihatuddarojah, D., & Prahmana, R. C. I. (2019). Analisis kesalahan siswa dalam menyelesaikan permasalahan operasi bentuk aljabar [Analysis of student errors in solving algebraic form operation problems]. *Jurnal Pendidikan Matematika*, *13*(1), 1–8. https://doi.org/10.22342/jpm.13.1.6668.1-8
Malisani, E., & Spagnolo, F. (2009). From arithmetical thought to algebraic thought: The role of the "variable." *Educational Studies in Mathematics*, *71*(1), 19–41. https://doi.org/10.1007/s10649-008-9157-x
Miguel, S., Chinchilla-Rodriguez, Z., & de Moya-Anegón, F. (2011). Open access and Scopus: A new approach to scientific visibility from the standpoint of access. Journal of the American society for information science and technology, 62(6), 1130-1145. https://doi.org/10.1002/asi.21532
Moorhead, G. (1981). Organizational analysis: An integration of the macro and micro approaches. *Journal of Management Studies*, *18*(2), 191-218. https://doi.org/10.1111/j.1467-6486.1981.tb00099.x
Mukhni, M., Mirna, M., & Khairani, K. (2021). Teachers' perspective of algebra learning in junior high school. *Journal of Physics: Conference Series*, *1742*(1), 012015. https://doi.org/10.1088/1742-6596/1742/1/012015
Mumford, R. A., Pierzchala, P. A., Strauss, A. W., & Zimmerman, M. (1981). Purification of a membrane-bound metalloendopeptidase from porcine kidney that degrades peptide hormones. *Proceedings of the National Academy of Sciences of the United States of America*, *78*(11 II), 6623–6627. https://doi.org/10.1073/pnas.78.11.6623
Nandiyanto, A. B. D., Al Husaeni, D. N., & Al Husaeni, D. F. (2021). A bibliometric analysis of chemical engineering research using vosviewer and its correlation with Covid-19 pandemic condition. *Journal of Engineering Science and Technology*, *16*(6), 4414–4422.
National Council of Teachers of Mathematics. (2000). *Principles and standards for school mathematics*. Reston, VA: Author.
Noto, M. S., Pramuditya, S. A., & Handayani, V. D. (2020). Exploration of learning obstacle based on mathematical understanding of algebra in junior high school. *EduMa: Mathematics education learning and teaching*, *9*(1), 14-20.
Novotná, J., & Hošpesová, A. (2014). *Traditional versus investigative approaches to teaching algebra at the lower secondary level: The case of equations*. In Algebra teaching around the world (pp. 59-79). Brill.
Nurmawanti, I., & Sulandra, I. M. (2020). Exploring of student's algebraic thinking process through pattern generalization using similarity or proximity perception. *Mosharafa: Jurnal Pendidikan Matematika*, *9*(2), 191–202. https://doi.org/10.31980/mosharafa.v9i2.603
Origgi, G., & Ramello, G. B. (2015). Current dynamics of scholarly publishing. *Evaluation*

Review, *39*(1), 3–18. https://doi.org/10.1177/0193841X15572017

Panorkou, N. (2020). Reasoning dynamically about the area of a rectangle: The case of Lora and Isaac. *Digital Experiences in Mathematics Education, 6*(3), 257-292. https://doi.org/10.1007/s40751-020-00074-4

Piaget, J. (1970). *Piaget's theory (Vol. 1, pp. 703-732)*. Wiley.

Pilet, J., Chenevotot, F., Grugeon, B., El Kechai, N., & Delozanne, E. (2013). *Bridging diagnosis and learning of elementary algebra using technologies.* In The Eighth Congress of the European society for Research in Mathematics Education CERME8 (pp. 2684-2693).

Pincheira, N., & Alsina, Á. (2021). Teachers' mathematics knowledge for teaching early algebra: A systematic review from the mkt perspective. *Mathematics*, *9*(20), 1-16. https://doi.org/10.3390/math9202590

Pinto, E., & Cañadas, M. C. (2021). Generalizations of third and fifth graders within a functional approach to early algebra. *Mathematics Education Research Journal, 33*(1), 113–134. doi: https://doi.org/10.1007/s13394-019 00300-2

Pramesti, T. I., & Retnawati, H. (2019). Difficulties in learning algebra: An analysis of students' errors. In A. A.M., W. A., & V. J.A. (Eds.), *Journal of Physics: Conference Series,*. 1320(1), 012061. https://doi.org/10.1088/1742-6596/1320/1/012061

Prendergast, M., & O'Donoghue, J. (2010). Developing and maintaining interest in school algebra. *Literacy Information and Computer Education Journal*, *1*(4) 245, 253.

