Journal of Research and Advances in Mathematics Education

Volume 10, Issue 1, January 2025, pp. 1 – 14
DOI: 10.23917/jramathedu.v10i1.6482
p-ISSN: 2503-3697, e-ISSN: 2541-2590

Growth mindset and mathematics: A bibliometric analysis

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Citation: Metu, C.A., Marbán, J.M., & Espina, E. (2025). Growth mindset in mathematics: A bibliometric analysis. *JRAMathEdu (Journal of Research and Advances in Mathematics Education)*, 10(1), 1–14. https://doi.org/10.23917/jramathedu.v10i1.6482

ARTICLE HISTORY:
Received August 2024
Revised 8 November 2024
Accepted 21 November 2024
Published 30 January 2025

KEYWORDS:
Bibliometric analysis
Growth mindset
Mathematics
Scopus
VOSviewer

ABSTRACT

A growth mindset is the belief that one's intellect and abilities may develop through effort. This mindset suggests that intelligence is not fixed but adaptable. With the continuous growth in literature on the growth mindset in mathematics, there is a need to investigate the current trends from a bibliometric perspective. To meet this need, the leading countries, source citations, author co-citations, and word co-occurrences were examined. A total of 317 articles were retrieved from the Scopus and Web of Science (WoS) databases spanning 2014–2023. The VOSviewer software was used to analyze the collected data. The United States was the leading contributor to growth mindset research, Frontiers in Psychology emerged as the major source of citations, with Dweck being the most cited author. The word co-occurrence map was grouped into different clusters. The Scopus database shows how belief systems shape mindsets and how motivation intersects with clinical and longitudinal investigations. WoS emphasizes the importance of interventions that narrow belief-achievement gaps, as well as the role of technology. These findings offer valuable insights into the expanding body of research on growth mindset in mathematics, paving the way for further research to explore interventions, cultural influences, and long-term effects on student outcomes.

INTRODUCTION

Mathematics learning is a critical aspect of education, yet many students experience negative emotions and negative attitudes in mathematics related contexts. These negative affective responses often stem from a lack of confidence in solving mathematical problems, which affects the student's motivation, engagement, and general perception (Aguilar, 2021; Metu et al., 2023). The mindset seems to provide a valuable base for increasing students' resilience, drive, and intellect. Over the years, there have been discussions on whether intelligence is fixed or malleable. In the late twentieth century, Dweck's (2000) work into self-theories and motivation reported that intelligence is stable but adaptive. The author continued that the hand that one is dealt with serves as a foundation for growth, as individual qualities are honed through dedication and strategic approaches, which Dweck (2006) termed "Growth Mindset'. According to the author, a growth mindset entails taking feedback, learning from experience, and coming up with strategies for improving. Success stems from having the correct mindset as opposed to talent, intelligence, or education. As a result, Dweck (2014) claims that not all individuals flourish in an organization with a growth mindset, as individuals must first gain a deep understanding of themselves before they can effectively communicate their developmental needs.

The earliest trace on growth mindset in mathematics was undertaken by Blackwell et al. (2007), who investigated how implicit ideas of intelligence can predict achievements in adolescents. They discovered that students with a growth mentality outscored those with a fixed perspective in

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math. According to Howard and Whitaker (2011), these growth mindset qualities are based on one's beliefs. Nix et al. (2015) built upon this idea by exploring how the belief in the malleability of mathematical ability, a key aspect of the growth mindset, affects gender disparities in STEM participation, especially favoring women's enrollment in health science professions. Then Pennington and Heim (2016) went further to explore how heightened in-group representation mitigates the impact of stereotype threats on women's arithmetic ability. The study's findings demonstrated that participants reported a poorer growth mentality when assessed both individually and in groups under stereotype threat. Bostwick et al. (2017) adopted an integrated approach to investigate how well-established and emerging growth constructs impacts the students' academic performance in mathematics. To evaluate the measurement and substantive hypotheses, the researchers used Structural Equation Modeling (SEM) and Confirmation Factor Analysis. In their research, they reported that self-based and task-based growth goals and growth mindsets are well represented by underlying growth-oriented components. According to McWilliam (2017), these growth-oriented components include: no negative self-bias when faced with difficult situations; risk-taking in learning through trial and error; receiving support, feedback, and guidance; applying purposeful effort and resilience to find a solution; thereby disregarding comparison with others; or the fear of being judged by others. Bedford (2017) emphasized the significance of establishing a growth-oriented component in education, stating that motivational variables are critical interventions for academic performance. Van Hoeve et al. (2023) implemented the interventions and discovered that students' mindset scores transformed to a more growth-oriented attitude. The findings of the study also highlight the practical benefits of encouraging a growth mindset in educational environments.

