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Trends of abstraction research in mathematics education: A bibliometric analysis

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Abstract

Abstraction is fundamental in mathematics learning because students can discover the studied concepts through abstraction. Bibliometric analyses of abstraction research in mathematics education have yet to be published. A bibliometric analysis is conducted to explore trends in abstraction research. The mathematics education researchers will gain insights from studying the development of abstraction research over the last fifteen years. The primary objective of this study is to evaluate the primary journals published, the most productive authors, universities, and countries and to identify current trends in abstraction research. Data were collected from the Scopus database and analysed using VOSviewer and R software. A thorough review was conducted on 271 articles published between 2008 and 2022. The collected data was analysed and presented using R studio and VOSviewer software. The publication of abstraction research has increased every year. Abstraction studies related to geometry, computational thinking, and preschool are trend and abstraction studies related to gesture, preschool child, arithmetic, physiology, mathematical concepts, geometry, language, and cognition. Abstraction research is exciting because it will still trend until 2022. This study offers valuable insights to researchers interested in mathematics education for exploring alternative research directions to the primary research trends. Based on these results, recommendations for further research are given so that they can explore various options for research trends.

Keywords:
Abstraction, Bibliometric, Constructing, Mathematics education, VOSviewer

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1. INTRODUCTION

In the last few decades, several abstraction studies in mathematics education were published in reputable international journals, such as the data obtained in this paper. This shows the importance of abstraction in mathematics education (Hodiyanto et al., 2024; Kiliçoğlu & Kaplan, 2019; Memnun et al., 2017; Nurjannah & Kusnandi, 2021; Ozmantar & Monaghan, 2007). Abstraction is essential to mathematics learning because some mathematical concepts are obtained through abstraction (Memnun et al., 2017). In addition, the primary objective of research in mathematics education is to gain insight into the process by which students develop abstract mathematical knowledge (Dreyfus, 2015; Dreyfus et al., 2015). By knowing students' abstraction processes, these results can be a reference for teachers in designing tasks and learning strategies to make mathematics learning more meaningful for students.

The fact that mathematics is an abstract discipline and mathematical concepts emerged through the process of abstraction underscores the particular significance of abstraction (Memnun et al., 2011). Abstraction is a crucial element in learning mathematics, as it significantly contributes to the development of mathematical concepts (Ferrari, 2003). This abstraction process is fundamental to mathematics and educational materials (Mitchelmore & White, 2007). Given its paramount role in mathematics, abstraction is vital in mathematics education, particularly in learning the subject (Hazzan & Zazkis, 2005). Abstraction is an essential part of learning because students constructing concepts or solving problems with themself make their learning more meaningful.

The term abstraction has two meanings: firstly, as a process of describing a situation, and secondly, as a concept as the result of a process (Gray & Tall, 2007). Skemp (1987) carried out the first fundamental study of the theory of hierarchical abstraction. Skemp offers insights into the concepts of abstracting and abstraction. Abstracting involves an individual recognising similarity among the experiences gathered by categorising, essentially organising experiences based on their commonalities. Simultaneously, abstraction is the final result of abstracting, enabling the identification of new experiences that share similarities with the previously formed categories. Thus, Skemp believes that abstracting is the activity while abstraction is the final product of the activity, which is then called a concept (Skemp, 1987). However, it differs from Ozmantar and Monaghan (2007), which say that abstraction refers to the process and a product. This means that abstraction can also be interpreted as constructing a new concept. Abstraction is a vital knowledge process by which we form concepts (Benis-Sinaceur, 2014; Breive, 2022; Memnun et al., 2017).

van Oers and Poland (2007) describe that abstraction occurs when specific attributes or qualities of an object are deemed unimportant and subsequently omitted, leaving only the essential shared properties to be focused on or retained. Yilmaz and Argun (2018) say that abstraction is a process of construction where mental frameworks are built based on mathematical frameworks, and the reverse is also true. This involves identifying an object's shared property or properties distinct from the object and assigning a name to it. This means that the abstraction process differentiates the general properties of an object from the object itself and gives a name to these properties. Furthermore, Yilmaz and Argun (2018) say that what is essential and appropriate is kept, while the rest is discarded, with its representation

transformed into more abstract concepts. This definition is the same as the previous definition, removing what is different or unnecessary and keeping what is the same. For example, there are several shapes of rectangles, so you do not need to pay attention to unimportant properties (such as the difference in length of each shape) and maintain essential properties that are shared (such as having right angles, opposite sides being the same length, and parallel opposite sides). This process of eliminating what is unimportant and retaining what is essential is called abstraction.

