International Journal of Essential Competencies in Education
https://journal-center.litpam.com/index.php/ijece/index

June 2023 Vol. 2, No. 1
e-ISSN: 2962-2131
pp. 75-87

Bibliometric Analysis of the Thinking Styles in Math and Its' Implication on Science Learning

Yusuf Sarkingobir [1*], Lukman Femi Egbebi [2], Adeneye O. A. Awofala [3]

[1] Shehu Shagari University of Education Sokoto, Sokoto, Nigeria
[2] Department of Science Laboratory Technology, Federal Polytechnic Nasarawa, Nasarawa, Nigeria
[3] Department of Science Education, Faculty of Education, University of Lagos, Akoka, Nigeria

*Correspondence: superoxidedismutase594@gmail.com

Article Info

Article History
Received: March 2023;
Revised: May 2023;
Published: June 2023

Keywords
Bibliometric analysis;
Thinking style;
Mathematics;
Science learning

Abstract

The exploration of mathematical thinking styles is a vital area of investigation, particularly concerning its influence on science education within the classroom, given the significant role mathematics plays in advancing scientific understanding. The examination of this subject holds great interest, and its pertinence strongly bolsters prospective teaching and research endeavors. This research aims to perform a bibliometric scrutiny of mathematical thinking styles and their implication on science learning. The focus of this bibliometric inquiry is to elucidate and scrutinize literature congruent with the concept of mathematical thinking styles and their alignment with science learning. The SCOPUS repository is employed as the primary source of document references. Document selection and analysis were conducted using specific keywords in the 'document search' section. Employing diverse document screening methodologies pertinent to mathematical thinking styles and their implication on science learning, a corpus of relevant documents addressing the subject matter was identified. The sequential screening procedures and document findings are discussed comprehensively in this article. Fundamentally, articles pertinent to the bibliometric analysis theme, 'mathematical thinking styles and their implications for science learning,' underscore the significance of delving into students' mathematical thinking styles. Variances in these cognitive styles pose significant challenges for educators' pedagogical approaches in both mathematics and science instruction. This constitutes a pivotal implication of the present study, necessitating educators to adeptly navigate diverse mathematical thinking styles when structuring pedagogy in science and mathematics. Ultimately, this study stands as a pivotal reference for future investigations delving into themes associated with mathematical thinking styles.

https://doi.org/10.36312/ijece.v2i1.1391

How to Cite
Sarkingobir, Y., Egbebi, L. F., & Awofala, A. O. A. (2023). Bibliometric Analysis of the Thinking Styles in Math and Its' Implication on Science Learning. *International Journal of Essential Competencies in Education*, *2*(1), 75–87. https://doi.org/10.36312/ijece.v2i1.1391

INTRODUCTION

Learning involves a modification in behavior that arises from repetitive experiences. These modifications manifest in diverse ways due to the distinctive attributes of each person, encompassing intelligence, competencies, personality traits, and learning approaches (Katranci & Bozkuş, 2014). These individual traits form the basis for acknowledging the assortment of methods students adopt to engage with specific knowledge domains within classroom settings (Steinbring, 2009). When educators encourage students to tackle mathematical challenges, some may derive solutions using algebraic or functional frameworks, while others might lean towards visual or metaphorical interpretations, among other possibilities. These preferences could even be considered as evaluative indicators (Huincahue et al., 2021).

Given the heterogeneity present within a class, it's natural for students to respond diversely to various modes of thought. Nonetheless, this multiplicity often introduces intricate challenges related to instructional strategies within the classroom. The inclination of an individual to present, grasp, and process mathematical facts and correlations through personal mental constructs and/or external representations is termed as their mathematical thinking style (Borromeo-Ferri, 2010, 2013, 2015).

The significance of thinking styles' impact is often connected to learning outcomes within STEM (Science, Technology, Engineering, and Mathematics) education. An illustration of this correlation can be observed in the link between learning attitudes and thinking styles, as demonstrated by Sirakaya et al. (2020). Further exploration delves into the intricate relationship between mathematical thinking frameworks and education, as investigated in-depth by Miller (2019). Notably, mathematical modeling emerges as a pivotal aspect acting as a bridge in STEM education, facilitating diverse teaching methods that foster creativity, skill acquisition, innovation, and multifaceted student development, as highlighted by Tezer (2020).

A distinct connection between thinking style and student learning achievement is revealed in the research conducted by Khalifaeva et al. (2020). Within the realm of STEM, specifically in the domain of science, the malleability of students' thinking styles across various stages of physics learning, guided by educators, is underscored by Utami et al. (2021). This underscores the consequential role of mathematical thinking style in shaping the landscape of STEM education, particularly within the sphere of science. It's noteworthy that mathematics and science, inseparable disciplines, mutually reinforce each other's foundations, as aptly articulated by Evendi & Verawati (2021).

The concept of mathematical thinking styles was initially formulated by Borromeo-Ferri in 2004. This theory emerged from a qualitative investigation involving students aged fifteen and sixteen. Over time, the research transitioned from qualitative to quantitative methodologies, as evident in Borromeo-Ferri's empirical studies in 2013. This progression led to the conceptualization and operationalization of the constructs pertaining to mathematical thinking styles within the realm of education. Central to these styles are the elements of internal imagination and external representation, both playing pivotal roles in the domain of mathematical thought (Borromeo-Ferri, 2010).