Radford, L. (2008). Theories in mathematics education: A brief inquiry into their conceptual differences. *ICMI Survey Team 7. The Notion and Role of Theory in Mathematics Education Research*, *Juni*, 1–17. http://pthurston.laurentian.ca/NR/rdonlyres/77731A60-1A3E-4168-9D3E-F65ADBF37BAD/0/radfordicmist7.pdf

Radford, L. (2018). *The emergence of symbolic algebraic thinking in primary school*. 3–25. https://doi.org/10.1007/978-3-319-68351-5_1

Ralston, N. C., Li, M., & Taylor, C. (2018). The development and initial validation of an assessment of algebraic thinking for students in the elementary grades. *Educational Assessment*, *23*(3), 211-227. https://doi.org/10.1080/10627197.2018.1483191

Reeves, P. M., Pun, W. H., & Chung, K. S. (2017). Influence of teacher collaboration on job satisfaction and student achievement. *Teaching and Teacher Education*. https://www.sciencedirect.com/science/article/pii/S0742051X17310053.https://doi.org/10.1016/j.tate.2017.06.016

Reyes, J. D., Insorio, A. O., Ingreso, M. L. V, Hilario, F. F., & Gutierrez, C. R. (2019). Conception and application of contextualization in mathematics education. *International Journal of Education Studies in Mathematics*, *6*(1), 1–18.

Rhine, S., Harrington, R., & Olszewski, B. (2015). The role of technology in increasing preservice teachers' anticipation of students' thinking in algebra. *Contemporary Issues in Technology and Teacher Education*, *15*(2), 85-105.

Ross, A., & Willson, V. (2012). The effects of representations, constructivist approaches, and engagement on middle school students' algebraic procedure and conceptual understanding. *School Science and Mathematics, 112*(2), 117-128. https://doi.org/10.1111/j.1949-8594.2011.00125.x

Roy, S. B., & Basak, M. (2013). Journal of Documentation: A bibliometric study. *Library Philosophy and Practice (e-Journal)*. Paper, 945.

Saputro, B. A., Suryadi, D., Rosjanuardi, R., & Kartasasmita, B. G. (2018). Analysis of students' errors in responding to TIMSS domain algebra problem. *Journal of Physics: Conference Series*, *1088*(1), 012031). https://doi.org/10.1088/1742-6596/1088/1/012031

Schifter, D. (2017). *Early algebra as analysis of structure: A focus on operations*. In Teaching and learning algebraic thinking with 5-to 12-year-olds: The global evolution of an

emerging field of research and practice (pp. 309-327). Springer International Publishing. https://doi.org/10.1007/978-3-319-68351-5_13
Schifter, D., Russell, S. J., & Bastable, V. (2009). Early algebra to reach the range of learners. *Teaching Children Mathematics, 16*(4), 230-237. https://doi.org/10.5951/TCM.16.4.0230
Shayer, M., Küchemann, D. E., & Wylam, H. (1976). The distribution of Piagetian stages of thinking in British middle and secondary school children. *British Journal of Educational Psychology*, 46(2), 164-173.
Slowe, S. (2018). The role of the institution in scholarly publishing. *Emerging Topics in Life Sciences*, *2*(6), 751–754. https://doi.org/10.1042/ETLS20180141
Snipes, J., & Finkelstein, N. (2014). Opening a gateway to college access: algebra at the right time. Research Brief. *Regional Educational Laboratory West*, 1–10. http://eric.ed.gov/?id=ED559739
Statistics, E. (2015). *Digest of education statistics*. NCES Publication, 11.
Stephens, M., & Ribeiro, A. (2012). Working towards algebra: The importance of relational thinking. *Revista latinoamericana de investigación en matemática educativa, 15*(3), 373-402.
Sibgatullin, I. R., Korzhuev, A. V., Khairullina, E. R., Sadykova, A. R., Baturina, R. V., & Chauzova, V. (2022). A systematic review on algebraic thinking in education. *Eurasia Journal of Mathematics, Science and Technology Education*, *18*(1), em2065. https://doi.org/10.29333/ejmste/11486
Sidik, G. S., Suryadi, D., & Turmudi, T. (2021). Learning obstacle on addition and subtraction of primary school students: Analysis of algebraic thinking. *Education Research International, 2021*, 1-10.
Stern, E. (2005). *Knowledge restructuring as a powerful mechanism of cognitive development: How to lay an early foundation for conceptual understanding in formal domains*. In BJEP Monograph Series II, Number 3-Pedagogy-Teaching for Learning (Vol. 155, No. 170, pp. 155-170). British Psychological Society.
Stout, R., & College, G. (1871). *The development of algebraic structures during the nineteenth century*. 153–158.
Suparman, S., Juandi, D., & Tamur, M. (2021). Does problem-based learning enhance students' higher order thinking skills in mathematics learning? A systematic review and meta-analysis. *ACM International Conference Proceeding Series, April*, 44–51. https://doi.org/10.1145/3451400.3451408
Tabak, J. (2004). *Algebra: Sets, symbols, and the language of thought (history of mathematics)*. In United States of America–USA: Library of Congress.
Tall, D., & Thomas, M. (1991). Encouraging versatile thinking in algebra using the computer. *Educational Studies in Mathematics, 22*(2), 125–147. https://doi.org/10.1007/BF00555720
Thomas, M., & Tall, D. (1988). Longer-term conceptual benefits from using a computer in algebra teaching. *Proceedings of the 12th Conference of PME, Budapest*, 601–608.
Tuominen, J., Andersson, C., Boistrup, L. B. & Eriksson., I. (2018). Relate before calculate: students' ways of experiencing relationships between quantities. *Didactica Matematicae, 40*, 5-33.
Usman, A. I. (2015). Secondary school pre-service mathematics teachers' content knowledge of algebraic word problem in Nigeria. *European Journal of science and mathematics education, 3*(4), 350-363.
Van Amerom, B. A. (2002). *5 Reinvention of early algebra. 2 Jumping ahead 9*, 47.
Van Amerom, B. A. (2003). Focusing on informal strategies when linking arithmetic to early algebra. *Educational Studies in Mathematics, 54*(1), 63–75.