Dreyfus (2007) and Hershkowitz et al. (2001) define abstraction as vertically rearranging pre-established mathematical elements to create a new mathematical structure. In this context, the term 'vertical' indicates that the emerging concept exists at a higher level than the preceding one. It elucidates the process of vertically reorganising the prior mathematical structure, guiding students to create something novel. If someone wants to construct an object, they must already have knowledge, so their abstraction also depends on the one they already have. For example, someone knows the properties of parallelograms and rectangles. Next, he concluded that a rectangle possesses all the properties of a parallelogram, so a rectangle is a parallelogram. The two views above are almost similar because someone who concludes that a rectangle is a parallelogram will discard the properties that both do not have and only take the properties that both have.

In addition, published articles can be a source of research data Kartika et al. (2023), and one of the analyses is called bibliometric analysis. Bibliometric research involves statistical analysis of published articles, identifying authorship and citation trends within a particular discipline and how these have evolved (Julius et al., 2021; Mathankar, 2018; Phan et al., 2022). Bibliometric data includes detailed information that characterises the source document, covering aspects like author contributions, affiliations, countries, keywords, language, publication source, year of publication, cited references, sources of those references, and subject categories (Drijvers et al., 2020; Kartika et al., 2023; Liu et al., 2013). This implementation enables the assessment of the reputation and influence of specific articles, authors, and research publications by analysing citation indices (Julius et al., 2021; Kartika et al., 2023).

Bibliometric analysis is commonly employed to examine the research progress in mathematics education and others, like argumentation research (Kartika et al., 2023), realistic mathematics education (Phan et al., 2022), mathematical problem-solving (Suseelan et al., 2022), critical thinking (Aktoprak & Hursen, 2022), flipped classrooms in mathematics learning research (Kadarisma et al., 2024), and mathematical creativity (Saefudin et al., 2023). Bibliometric analyses of abstraction research have yet to be published based on search results in the Scopus database. However, it is important to understand current trends and developments. This bibliometric analysis aims to explore and identify the latest trends in abstraction research. It seeks to provide an overview of the existing literature, offer insights into the future direction of abstraction research, and highlight areas for further research. . Specifically, the following three research aims will be explored: (1) Exploring the most essential journal sources, the most productive universities, and the most influential authors in abstraction research. (2) Exploring the most productive countries and the most significant impact countries of collaboration of authors in abstraction research. (3) Exploring the most

popular research topics and trends based on analysing the words in the title, abstract, and keywords in abstraction research. Thus, this study's results will provide information to mathematics education researchers related to the trend of abstraction research so that the results can be novel for further research.

2. METHOD

This study utilised a conventional scientific mapping procedure encompassing the subsequent five systematic phases: research design, compilation of bibliometric data, analysis, visualisation, and interpretation (Börner et al., 2003; Kartika et al., 2023; Zupic & Čater, 2015).

2.1. Study Design

Bibliometry involves analysing data derived from scientific publications' bibliographic aspects through quantitative and statistical methods (Ellegaard & Wallin, 2015; Hallinger & Kovačević, 2019). One of these research studies aims to analyse the publication characteristics and determine research trends in mathematical abstraction through bibliometric analysis methods. The substantial volume of published articles poses challenges for researchers seeking to discern trends in mathematical abstraction. Therefore, a bibliometric analysis related to this research is needed. This research is a quantitative meta-analysis design research because this research aims to identify bibliometric data related to mathematical abstractions registered in the Scopus database.

2.2. Compilation of Bibliometric Data

This stage is related to retrieving data from the database and filtering the data. In this stage, researchers took data provided by Scopus as had been done by previous research in mathematics education (Huan et al., 2022; Julius et al., 2021; Kartika et al., 2023; Phan et al., 2022). The material coverage in Scopus data is 70% wider than other data sources (Ha et al., 2020). Scopus data taken in research is limited to 2008-2022 (the last 15 years) because generally papers cite the last 10 years of publication, but the researchers took 15 years to enrich the data.