What sets mathematical thinking style apart is its focus not on individual performance, but rather on personal preferences. This characteristic adds to the intrigue surrounding the exploration of mathematical thinking styles among students engaged in mathematics education. A related perspective by Sternberg (cited in Huincahue et al., 2021) defines thinking style as a unique approach to thinking, signifying an individual's favored method of utilizing their cognitive abilities – in essence, a preferred manner of tackling tasks. This conception lays the foundation for the development of an approach centered around mathematical thinking style. Importantly, this notion of thinking style is concerned not with the quality of execution, but rather with the manner in which individuals find satisfaction in task execution (Huincahue et al., 2021).

Borromeo-Ferri (2015) introduces distinctive thinking styles: analytical thinking style, visual thinking style, and the integrated thinking style (a blend of visual and analytical). Analytical thinkers exhibit a penchant for internal formal mental constructs and external formal representations. They tend to comprehend mathematical facts more effectively through symbolic or verbal means, leaning toward a sequential approach. Visual thinkers, on the other hand, gravitate toward vivid internal visualizations and external visual representations, seeking holistic understandings of mathematical facts and connections. Their internal mental imagery is primarily influenced by strong associations with the encountered context. Meanwhile, integrated thinking style melds visual and analytical modes and demonstrates a flexible capability to shift between various representations.

Notably, mathematical thinking styles diverge from mathematical abilities, signifying preferences in how these abilities are harnessed. Essentially, mathematical thinking styles align with traits of personality, as preferences are often linked to positive emotional responses. In contrast to the wealth of research on mathematical abilities and learning styles, the study of mathematical thinking styles is relatively scarce (for instance, Danişman & Erginer, 2017; Güneş & Şahin, 2019; Kablan, 2016; Orhun, 2007; Tatar & Dikici, 2009, among others).

The current study seeks to perform a bibliometric analysis concerning mathematical thinking styles and their implications in science education. Specifically, this bibliometric exploration aims to characterize and investigate literature that intersects with the concept of mathematical thinking style, along with its interconnections with science learning. This study is anticipated to serve as a cornerstone for subsequent research endeavors delving into the realm of mathematical thinking styles and their significance for science education.

METHOD

In this research, the primary objective is to perform a bibliometric examination of different styles of mathematical thinking and their relevance to the advancement of science education. This investigation aligns with an integrated survey of literature focused on the subject of 'mathematical thinking styles and their implication on science learning.' This type of study is commonly referred to as a bibliometric analysis study (BAS) or a meta-analytic study. The BAS is grounded in the use of the SCOPUS database, which serves as the primary information source for the selection and analysis of documents. Several stages of document screening and analysis were executed to align with the study's objectives.

The SCOPUS database, accessible at (https://www.scopus.com/), was employed to access and examine pertinent documents. This choice was driven by SCOPUS's reputation as a credible indexer of high-quality scientific publications, encompassing books and journals. Its global recognition and high precision in data sourcing establish it as a reliable yardstick for evaluating the caliber of articles across various publishers. Furthermore, the comprehensive features provided on the SCOPUS platform enable users to meticulously explore the content of manuscripts, encompassing details like titles, authors, publishers, metrics, citations, quartiles, and more.

Conducted on June 29, 2023, the bibliometric analysis was executed by navigating the SCOPUS database using the search function available at (https://www.scopus.com/search). Concentrating on the initial objective of conducting a bibliometric analysis within the domain of mathematical thinking style, the procedure encompassed the following steps:

a) In the "search documents" section, the keyword "mathematical thinking style" was inputted to ensure comprehensive exploration and thorough comprehension on the SCOPUS platform.

b) The process of document screening was conducted twice. Initially, by employing the keywords [TITLE-ABS-KEY (mathematical AND thinking AND styles)], without any restrictions on the document's publication year or subject area. Subsequently, a more refined search was conducted using the keywords [TITLE-ABS-KEY (mathematical AND thinking AND styles) AND (LIMIT-TO (SUBJAREA, “MATH”)], restricting the search to the past decade and focusing specifically on the field of mathematics.
c) Each outcome from the document search displayed on the SCOPUS interface was meticulously recorded and presented.
d) The data visualizations provided by SCOPUS were captured (via screenshots) and subjected to descriptive analysis. The findings were then discussed in alignment with the study's requirements.

By following this systematic approach, the bibliometric analysis aimed to delve into the landscape of mathematical thinking styles and their implications in science education, utilizing the robust capabilities of the SCOPUS database as a foundation for insights. Moreover, the focus shifts to the second objective, which involves conducting a bibliometric analysis in the intersecting realm of mathematical thinking styles and science learning. The following steps outline the approach taken:

a) Navigate to the "search documents" section and input the designated keyword, "mathematical thinking style in science learning," enabling comprehensive exploration and review within the SCOPUS platform.
b) The document screening process employs the input of keywords [TITLE-ABS-KEY (mathematical AND thinking AND styles AND science AND learning)], without imposing any restrictions on the publication year or subject domain.
c) Each outcome of the search, as displayed on the SCOPUS platform, is methodically documented and presented.
d) The data presented through SCOPUS visualization is captured via screenshots and subjected to descriptive analysis. Pertinent discussions are incorporated as required within this research context.