Several variables have been identified as supporting fostering a growth mindset in students, such as socioeconomic background (Claro, 2016), school motivation and teacher support (Bedford, 2017), parental influence (Gorleku et al., 2018), peer influence and societal cues (Limeri et al., 2020), feedback and willingness (Masalee et al., 2021), recognizing individual differences and good emotional control (Masalee et al., 2021), cognitive components (Bosch, 2021) and cultural variations (Dong & Kang, 2022), among others. Despite the increasing popularity of growth mindset among researchers and the exponential growth in literature, there is still a lack of quantitative data on growth mindset in mathematics. Available literature also fails to provide fresh insights on how the growth mindset has evolved in mathematics, hence, the need for a bibliometric study. As a result, this examination of the growth mindset in mathematics will provide a closer look at (1) the bibliographic coupling of countries, which could demonstrate state actions and countries that led the way in advancement in the realm of growth mindset; (2) the source citation, which could highlight the journals where the articles on growth mindset came from; (3) the author co-citation, which could show the various researchers and their contributions to growth mindset in mathematics; and (4) the word co-occurrence which may show which were the most meaningful keywords related to growth mindset in mathematics.

METHODS

This study was conducted from a bibliometric perspective. Bibliometric analysis is an effective method for discovering and evaluating massive amounts of scientific data (Ellegaard & Wallin, 2015; Liao et al., 2018). It is a technique that adopts a statistical approach to qualitatively and quantitatively analyze academic publications in a specific field (Chain et al., 2019; Shen et al., 2022). According to Parlina et al. (2020), bibliometric analysis provides a better understanding of major research directions, trends, their evolution, and the relationships between literatures. Hence, bibliometric methods stand poised as a valuable instrument which allows a researcher to navigate the evolutionary intricacies of a certain discipline and shed light on the developing regions in that field (Verma & Gustafsson, 2020; Donthu et al., 2020; Donthu et al., 2021; Mas-Tur et al., 2021).

In a bibliographic analysis, data can be classified into several characteristics such as keywords, nations, citations, authors, publications, subjects, titles and affiliations. Researchers can use advanced bibliometric analysis tools to establish bibliographic couplings, measure the intensity of the generated coupling connections, examine bibliometric networks, generate bibliographic maps,

then explore and display the maps (Karakus, 2019). Properly conducted bibliometric research can lay the groundwork for unique and substantial advances in a discipline (Öztürk, et al., 2024). Available literature on the Web of Science and Scopus shows that a bibliometric analysis was undertaken on latent issues and research trends in growth mindset literature, for mathematics instruction (Xu et al., 2022). However, the researchers used the R programming language (biblioshiny package & structural topic modeling) to analyze the data, whereas the data in this present study was analyzed using VOSviewer (version 1.6.20) software. Growth mindset appears to be the only keyword the researchers considered in their search. According to literature, several authors considered other terms that are synonymous with growth mindset in mathematics, such as ability mindset (Puusepp et al., 2023), mindset belief (Sun, 2019; Degol et al., 2019; Mielicki et al., 2022; Gonzalez-DeHass et al., 2023) and creativity mindset (Orr & Kukner, 2015; Haq, 2021). These terms all formed part of the keywords used in this present study. Some certain features were left unexplained in the previous study like the source of the citations, author co-citation and word co-occurrence. The previous study also failed to specify the counting methods (full or fractional) used during the analysis of data, which this current study addressed.

Data collection

A total of 317 previous works related to growth mindset in mathematics were obtained from the Scopus and Web of Science (WoS) databases, from the years 2014–2023 (retrieved April 1, 2024). These two bibliographic databases are often regarded as the most extensive data sources for a variety of applications (Pranckutė, 2021). In both databases, the terms "Growth Mindset" or "Mindset Belief" or "Ability Mindset" or "Creativ* Mindset" and Math*, were included in the search, with the aim of retrieving as many documents as possible. The paper title, abstract, and keywords were the focus of the search. Only publications in English were considered for this study. This study also consisted of only articles and book reviews. Previous bibliometric analysis demonstrates that individuals are interested in articles and reviews of books because of their scientific impact, and they include a list of references used in conducting citation-based analysis (Naveed et al., 2021). In addition, the database exporting choices varied significantly. WoS provides several output formats, the most ideal for bibliometric purposes being plain text or tab-delimited. Scopus, on the other hand, uses RIS or CSV formats. Moreover, the search on Web of Science (WoS) was constrained to specific databases, namely the Social Science Citation Index (SSCI), the Book Citation Index - Social Sciences and Humanities (BKCI-SH), the Emerging Sources Citation Index (ESCI), the Science Citation Index Expanded (SCI-EXP), and the Book Citation Index – Science (BCI-S). These databases were not accessible within the Scopus platform.