2.3. Analysis and Visualisation

This stage is related to the software used to analyse the data. To analyse data from the Scopus database, Scopus has provided analysis and visualisation results such as the number of article publications in Scopus-indexed journals each year, sources of Scopus-indexed journals, influential authors, and productive universities. However, more than bibliometric analysis is needed based on the Scopus analysis, so auxiliary software is required to analyse and visualise it. This paper uses R studio and VOSviewer software to analyse and visualise bibliographic data using bib and RIS data. The reason for using these two applications is because R Studia is more complete in viewing visualisation results such as general article information, article growth, and others. This means that the visualisation results from R will strengthen the analysis results displayed by Scopus. However, the R application cannot edit the keywords we want in the relationship analysis. Nevertheless,

VOSviewer can be edited according to the author's needs, making it more practical. Apart from that, analysing the novelty of research using VOSviewer is more accessible than using the R application. The study's novelty can be seen enough by Network Visualisation, Overlay Visualisation, and Desity Visualisation in the VOSviewer application.

Figure 1 presents the flowchart for the data collection and search strategy within the Scopus database, conducted before any subsequent analysis. The first step involved retrieving all mathematics-related articles, resulting in 1,152 articles. The second step was filtering the articles by language, identifying 453 articles written in English. The final filtering step excluded articles that were not focused on the humanities, arts, psychology, or multidisciplinary fields. After this process, the final set of 271 articles was selected for bibliometric analysis.

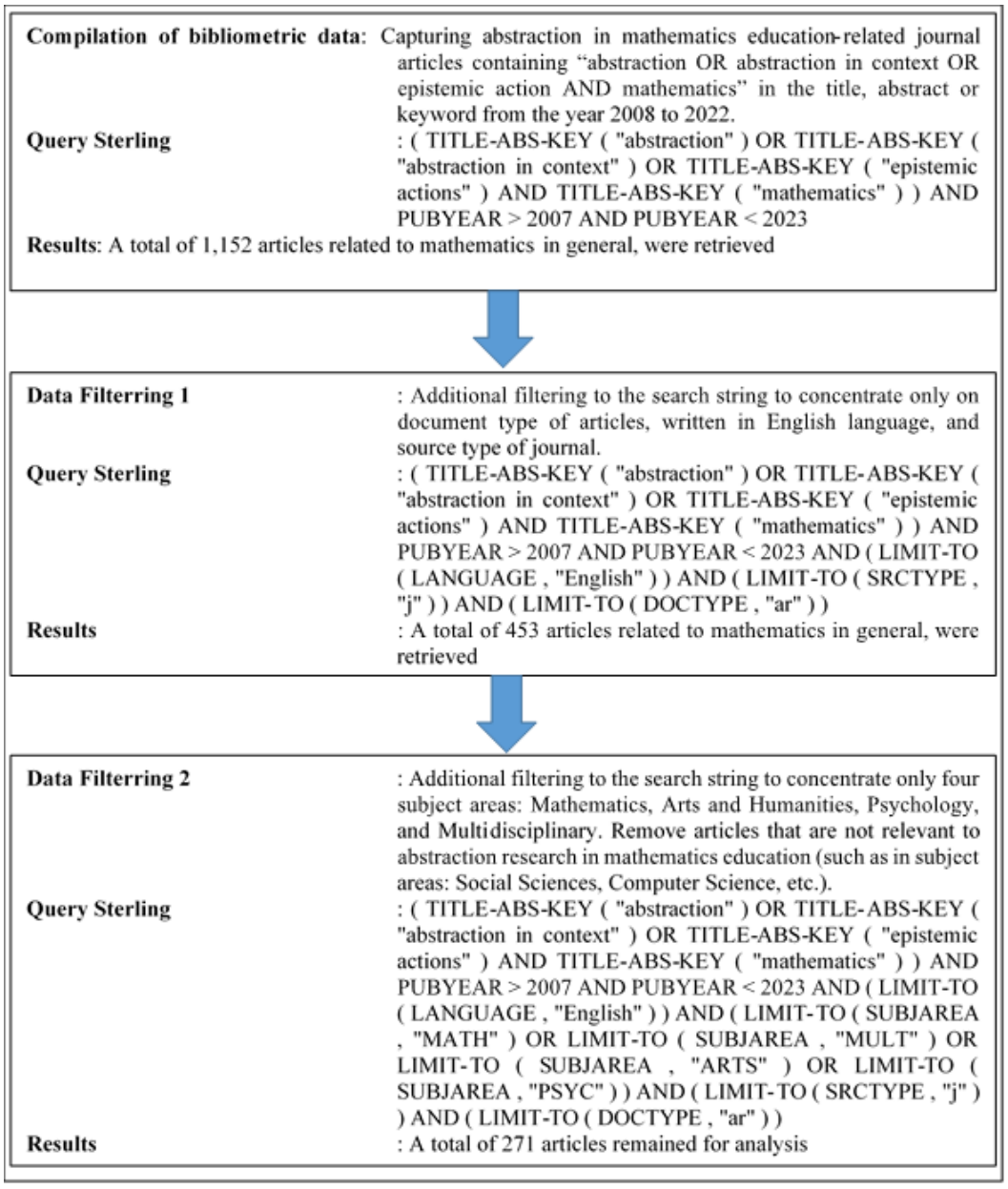
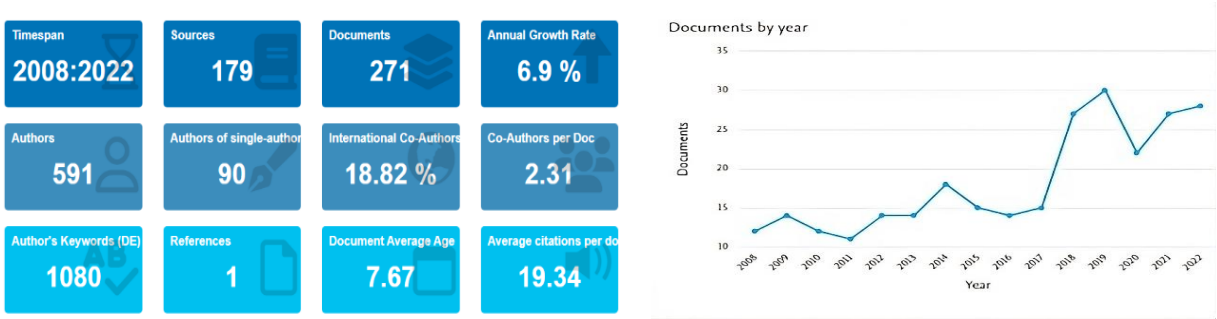