RESULTS AND DISCUSSION

The initial document screening involved the utilization of specific keywords, [TITLE-ABS-KEY (mathematical AND thinking AND styles)]. Notably, this initial phase of screening was not confined by the document publication year or subject area constraints. Employing these criteria, a total of 209 documents were identified within the timeframe of 1977-2022 (no records were discovered preceding 1977). A visual representation of the distribution of these documents across different years is depicted in Figure 1.

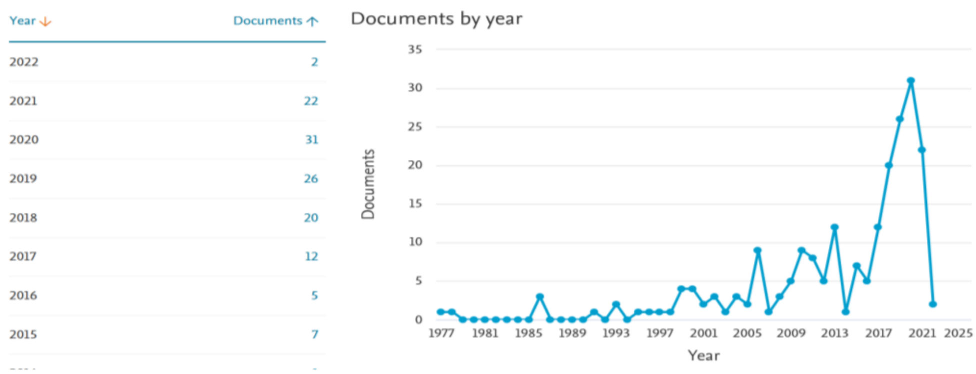


Figure 1. The outcomes of the search utilizing the term 'mathematical thinking styles' within the TITLE-ABS-KEY (mathematical AND thinking AND styles)

The prevalence of research pertaining to mathematical thinking styles has shown a consistent rise from its inception in 1977 up to the current time. Notably, the year 2020 marked the zenith with the identification of a remarkable 31 documents dedicated to exploring the nuances of mathematical thinking styles. Particularly intriguing is the revelation from this investigation that Indonesia emerges as the leading contributor in terms of territorial or national origins for research on mathematical thinking styles (refer to Figure 2).

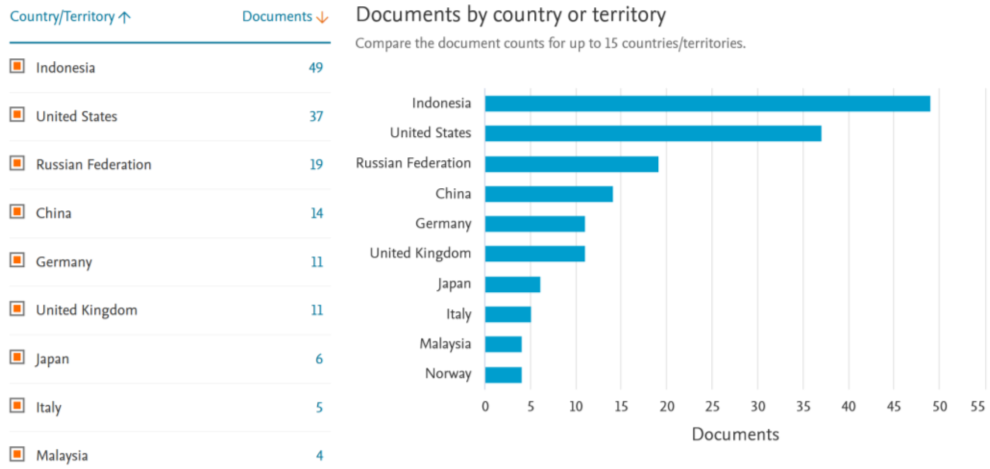
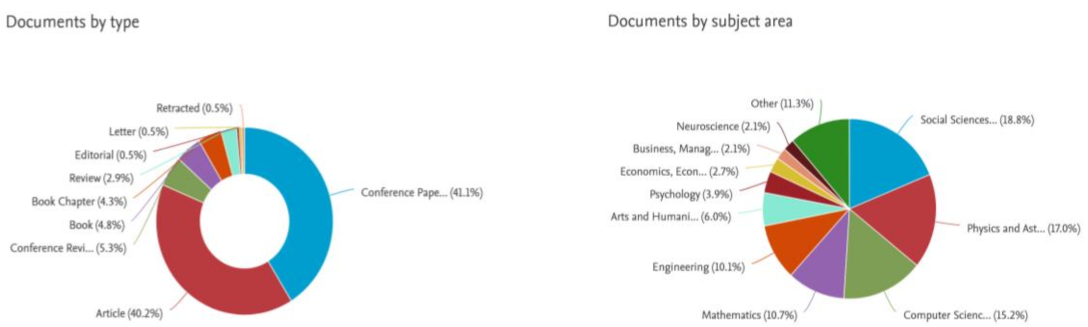


Figure 2. Retrieve search outcomes categorized by region or nation pertaining to mathematical cognitive approach

The results presented in Figure 2 depict the outcomes of a search conducted for documents concerning mathematical thinking styles, organized by territory or country. The data illustrates the distribution of study documents related to mathematical thinking styles across different countries. Among the leading contributors to this research domain, Indonesia emerges with the highest count at 49 documents, followed by the USA with 37 documents, Russia with 19 documents, China with 14 documents, and both Germany and the UK with 11 documents each. The remaining countries have contributed fewer than 10 documents each.