https://doi.org/10.1023/B:EDUC.0000005237.72281.bf

Van Raan, A. F., Visser, M. S., Van Leeuwen, T. N., & Van Wijk, E. (2003). Bibliometric analysis of psychotherapy research: Performance assessment and position in the journal landscape. *Psychotherapy Research*, *13*(4), 511-528. https://doi.org/10.1093/ptr/kpg038

Veith, J. M., Beste, M. L., Kindervater, M., Krause, M., Straulino, M., Greinert, F., & Bitzenbauer, P. (2023). Mathematics education research on algebra over the last two decades: quo vadis? *Frontiers in Education*, *8*. https://doi.org/10.3389/feduc.2023.1211920

Vergel, R. (2015). Generalización de patrones y formas de pensamiento algebraico temprano. *PNA. Revista de Investigación En Didáctica de La Matemática*, *9*(3), 193–215. https://doi.org/10.30827/pna.v9i3.6220

Wahyuni, R., Herman, T., & Fatimah, S. (2022). Students' interpretation of the algebraic letters: The Case of the early year in middle school. *AIP Conference Proceedings*, *2468*(December). https://doi.org/10.1063/5.0102659

Wahyuni, R., Prabawanto, S., & Herman, T. (2020). Students' difficulties in solving algebra task in middle school. *Journal of Physics: Conference Series*, *1521*(3), 032071. https://doi.org/10.1088/1742-6596/1521/3/032071

Waltman, L., van Eck, N. J., & Noyons, E. C. M. (2010). A unified approach to mapping and clustering of bibliometric networks. *Journal of Informetrics*, *4*(4), 629–635. https://doi.org/10.1016/j.joi.2010.07.002

Warren, E. (2003). The role of arithmetic structure in the transition from arithmetic to algebra. *Mathematics Education Research Journal*, *15*(2), 122–137

Warren, E. (2004). Generalising Arithmetic : Supporting the Process in the Early Years. *Psychology*, *4*, 417–424. https://doi.org/10.1093/ptr/kpg038

Watanabe, T. (2011). *Shiki: A critical foundation for school algebra in Japanese elementary school mathematics*. In Early algebraization (pp. 109–124). Springer. https://doi.org/10.1007/978-3-642-17735-4_7

Weinert, F. E., & De Corte, E. (2001). *Educational research for educational practice*. In International encyclopedia of the social and behavioral sciences (pp. 4316-4323). Elsevier.

Welder, R. M. (2012). Improving algebra preparation: Implications from research on student misconceptions and difficulties. *School science and mathematics*, *112*(4), 255-264. https://doi.org/10.1111/j.1949-8594.2012.00136.x

Wilder, S. (2013). *Algebra: The Key to Student Success, Or Just Another Hurdle?*

Wulach, J. S. (1977). Piagetian cognitive development and primary process thinking in children. *Journal of personality assessment*, *41*(3), 230-237.

Zan, B. U. (2019). Doğrudan atıf, ortak atıf ve bibliyografik eşleşme yaklaşımlarına dayalı olarak araştırma alanlarının değerlendirilmesi. *Sosyal Bilimler Araştırmaları Dergisi*, *14*(2), 501–516.

Zupic, I., & Čater, T. (2015). Bibliometric methods in management and organization. *Organizational Research Methods*, *18*(3), 429–472. https://doi.org/10.1177/1094428114562629