Figure 1. Flowchart of data collection

3. RESULTS AND DISCUSSION

3.1. General Information and Growth Trends

The database from Scopus in this paper starts from 2008 to 2022 (the last 15 years) because, generally, citations in articles must be published at least in the previous ten years. However, the authors added five years to make it 15 years so that the data obtained is more analysed. Furthermore, there have been a lot of published articles related to abstraction over the last 15 years, so it is enough to carry out an analysis. In Figure 2a, you can see general information from 271 articles from 2008-2022.



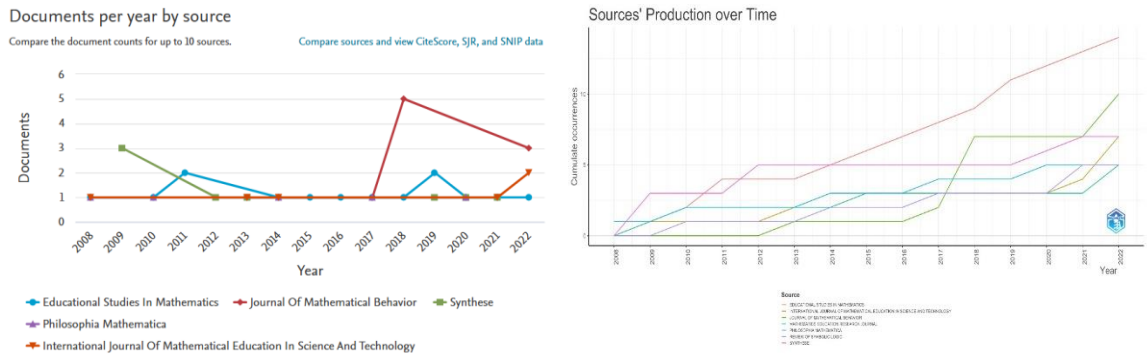
(a) (b)

Figure 2. General information and growth trends of articles: (a) Main information; (b) Publication of Articles Per Year

Figure 2a shows that the number of articles from the Scopus database is 271. Authors of single-authored docs were only 90 authors (15.2%) of 591 authors. In addition, the data source for this research is only one reference, a journal article from the Scopus database. The growth rate was 6.9% from 2008 to 2022, which is considered good. The annual growth of articles can also be seen in Figure 2b. Based on the results of journals indexed by Scopus, the publication of published articles fluctuates. Publications increased quite significantly in 2019 at 11.07% (30 articles). There was a decline of only 22 articles in 2020, but starting in 2021, it began to rise again. In 2022, there were 28 articles. The fewest publications occurred in 2011 at 4.06% (11 articles). The data indicates that mathematics abstraction research has been a popular topic among mathematics researchers despite fluctuations in interest over the years, and it should be further developed through continued research and publication.