These observations from Figure 2 suggest a significant focus by Indonesian researchers on investigating mathematical thinking styles. One potential explanation for this trend can be attributed to the possibility that the country is facing multiple challenges in areas encompassing education, mathematics, and thinking styles, all of which necessitate comprehensive research efforts. However, it's important to note that this assumption is based on an overview and initial screening, as the study did not delve deeply into the specific aspects explored within the 49 documents originating from Indonesia. For a more detailed breakdown, including information on document type and subject area, refer to Figure 3.



(a) **(b)**

Figure 3. Comprehensive information categorized by: (a) type of document, and (b) field of study (subject area)

The data presented in Figure 3a illustrates the distribution of document types across nine distinct categories. These categories encompass various document types, with conference papers constituting the largest portion at 41.1% (86 documents), followed closely by journal articles at 40.2% (84 documents). Other categories include conference reviews with 5.3% (11 documents), books and book chapters each accounting for 4.8% (10 documents), and 4.3% (9 documents) respectively. Additionally, there are several document types comprising less than 3% of the total.

Regarding the distribution of documents across different subject areas, as depicted in Figure 3b, a wide range of subject fields were identified. These fields encompass social sciences, physics and astronomy, computer science, mathematics, engineering, and others. The breakdown of documents in each subject area is as follows: social science contributes 18.8% (63 documents), physics and astronomy contribute 17% (57 documents), computer science contributes 15.2% (51 documents), mathematics contributes 10.7% (36 documents), and engineering contributes 10.1% (34 documents). Additionally, there are subject areas, such as psychology, that account for less than 10%, specifically 3.9%.

Moving forward, the subsequent phase of document screening focuses on the field of mathematics using specific keywords [TITLE-ABS-KEY (mathematical AND thinking AND styles) AND (LIMIT-TO (SUBJAREA, “MATH”)]. This search yielded a total of 36 documents, and their distribution is outlined in Figure 4.

Year ↓	Documents ↑
2022	1
2021	4
2020	0
2019	1
2018	1
2017	2
2016	0
2015	2

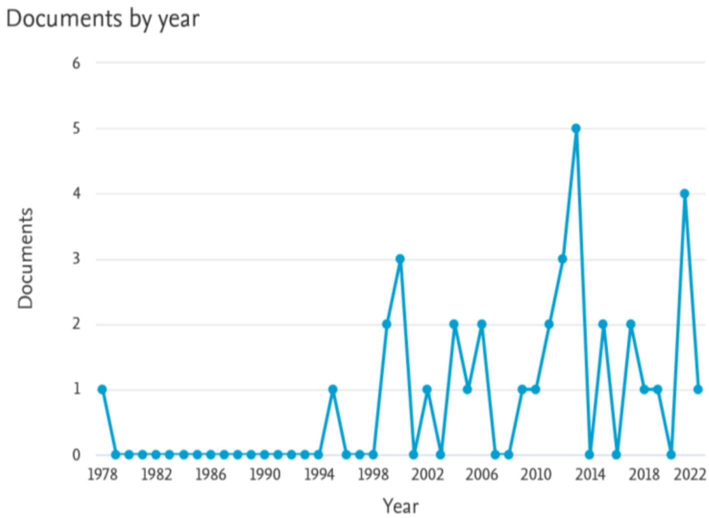


Figure 4. Explore the outcomes of queries using terms [TITLE-ABS-KEY (mathematical AND thinking AND styles) AND (LIMIT-TO (SUBJAREA, "MATH")]

The outcomes of the second examination illustrated in Figure 4 pertain exclusively to the realm of mathematics. The pattern in document count spanning the years 1977 to 2022 exhibited fluctuations, with notable peaks occurring in 2013 and 2021, yielding document counts of 5 and 6, respectively. The breakdown of document categorization among the 36 filtered documents was as follows: articles accounted for 19 documents (52.8%), conference papers constituted 8 documents (22.2%), while books and book-chapters each comprised 4 documents (11.1%), and a single review document (2.8%).

Utilizing the search terms [TITLE-ABS-KEY (mathematical AND thinking AND styles) AND (LIMIT-TO (SUBJAREA, "MATH")] and constrained to documents published within the last decade (2012 to 2022), the findings are depicted in Figure 5.

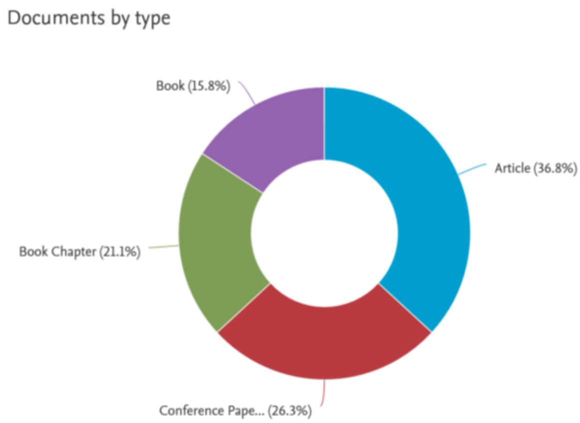


Figure 5. I conducted a search using the terms [TITLE-ABS-KEY (mathematical AND thinking AND styles) AND (LIMIT-TO (SUBJAREA, "MATH")] within the specified parameters of documents published between the years 2012 and 2022

Moreover, when focusing on a single format, specifically articles, it becomes evident that out of the 19 article documents available, a notable proportion of 7 documents (making up 36.8% of the total) delve into the exploration of various styles of mathematical thinking or examine the interplay among the three variables within the distinct context of mathematics. Notably, all of these instances have emerged within the past decade, and their details can be found in Table 1.