Data analysis

All the data retrieved from the Scopus and WoS databases were analyzed using the VOSviewer software, considering the bibliographic coupling of countries, the source citation, the author co-citation, and the word co-occurrence. The VOSviewer software which was developed by Van Eck and Waltman (2010) is a commonly used software application for constructing and visualizing various bibliometric networks. The VOSviewer was considered most appropriate for this investigation because it has a low-dimensional visualization in which the distance between any pair of items shows their similarity as accurately as possible (Van Eck & Waltman, 2010; Van Eck et al., 2010; Nadzar, 2017; Hong et al., 2020; Rodriguez-Rodriguez et al., 2021, Wani, 2023).

The software can generate three different visualization maps, but this present study made use of the network and density visualization maps. The nodes on the map represent elements such as authors, institutes, and countries, with links between them representing interactions among these elements (Van Eck & Waltman, 2010; Cheng et al., 2022). Lines linking the nodes signify relationships, with the size of each element influenced by factors like publication count, citation frequency, or occurrences. To differentiate clusters or denote the average appearance year, nodes and lines are colored differently (Yeung et al., 2019b). These colours indicate the emergence of clusters with similar terms. The nodes on density visualization maps are identical to those on the network visualization maps, but their colour shows the density of the elements at every point (Espina et al., 2022). The fractional counting method was used to ensure that all references cited in a publication

were equally representative. According to Perianes-Rodriguez et al. (2016), full counting findings can easily lead to misconceptions or misinterpretations, which could be avoided by utilizing fractional counting as opposed.

FINDINGS AND DISCUSSION

The analysis of the WoS produced 165 documents, while Scopus contained 152 documents across 199 journals. These publications involved contributions from 1078 authors and co-authors and garnered a total of 15,664 citations. The retrieved data also showed the documents on growth mindset in mathematics, that were published in scientific literature and their evolution from 2014 to 2023.

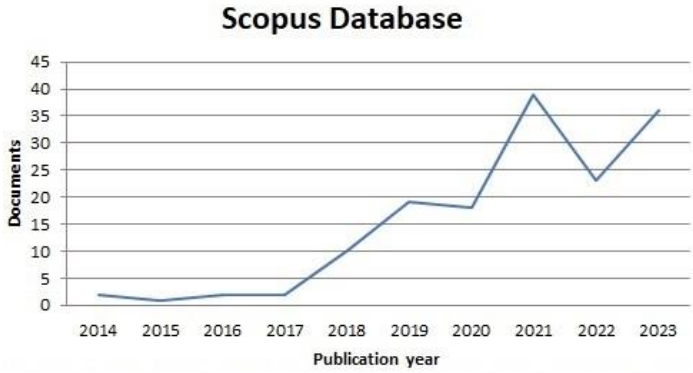

Figure 1. Frequencies of documents on growth mindset in math per year (Scopus)

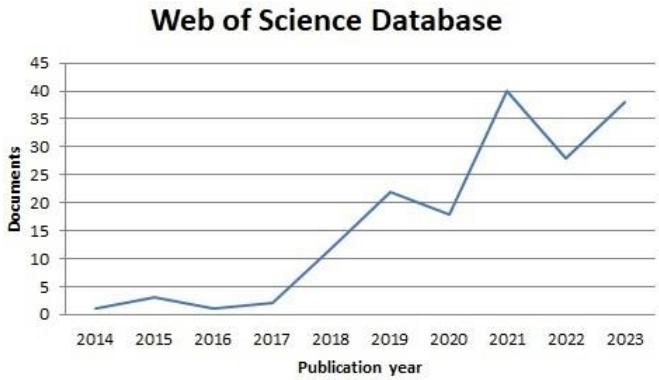

Figure 2. Frequencies of documents on growth mindset in math per year (WoS)

Figure 1 and Figure 2 show the charts from the Scopus and WoS databases displaying the rise in literature on growth mindset in mathematics. Though this rise has been undulating, the data found reflected the steady rise in research interest and attention. The focus of most of these studies was to determine if growth mindset can predict student outcomes, the effectiveness of growth mindset interventions, and if teachers can successfully instill a growth mindset in students (Fuesting et al., 2019; Huang, et al., 2019; Bostwick, et al., 2019; Porter et al., 2020). The year 2021 produced the highest number of documents, with 39 from Scopus and 40 from WoS. Perhaps this was owing to the COVID-19 pandemic, which prompted educators to reassess traditional teaching approaches and shift towards hybrid learning contexts. This shift may have prompted more research into strategies for supporting students' mathematical learning, including the role of the growth mindset.