3.2. Contribution by Journals

There are 179 journals contributed to publishing papers related to abstraction. Figure 3 shows the distribution of the top 5 journals that publish the most articles.



(a) (b)

Figure 3. Contribution by journals to articles: (a) Distribution of articles based on scopus-indexed journal sources; (b) Sources' Production over Time

In Figure 3a, journal sources indexed by Scopus publish themes related to abstraction. The highest number of publications was published in Educational Studies in Mathematics (Q1), with 14 articles published. The top five journal sources can also be a reference for publishing papers related to this theme. The five journals are Educational Studies in Mathematics, Journal of Mathematical Behavior (10 articles), Synthese (7 articles), International Journal of Mathematical Education in Science and Technology (7 articles), and Mathematics Education Research Journal (5 articles). Although there are many other journal sources, these five journals have the most significant number of articles published compared to other journals. Furthermore, the growth of publications published in journals from 2008-2022 can be seen in Figure 3b.

Table 1. Top five journals

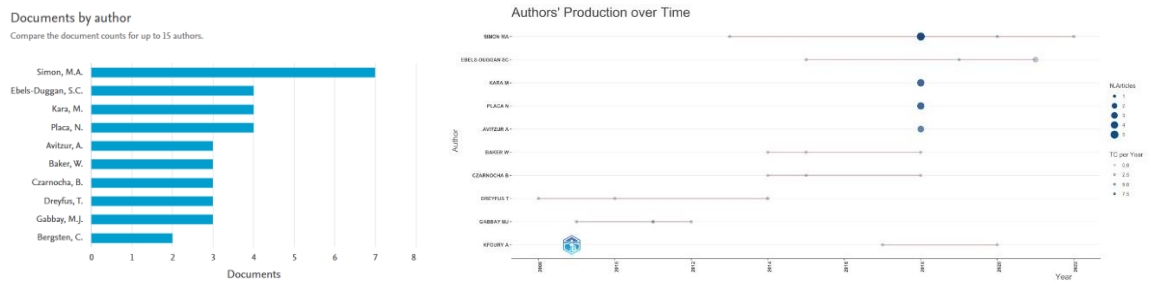
Source Title	Cite Score	Highest percentile	% Cited	SJR	Publisher	The number of articles
Educational Studies in Mathematics	4.7	92.0% (Q1)	78	1.636	Springer Nature	14
Synthesis	2.6	91.0% (Q1)	59	0.808	Springer Nature	7
Mathematics Education Research Journal	3.7	89.0% (Q1)	87	0.957	Springer Nature	5
Journal of Mathematical Behavior	2.7	80.0% (Q1)	67	1.081	Elsevier	10
International Journal of Mathematical Education in Science and Technology	2.6	79.0% (Q1)	68	0.516	Taylor & Francis	7

Table 1 shows the top five journals that publish papers related to abstraction. These journals have a percentile range of 75%-99%, which means they are in Quartile 1. Apart from that, the journal's SJR is above 0.5. Thus, these five journals are considered very good for publishing papers, especially in mathematics education. In addition, Figure 3b shows the development of journal-published papers over 15 years. Figure 3b shows that Educational

Studies in Mathematics (Q1) from 2010-2022 (13 years) published 14 articles. It is a journal with the most publications. The Journal of Mathematical Behavior published ten articles from 2013-2022 (10 years). The International Journal of Mathematical Education in Science and Technology published seven articles from 2009-2022 (14 years). Synthese published seven articles from 2009-2022 (14 years). Mathematics Education Research Journal published five articles from 2008-2022 (15 years). Educational Studies in Mathematics is the most productive because it published 14 articles in 13 years, with a publication percentage that is 5.2% higher than that of other journals. These journals can be a reference for researchers whose focus is abstraction studies to publish their papers in these journals.

3.3. Contributions by Authors

There were 591 authors from various countries. Figure 4 shows the distribution of the top 10 authors who have published the most papers and cites in the field of abstraction.