Table 1. Capture information about the nature of mathematical thought within the realm of 'article' document category during the past decade

No	Author(s)	Title	Source
1	Hu et al. (2022)	The optimal solution of feature …..	App. Math. Nonlin. Sci.
2	Schütte et al. (2021)	Discourses as the place for the development …..	J. Math. – Did.
3	Haavold (2021)	Impediments to mathematical creativity …..	Math. Enth.
4	Rowlett et al. (2019)	The potential of recreational mathematics …..	Intl. J. of Math. Edu. in Sci. Tech.
5	Huang and Lin (2013)	Using activity theory to model …..	Intl. J. of Sci. Math. Edu.
6	Xiang et al. (2012)	Computational phenotyping of two-person …..	PLoS Comp. Bio.
7	Spangenberg (2012)	Thinking styles of mathematics …..	Pythagoras

In alignment with the central theme of the study under review, this article draws upon Hu et al.'s (2022) research, which explores the operational approach based on the framework of nonlinear thinking (without explicit discourse on thinking style). The work by Schütte et al. (2021) adopts an interactionist perspective to delve into mathematics learning, wherein the evolution of mathematical thought is depicted as heightened engagement in mathematical dialogues. Through empirical examination in this paper, diverse discourse methodologies are reconstructed and offer a potential foundation for longitudinally reconstructing students' involvement in mathematical negotiation processes, facilitating the elucidation of their mathematical development.

Haavold's (2021) study subtly hints at a mathematical technique for composing proofs, which can be refined to a specific proof style. The composition of mathematical proofs involves the interplay of both thinking skills and styles. The contributions of Rowlett et al. (2019) underscore the importance of mathematical thought and skills in education, serving as effective tools to kindle student participation by fostering comprehension of mathematical notions. Drawing insights from Huang and Lin's (2013) study, articles based on their findings emphasize that the holistic and analytic thinking modes presented in teaching materials and activities significantly influence students' grasp of mathematical concepts.

Xiang et al.'s (2012) publication introduces a computational system designed to predict the depth of subject's thinking. While this work aligns with the designated keywords, it doesn't explicitly connect with mathematical learning or discuss distinct mathematical thinking styles. Lastly, Spangenberg's (2012) work focuses on characterizing and contrasting students' thinking styles in the context of mathematical learning, highlighting the individuality of each student's cognitive approach, which poses a challenge for educators dealing with the diversity of thinking styles in mathematics education.

Concentrating on the examination of bibliometrics within the interconnected realm of mathematical thinking styles and science education, Figure 6 showcases the evolving patterns identified through document retrieval outcomes (documents categorized by year). These findings were obtained by utilizing the search query [TITLE-ABS-KEY (mathematical AND thinking AND styles AND science AND learning)] within the document search interface.

Year ↓	Documents ↑
2022	1
2021	2
2020	0
2019	1
2018	0
2017	1
2016	0
2015	0
2014	1

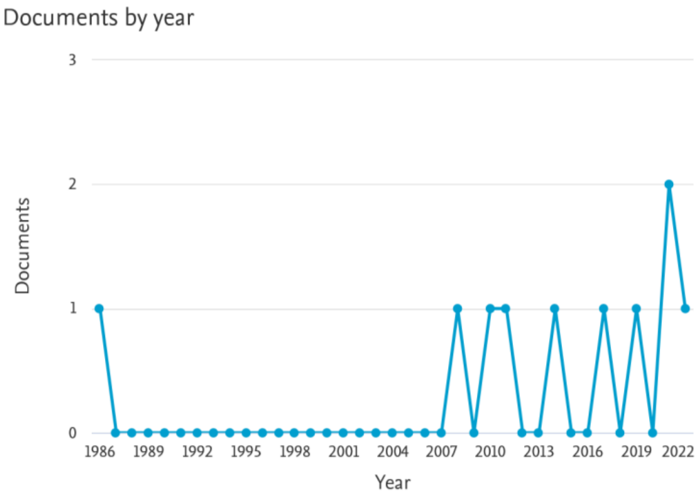


Figure 6. Search outcomes using the phrase 'mathematical thinking styles in the context of science education' [TITLE-ABS-KEY (mathematical AND thinking AND styles AND science AND learning)]

The trends depicted in Figure 6 illustrate the patterns of research in the field of 'mathematical thinking styles in science learning,' encompassing an unrestricted time frame for document retrieval and without confining the search to specific subject areas. Under these inclusive search criteria, a total of 10 documents were located, spanning the years from 1986 to 2022. It is evident that this numerical count is notably limited, highlighting the scarcity of investigations that establish a connection between mathematical thinking styles and the acquisition of scientific knowledge. Notably, these observations are drawn from content available on the SCOPUS database.