Analysis of bibliographic coupling of the countries

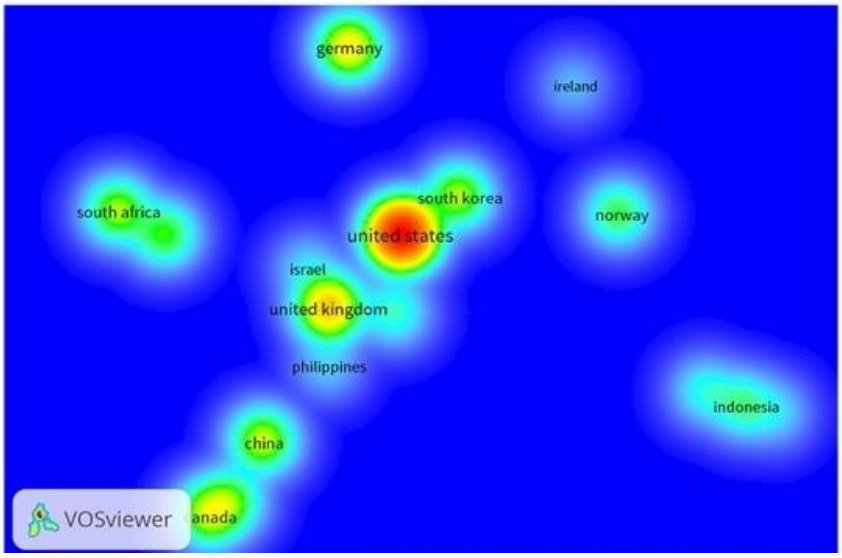

Figure 3. Density map visualization of bibliographic coupling of countries (Scopus)

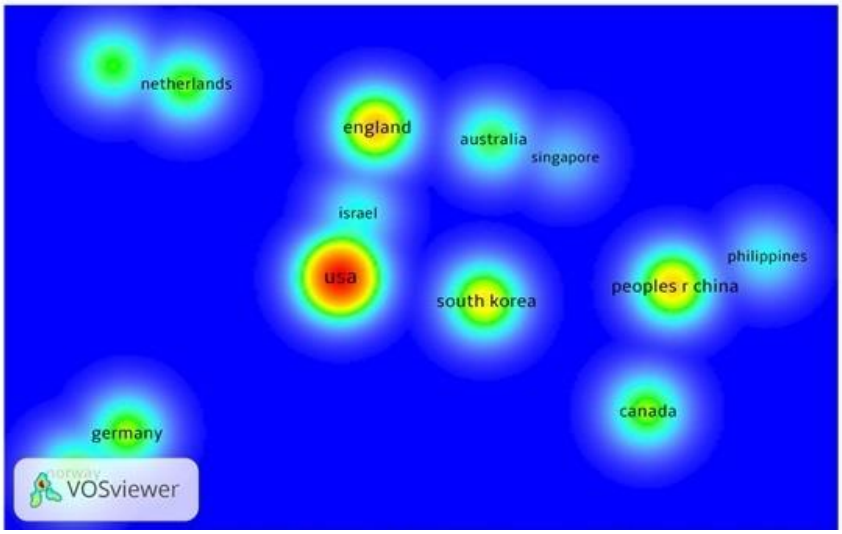

Figure 4. Density map visualization of bibliographic coupling of countries (WoS)

To determine the distribution of publications as a result of the country of origin, an analysis on the bibliographic coupling of countries was conducted. In the initial search, 58 countries were found both in the Scopus and WoS databases. Given that the metric for analysis only considered countries with at least 10 associated publications, the threshold met was 17 countries in Scopus, and 13 countries in WoS. This represents 51.7% of the total number of countries. Countries with at least 10 publications were considered for this study, as they were seen as the major contributors to the growth mindset in mathematics. Figure 3 and Figure 4 show the density map visualization of the analysis.

The United States, United Kingdom, China, Australia and Canada were the leading countries, accordingly, in the progress of growth mindset research in mathematics, with a remarkable 81.5% of the total publications in Scopus and WoS databases. Incidentally, the first work on growth mindset in mathematics was also conducted in USA, thereby setting the stone for subsequent research in this field. Given that growth mindset is a psychological construct, it is not also surprising that these countries led research in this field as psychologists in these countries are concerned about bridging the gap between psychology and mathematics education (Newcombe et. al., 2009; Laski, et al., 2013; Steffe, 2017; Outhwaite, et al., 2019). In addition, all these countries were also on the list of the world's leading nations in research and development (Boroush & Guci, 2022). These countries are