(a) (b)

Figure 4. Contributions by authors to articles: (a) Distribution of articles based on the author; (b) Authors Productivity

Based on Figure 4a, the most influential author related to abstraction is Martin A. Simon from New York University, New York, United States. This means that the authors are productive people and can be a reference in abstraction research. The focus of Martin A. Simon's study is a reflective abstraction. At the same time, Tommy Dreyfus developed the theme of abstraction in context and epistemic action, so Martin A. Simon has become a reference for researchers who study reflective abstraction. Dreyfus has become a reference for researchers who study abstraction in context and epistemic action. Furthermore, the influential authors from 2008-2022 can be seen in Figure 4b. The larger circles in Figure 4b indicate the more articles published by the author, and the darker circles indicate more citations. Based on Figure 4b, the most influential author is Martin A. Simon because the circles are bigger and darker than the others. He started publishing articles from 2013-2022 and published five articles in 2018 related to reflective abstraction (Simon, 2020; Simon, Kara, Norton, et al., 2018; Simon, Kara, & Placa, 2018; Simon, Placa, et al., 2018). Therefore, Martin A. Simon is the author who has published the most articles and is the most cited. The theme of abstraction in context, observed using epistemic actions, was introduced by Tommy Dreyfus and Rina Hershkowitz in 2001 (Dreyfus et al., 2015; Hershkowitz et al., 2023).

3.4. Contributions by Institutions

Three hundred thirty-eight universities from various countries were obtained. Figure 5 shows the distribution of the top 10 universities that publish the most papers in the field of abstraction.

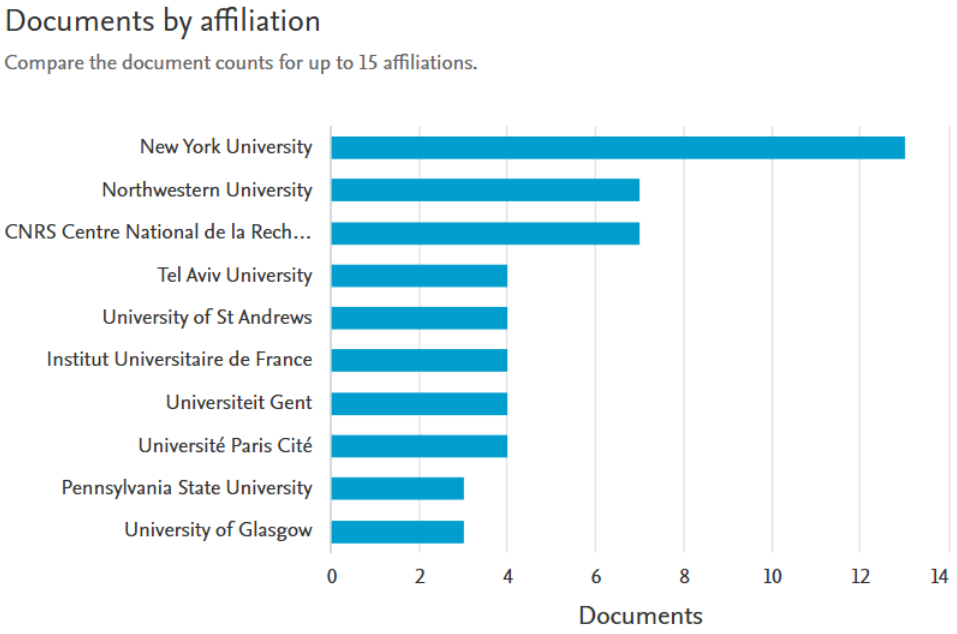
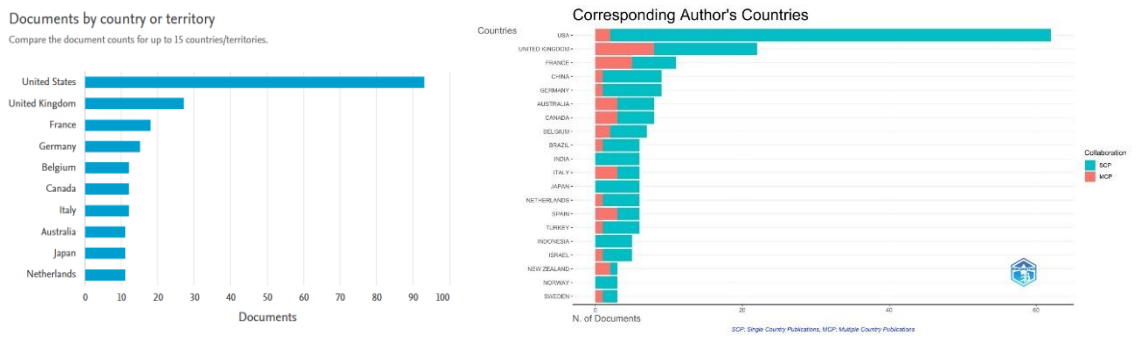