Likewise, employing the identical set of keywords, Figure 7 delineates the breakdown of document types as furnished by the SCOPUS database.

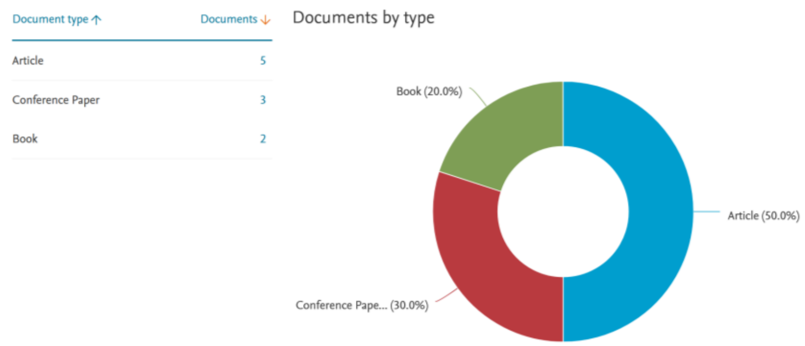


Figure 7. Information derived from the classification (type) of documents

The outcomes of the search yielded ten documents, categorized into three distinct types: there were 5 articles (50%), 3 conference papers (30%), and 2 books (20%). The specifics of these documents, focusing on the styles of mathematical thinking in the context of science education, can be found in Table 2.

Table 2. Record information concerning the various modes of mathematical thinking in the context of learning science.

No	Author(s)	Title	Source
1	Utami et al. (2021)	The implementation of STEM learning ….	AIP Conf. Proc.
2	Bellettini et al. (2019)	Situated Learning with Bebras ….	Lec. Not. in Comp. Sci.
3	Vasileva-Stojanovska et al. (2014)	The educational prospects of ….	Proc. of the Europ. Conf.
4	Keating et al. (2022)	Quantification of Learning Gains in a Science ….	FASEB J.
5	Flowerdew (1986)	Cognitive style and specific-purpose course design ….	Eng. for Spec. Purp.
6	Kelter et al. (2021)	Constructionist co-design: A dual approach ….	Brit. J. of Edu. Tech.
7	Shih et al. (2017)	STEAMing the ships for the ….	Int. Des. and Arc.
8	O'Boyle (2008)	Mathematically gifted children: Developmental ….	Roep. Rev.
9	Katz and Nodelman (2011)	The shape of algebra in the mirrors ….	Book
10	Smutny (2022)	Differentiating for the young child ….	Book

The segment provided discusses various articles that investigate the relationship between different thinking styles and science or mathematics learning. Among the ten articles listed in Table 2, one particular study stands out for its focus on the connection between thinking styles and physics learning. This specific research, conducted by Utami et al. in 2021, highlights how students' thinking styles evolve in response to distinct stages of physics instruction. Their study reveals the significant impact of teaching methods on shaping students' cognitive approaches to learning (Utami et al., 2021).

In the realm of science education, as well as social sciences in a broader context, a recurring theme is the significance of individual preferences, such as learning styles, in tailoring instructional approaches to enhance learning outcomes. This idea is strongly supported by Vasileva-Stojanovska et al. (2014), who emphasize the importance of considering learners' personal inclinations. Furthermore, insights from cognitive neuroscience, as explored by O'Boyle (2008), emphasize the need for educators to harness students' mathematical learning tendencies. This strategic approach empowers teachers to design effective learning paths that align with each student's distinctive learning style, particularly in mathematics and science education.

In a separate strand of research, the literature surrounding mathematical thinking styles offers substantial potential for future exploration. Works by Haavold (2021), Huang and Lin (2013), Rowlett et al. (2019), Schütte et al. (2021), and Spangenberg (2012) collectively contribute valuable insights into the multifaceted nature of mathematical cognition. These studies collectively underscore the complexity of addressing diverse thinking styles within mathematics education and the subsequent pedagogical challenges it presents to instructors.

Moreover, findings that delve into the intersection of mathematical thinking styles and science learning (e.g., O'Boyle, 2008; Utami et al., 2021; Vasileva-Stojanovska et al., 2014) yield important implications for pedagogical practice. These findings advocate for instructional strategies that harness students' inherent mathematical learning tendencies as a guiding principle for crafting effective science education approaches. This assertion aligns with current bibliometric studies, highlighting the critical need for educators to navigate the intricate landscape of differing mathematical thinking styles in the pursuit of delivering impactful mathematics and science instruction.

In conclusion, the synthesis of these studies underscores the intricate interplay between thinking styles and science or mathematics education. Whether in the context of physics or broader science disciplines, or within the realm of mathematical cognition, understanding and leveraging individual thinking styles emerge as pivotal strategies for crafting effective pedagogical practices. This synthesis serves as a foundational reference for educators striving to address the diverse cognitive inclinations of their students while delivering comprehensive and engaging instruction in these critical subjects.