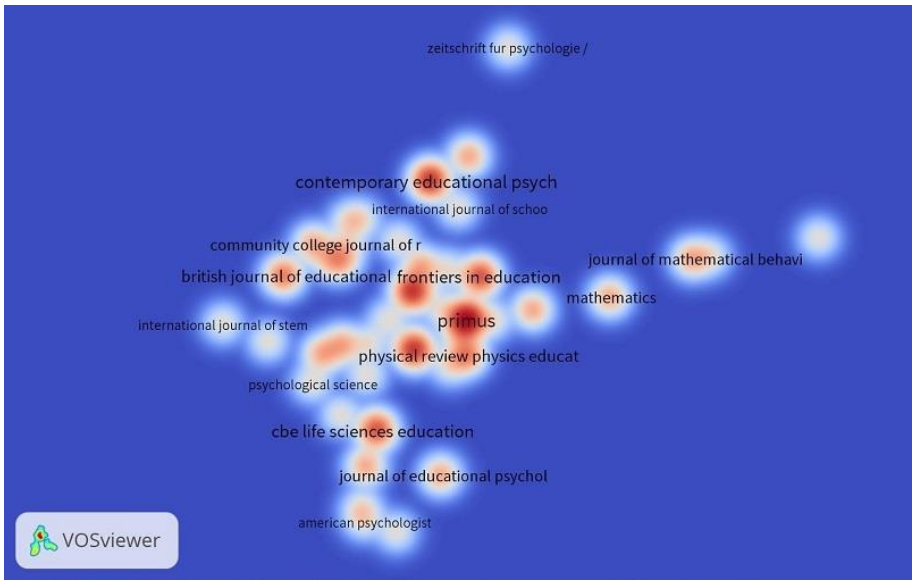

Figure 5. Density map visualization of source citations (Scopus)

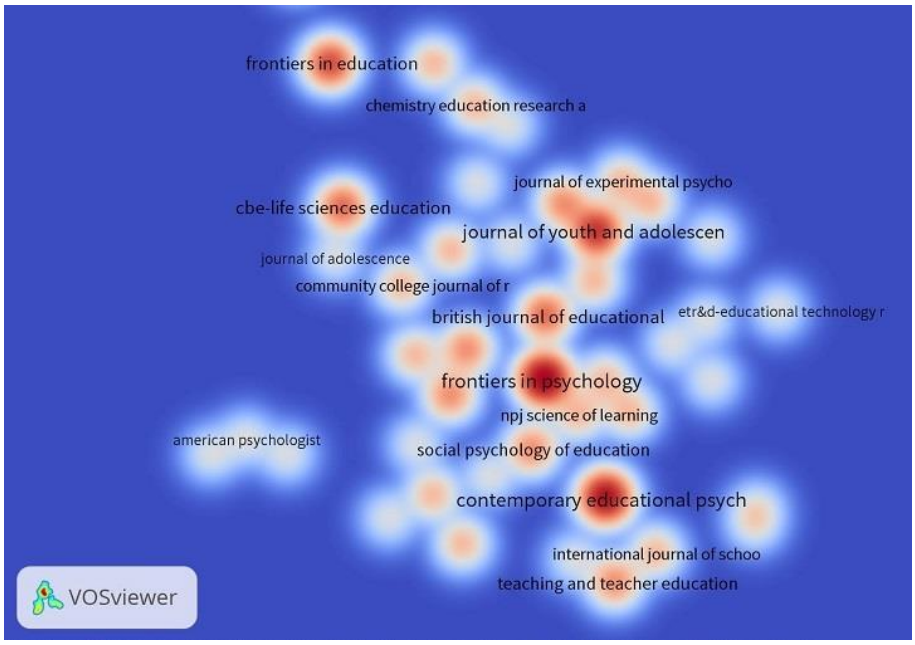

Figure 6. Density map visualization of source citations (WoS)

keen on scientific discoveries, and inventive applications of cutting-edge knowledge to address both problems and possibilities in diverse societal sectors such as health and the environment. With the exception of China, which has an increasing number of English speakers yearly, all four other countries have English as their official language, which is one of the criteria the researcher considered in the initial search.

Analysis of the bibliographic coupling of source citation

To find out the sources that have the most publications on growth mindset in mathematics, a bibliographic analysis of the source citations was carried out. The criteria used were sources with at least 10 publications, as these were considered the major source citations on growth mindset. The threshold met was 46 out of 99 in Scopus and 47 out of 101 in WoS. This represents 46.5% of the total sources. Figure 5 and Figure 6 show the density visualization maps of the analysis.