CONCLUSION

A bibliometric investigation focusing on 'mathematical thinking styles and their implication on science learning' was conducted utilizing the SCOPUS database as the primary information source. The study pursued objectives aligned with the concept of mathematical thinking style, employing a systematic sequence of screening steps. The discerned articles within the context of the bibliometric scrutiny emphasize the significance of investigating students' mathematical thinking styles. The diversities in these thinking styles pose noteworthy challenges for educators in their pedagogical approaches to teaching mathematics and science. This challenge underscores a pivotal implication of the study, necessitating that teachers adeptly tailor mathematics and science instruction to accommodate diverse mathematical thinking styles exhibited by their students. In conclusion, the insights from this study can serve as a foundational resource for subsequent research endeavors delving into themes associated with mathematical thinking styles.

RECOMMENDATION

Based on the research, it is recommended that educators and researchers in the field of science and mathematics education should pay careful attention to the diverse mathematical thinking styles exhibited by students. The study highlights the crucial role mathematical thinking styles play in shaping students' learning experiences and outcomes, particularly in science education. Therefore, educators should adopt pedagogical approaches that consider and accommodate these varying cognitive styles, enhancing the effectiveness of teaching in both mathematics and science. Moreover, future research endeavors should build upon the insights provided by this study, further investigating the intersection of mathematical thinking styles and their implications on science learning. This research serves as an essential reference for anyone interested in developing more inclusive and effective instructional methods that align with the diverse cognitive needs of students in these disciplines.

Author Contributions

The authors have sufficiently contributed to the study, and have read and agreed to the published version of the manuscript.

Funding

This research received no external funding.

Acknowledgement

The author expresses gratitude to all those who participated by offering suggestions and insights in this bibliometric analysis investigation. Any limitations identified within this study can serve as valuable areas for enhancement in future research endeavors.

Declaration of Interest

The authors declare no conflict of interest.

REFERENCES

Bellettini, C., Lonati, V., Monga, M., Morpurgo, A., & Palazzolo, M. (2019). Situated Learning with Bebras Tasklets. *Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, *11913 LNCS*, 225–239. Scopus. https://doi.org/10.1007/978-3-030-33759-9_18

Borromeo Ferri, R. (2010). On the Influence of Mathematical Thinking Styles on Learners' Modeling Behavior. *Journal Für Mathematik-Didaktik*, *31*(1), 99–118. https://doi.org/10.1007/s13138-010-0009-8

Borromeo Ferri, R. (2013). Mathematical Modelling in European Education. *Journal of Mathematics Education at Teachers College*, Vol. 4 No. 2: FallWinter 2013. https://doi.org/10.7916/JMETC.V4I2.624

Borromeo Ferri, R. (2015). Mathematical Thinking Styles in School and Across Cultures. In S. J. Cho (Ed.), *Selected Regular Lectures from the 12th International Congress on Mathematical Education* (pp. 153–173). Springer International Publishing. https://doi.org/10.1007/978-3-319-17187-6_9

Danişman, Ş., & Erginer, E. (2017). The predictive power of fifth graders' learning styles on their mathematical reasoning and spatial ability. *Cogent Education*, *4*(1), 1266830. https://doi.org/10.1080/2331186X.2016.1266830

Evendi, E., & Verawati, N. N. S. P. (2021). Evaluation of Student Learning Outcomes in Problem-Based Learning: Study of Its Implementation and Reflection of Successful Factors. *Jurnal Penelitian Pendidikan IPA*, *7*(SpecialIssue), 69–76. https://doi.org/10.29303/jppipa.v7iSpecialIssue.1099

Flowerdew, J. (1986). Cognitive style and specific-purpose course design. *English for Specific Purposes*, *5*(2), 121–129. Scopus. https://doi.org/10.1016/0889-4906(86)90018-9

Güneş, G., & Şahin, V. (2019). The algorithm of mathematical modelling for learning styles of pre-school children. *Education 3-13*, *47*(3), 277–292. https://doi.org/10.1080/03004279.2018.1430844

Haavold, P. Ø. (2021). Impediments to mathematical creativity: Fixation and flexibility in proof validation. *Mathematics Enthusiast*, *18*(1–2), 139–159. Scopus.

Hu, S., Meng, Q., Xu, D., & Hasan, H. (2022). The Optimal Solution of Feature Decomposition Based on the Mathematical Model of Nonlinear Landscape Garden Features. *Applied Mathematics and Nonlinear Sciences*. Scopus. https://doi.org/10.2478/amns.2021.1.00070

Huang, C.-H., & Lin, F.-L. (2013). Using Activity Theory to Model the Taiwan Atayal Students' Classroom Mathematical Activity. *International Journal of Science and Mathematics Education*, *11*(1), 213–236. Scopus. https://doi.org/10.1007/s10763-012-9381-9

Huincahue, J., Borromeo-Ferri, R., Reyes-Santander, P., & Garrido-Véliz, V. (2021). Mathematical Thinking Styles—The Advantage of Analytic Thinkers When Learning Mathematics. *Education Sciences*, *11*(6), 289. https://doi.org/10.3390/educsci11060289

Kablan, Z. (2016). The effect of manipulatives on mathematics achievement across different learning styles. *Educational Psychology*, *36*(2), 277–296. https://doi.org/10.1080/01443410.2014.946889

Katranci, Y., & Bozkuş, F. (2014). Learning Styles of Prospective Mathematics Teachers: Kocaeli University Case. *Procedia - Social and Behavioral Sciences*, *116*, 328–332. https://doi.org/10.1016/j.sbspro.2014.01.216

Katz, G., & Nodelman, V. (2011). *The shape of algebra in the mirrors of mathematics: A visual, computer-aided exploration of elementary algebra and beyond* (p. 607). Scopus. https://doi.org/10.1142/7810

Keating, R., Saco Vertiz, L., Manly, V., Sastry, A., De, S., & Sikora, A. K. (2022). Quantification of Learning Gains in a Science CURE: Leveraging Learning Objectives to Substantiate and Validate the Benefits of Experiential Education. *FASEB Journal : Official Publication of the Federation of American Societies for Experimental Biology*, *36*. Scopus. https://doi.org/10.1096/fasebj.2022.36.S1.R1995

Kelter, J., Peel, A., Bain, C., Anton, G., Dabholkar, S., Horn, M. S., & Wilensky, U. (2021). Constructionist co-design: A dual approach to curriculum and professional development. *British Journal of Educational Technology*, *52*(3), 1043–1059. Scopus. https://doi.org/10.1111/bjet.13084

Khalifaeva, O. A., Kolenkova, N. Y., Tyurina, I. Y., & Fadina, A. G. (2020). The Relationship of Thinking Styles and Academic Performance of Students. *Obrazovanie i Nauka*, *22*(7), 52–76. Scopus. https://doi.org/10.17853/1994-5639-2020-7-52-76

Miller, J. (2019). STEM Education in the Primary Years to Support Mathematical Thinking: Using Coding to Identify Mathematical Structures and Patterns. *ZDM: The International Journal on Mathematics Education*, *51*(6), 915–927. https://doi.org/10.1007/s11858-019-01096-y

O'Boyle, M. W. (2008). Mathematically gifted children: Developmental brain characteristics and their prognosis for well-being. *Roeper Review*, *30*(3), 181–186. Scopus. https://doi.org/10.1080/02783190802199594

Orhun, N. (2007). An investigation into the mathematics achievement and attitude towards mathematics with respect to learning style according to gender. *International Journal of Mathematical Education in Science and Technology*, *38*(3), 321–333. https://doi.org/10.1080/00207390601116060

Rowlett, P., Smith, E., Corner, A. S., O'Sullivan, D., & Waldock, J. (2019). The potential of recreational mathematics to support the development of mathematical learning. *International Journal of Mathematical Education in Science and Technology*, *50*(7), 972–986. Scopus. https://doi.org/10.1080/0020739X.2019.1657596

Schütte, M., Jung, J., & Krummheuer, G. (2021). Discourses as the Place for the Development of Mathematical Thinking. *Journal fur Mathematik-Didaktik*, *42*(2), 525–551. Scopus. https://doi.org/10.1007/s13138-021-00183-6

Shih, J.-L., Huang, S.-H., Lin, C.-H., & Tseng, C.-C. (2017). STEAMing the ships for the great voyage: Design and evaluation of a technology-integrated maker game. *Interaction Design and Architecture(s)*, *34*, 61–87. Scopus.

Sirakaya, M., Alsancak Sirakaya, D., & Korkmaz, Ö. (2020). The Impact of STEM Attitude and Thinking Style on Computational Thinking Determined via Structural Equation Modeling. *Journal of Science Education and Technology*, *29*(4), 561–572. https://doi.org/10.1007/s10956-020-09836-6

Smutny, P. (2022). Learning with virtual reality: A market analysis of educational and training applications. *Interactive Learning Environments*, *0*(0), 1–14. https://doi.org/10.1080/10494820.2022.2028856

Spangenberg, E. D. (2012). Thinking styles of mathematics and mathematical literacy learners: Implications for subject choice. *Pythagoras*, *33*(3). Scopus. https://doi.org/10.4102/pythagoras.v33i3.179

Steinbring, H. (2009). *The Construction of New Mathematical Knowledge in Classroom Interaction*. Springer Dordrecht. https://link.springer.com/book/9789048132034

Tatar, E., & Dikici, R. (2009). The effect of the 4MAT method (learning styles and brain hemispheres) of instruction on achievement in mathematics. *International Journal of Mathematical Education in Science and Technology*, *40*(8), 1027–1036. https://doi.org/10.1080/00207390903121750

Tezer, M. (2020). The Role of Mathematical Modeling in STEM Integration and Education. In K. George Fomunyam (Ed.), *Theorizing STEM Education in the 21st Century*. IntechOpen. https://doi.org/10.5772/intechopen.88615

Utami, I. S., Vitasari, M., Langitasari, I., & Muliyati, D. (2021). *The implementation of STEM learning on creative-critical thinking styles (study on pre-service physics teacher)*. *2331*. Scopus. https://doi.org/10.1063/5.0041991

Vasileva-Stojanovska, T., Vasileva, M., Malinovski, T., & Trajkovik, V. (2014). *The educational prospects of traditional games as learning activities of modern students*. *2*, 746–759. Scopus.

Xiang, T., Ray, D., Lohrenz, T., Dayan, P., & Montague, P. R. (2012). Computational Phenotyping of Two-Person Interactions Reveals Differential Neural Response to Depth-of-Thought. *PLoS Computational Biology*, *8*(12). Scopus. https://doi.org/10.1371/journal.pcbi.1002841