The sources with the most citations are Frontier in Psychology, Contemporary Educational Psychology, Journal of Youth & Adolescence, Frontier in Education, and CBE Life Science Education has the highest number of citation sources. Frontiers in Psychology was the most productive source

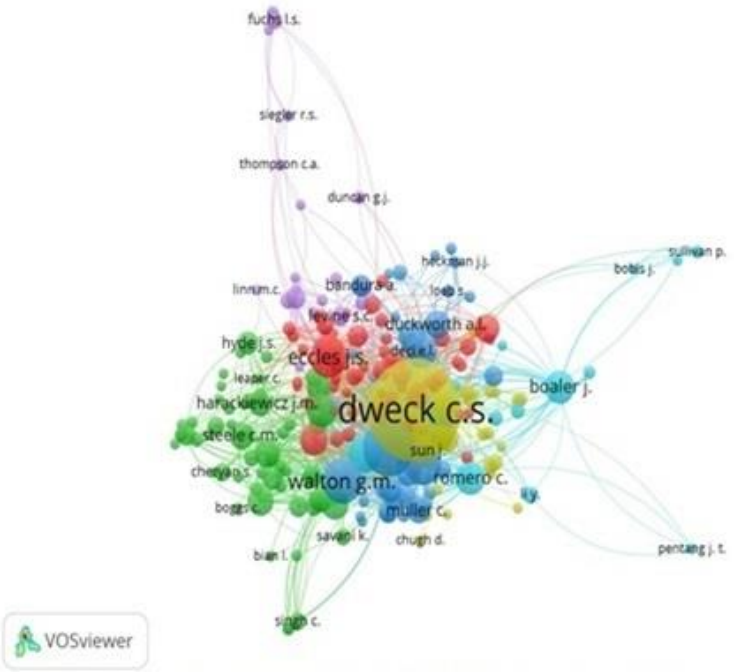

Figure 7. Network map visualization of author co-citation (Scopus)

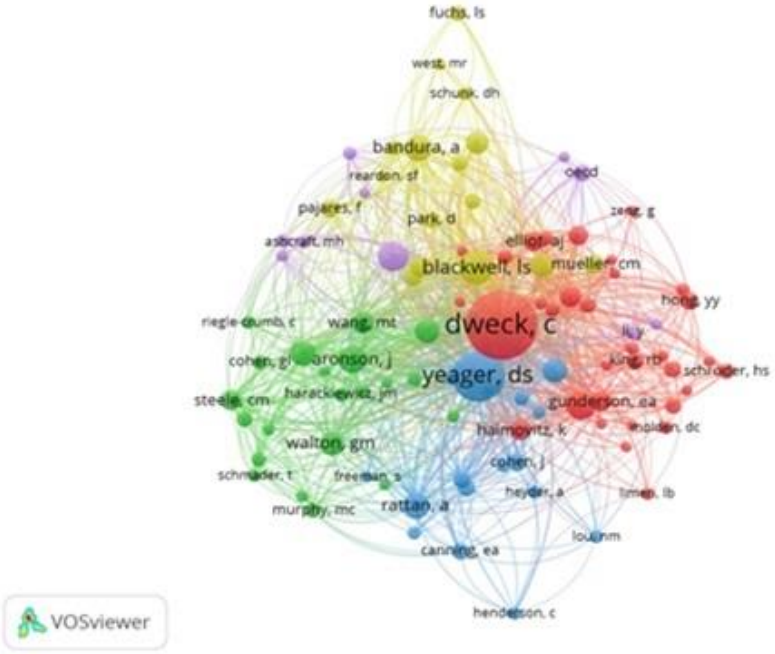

Figure 8. Network map visualization of author co-citation (WoS)

with 14 articles, accounting for 7.4% of total publications and 119 citations. It was followed by Contemporary Educational Psychology with 13 articles (6.91% of total publications and 140 citations), Journal of Youth & Adolescence with 11 documents (5.85%; 296 citations), Frontier in Education with 9 documents (4.79%; 61 citations), and CBE Life Science Education with 8 documents (4.26%; 142 citations). These sources emphasize the importance of the growth mindset from a psychological perspective. These citation sources emphasize the psychological significance of a growth mentality. The literature on growth mindset in mathematics across these publications demonstrates the importance of the concept in understanding how people approach and engage with mathematical learning. Given this importance, effective mathematical interventions may be designed

in the field of mathematics education for a real teaching-learning environment concerned with fostering a growth mindset in mathematics among the students.

Analysis of author co-citation

In order to find out how various citations on growth mindset in mathematics were made among authors, an analysis of the author co-citation was conducted. In order to select the most co-cited authors, h-index of 10 was used to select authors with a minimum of 10 citations. In the Scopus database, a total of 264 out of 11228 authors met the criterion, while 99 out of 5584 authors met the threshold in the WoS database. The thesaraus was used to clean files (34 in Scopus & 2 in WoS) that were duplicated. The final data used for the analysis were 230 authors in Scopus and 97 authors in WoS. Figure 7 and Figure 8 show network visualization maps of the analysis.

The analysis of this data from Scopus and WoS databases shows the important role various authors played in the development of the growth mindset in mathematics. Taking into account the clusters of author co-citation shown in Figure 7 and Figure 8, it could be interpreted that the clusters are based on how literature has been cited among authors. Dweck has the most citations among all the authors, with a total of 1261. Yeager has the 2nd most citation with 487, Walton with 217, Eccles with 190 and Blackwell with 180. Dweck's work is foundational to the concept of mindset, as it distinguishes between a "fixed mindset" and a "growth mindset. Dweck's (2008) study on mindset and mathematics achievement has shaped educators' approaches to teaching mathematics, emphasizing students' beliefs regarding mathematics learning and intelligence. The study revealed that the differences in math grades were influenced by several significant variables. Students with a growth mindset demonstrated a significantly greater orientation toward learning goals than their counterparts with a fixed mindset. While they valued their grades, they prioritized learning to an even greater extent. Yeager alongside other researchers concentrated on the practical application of mindset theory, especially in educational contexts. The authors contributed to the research on how schools can enhance students' approaches to mathematics by shaping students' potential to benefit from their efforts. This is geared towards increasing students' perseverance in math (Bettinger et al., 2018). Walton, Eccles, and Blackwell were concerned with the social and psychological factors that influence mindset, thereby conducting studies demonstrating how to foster a growth mindset in everyday activity. (Eccles, 2009; Blackwell et al., 2015; Hwang et al., 2019; Wingfield et al., 2021; Yeager et al., 2021). These authors' contributions to the field of mathematics, such as their study of math-related career aspirations and choices within Eccles et al.'s expectancy (Lauermann et al., 2017) and the role of implicit theories of intelligence in adolescents' math achievement (Blackwell et al., 2007), have helped teachers learn more about the psychological traits that affect a student's ability to do well in math. Their research demonstrates that cultivating a growth mindset can improve desire, perseverance, and better outcomes for learners in math and science-related subjects.

Analysis of word co-occurrence

In word co-occurrence analysis, the relevant keywords and the topics most commonly pertaining to growth mindset were identified. Figure 9 and Figure 10 show the network visualization maps of said analysis. The search for the word co-occurrence produced 583 and 854 words in Scopus and WoS, respectively. The criteria for words that appeared at least 10 times yielded very few results, thereby eliminating important keywords. Therefore, a criterion of at least 5 words was used for this analysis. 37 terms came from the Scopus database and 61 from the WoS database. These numbers dropped to 14 (Scopus) and 19 (WoS) when the repeated keywords and words considered irrelevant to the present study were manually eliminated.

The analysis of word co-occurrence serves as a significant indicator of a research focal point. The identified keywords each serve distinct functions within the domain of mathematics education. In both databases, the keywords with the most occurrences are growth mindset, motivation, achievement, implicit theories, and math. The keywords are organized into several clusters. In the Scopus database, the first cluster (blue) combines growth mindset, fixed mindset, and belief. It suggests the knowledge of how belief systems shape one's attitude towards mathematics . It also

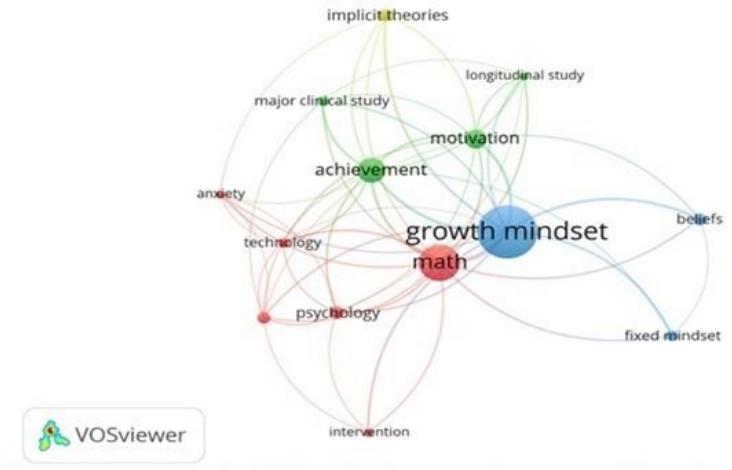

Figure 9. Network map visualization of word co-occurrence (Scopus)

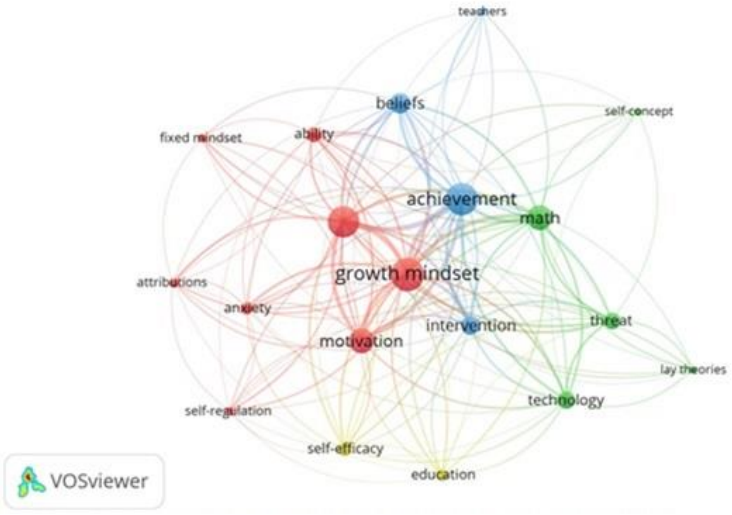

Figure 10. Network map visualization of word co-occurrence (WoS)

demonstrates the recognition of their interrelationship in influencing one's attitude and approach to mathematics learning, challenges, and personal growth. Math, intervention, anxiety, and technology are all represented in the second cluster (red). This demonstrates how technology-based interventions can reduce math anxiety and improve learning outcomes in mathematics education. The third cluster (green) includes motivation, achievement, clinical, and longitudinal research. This could indicate how motivation, therapeutic variables, and longitudinal dynamics interact to affect ones attainment in mathematics realted context. The red cluster in the WoS database includes growth mindset, fixed mentality, motivation, ability, and self-regulation, all of which are related to psychological resilience and personal development principles. A significant relationship exists between self-efficacy and education, thereby being included in the same cluster (yellow). The blue cluster includes achievement, beliefs and intervention, indicating that interventions are a necessity in bridging the gap between mathematics achievement and belief. The green cluster has technology, stereotype threat, self-concept, math and lay theories together, thus highlighting their relevance to understanding educational outcomes, particularly in the context of mathematics education.

CONCLUSION

Growth mindset research is rapidly evolving and is expected to expand considerably in the future, notably in the field of mathematics education. The essential point is that mindset, rather than

intrinsic aptitude or intelligence, determines success in mathematics. Students can adopt a growth-oriented approach to mathematics by devising improvement plans, learning from experience and prioritizing feedback. This mentality shift is viewed as critical for motivation, engagement, and overall perception of the subject. The study presents a bibliometric study that offers a better understanding of the progress of growth mindset research in mathematics. It explains how bibliometrics, a statistical method for evaluating academic publications, can identify key research directions, trends, and correlations in a particular field. From 2014 to 2023, the analysis shows a consistent increase in the literature on growth mindsets in mathematics. The analysis also revealed the leading countries, important journal sources, author co-citations, and relevant keywords, making it the first study to investigate all four analyses based on accessible literature.

The United States, United Kingdom, China, Australia, and Canada made the most significant contributions to growth mindset research in mathematics. This is consistent with their role as leading nations in research and development, with an emphasis on bridging gaps between psychology and mathematics education (Norton & Nurnberger-Haag, 2018; Vamvakoussi et al., 2018). The key sources of growth mindset literature included Frontiers in Psychology, Contemporary Educational Psychology, and the Journal of Youth & Adolescence. Dweck's works on the growth mindset laid the foundation and has continues to influence the area, while other authors such as Yeager, Walton, Eccles, and Blackwell have added to different facets of the idea. The word co-occurrence highlighted clusters of keywords connected to growth mindset, illustrating the many facets of growth mindset research, which includes motivation, beliefs, interventions, and education results.

There were some limitations to this study. First, only the Scopus and WoS databases were used in the current study for data retrieval. Although Scopus and WoS are among the largest global databases, they still do not include every publication on growth mindset in mathematics. Future researchers may look at other databases not used in the present study to draw comparisons based on the findings. Other types of texts, such as book chapters, books, and grey literature, should be included in future research to expand the database. In addition to the bibliometric metadata, the contents of the database could be analyzed in the future by conducting a review using the grounded theory. The parameters, such as the threshold, are relatively arbitrary. A further limitation is that bibliometric analysis employs quantitative techniques. As a result, the content and quality of publications cannot be deciphered (Kumar et al., 2023). Finally, this study relied solely on English-language publications. The increasing number of growth mindset publications indicates a growing interest in the subject. Future research could investigate specific interventions, cultural impacts, and the long-term effects on student outcomes. In conclusion, the addition of bibliometric analysis provides a quantitative viewpoint, indicating trends and key contributions to the area. As research advances, understanding the importance of mindset in learning opens up new possibilities for improving mathematics education around the world.

ACKNOWLEDGMENT

ERASMUS+ KA171 (ICM) for funding the corresponding author doctoral internship research.

AUTHOR'S DECLARATION

Authors' contributions	CM: conceptualization, collecting data, data analysis, reporting and writing of the manuscript, JMM: main idea, conceptualization, review and validation, EE: collecting data and reporting.
Funding Statement	This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.
Availability of data and materials	All data are available from the authors.
Competing interests	The authors declare that the publishing of this paper does not involve any conflicts of interest. This work has never been published or offered for publication elsewhere, and it is completely original.

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