Figure 5. Distribution of articles per the university

Figure 5 shows the university that contributed to publishing articles related to the abstraction. The top ten campuses are New York University, Northwestern University, CNRS Center National de la Recherche Scientifique, Tel Aviv University, Institut Universitaire de France, Universiteit Gent, Université Paris City, Pennsylvania State University, University of Glasgow, and Hunter College. These ten campuses can be a reference for authors who study abstraction. For example, New York University is a campus that is productive in publishing articles related to reflective abstraction. New York University published 4.8% (13 articles). Tel Aviv University is a campus that is productive in publishing articles about abstraction in context and epistemic action. Martin A. Simon from New York University focuses his research on reflective abstraction. Tommy Dreyfus and Rina Herkowitz are Tel Aviv University lecturers who put forward the idea of observing abstraction by epistemic action.

3.5. Distribution by Country

Thirty-nine countries contributed to the publication of this article. Figure 6 shows the distribution of the top 10 countries that publish the most papers in the abstraction research.



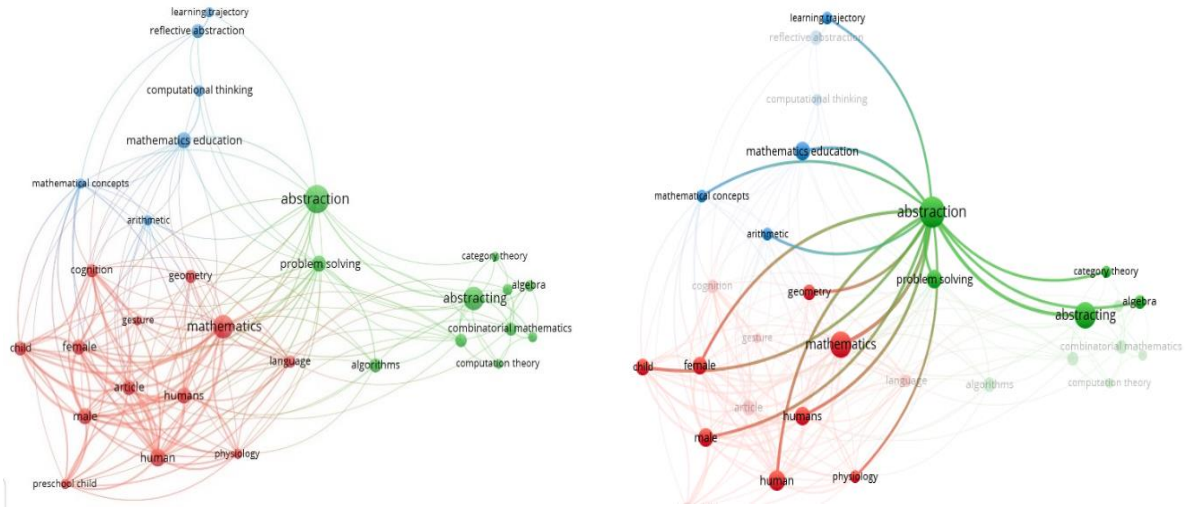
(a) (b)

Figure 6. Distribution by country to articles: (a) Distribution of articles per country; (b) Distribution of articles per SCP and MCP

Based on Figure 6a, the country that contributed the most to the publication of articles on the theme of abstraction was the United States, with 34.69% (94 articles), followed by the United Kingdom, with a percentage of 9.96% (27 articles). 8 of the top 10 authors are from the United States. Thus, abstraction is more dominant and productive in the United States, especially New York University and Hostos Community College. Thus, authors from the United States have widely researched abstraction studies. The United States is the most productive country in publishing papers (Gökçe & Güner, 2021; Suseelan et al., 2022). Therefore, future researchers can use the United States as a reference in abstraction research, especially reflective abstraction because Martin A. Simon from New York University, New York, United States is the most productive author in abstraction research. However, abstraction in context was initiated by Tommy Dreyfus and Rina Herkowitz from Tel Aviv University, Tel Aviv-Yafo, Israel, and published in 2001 (Hershkowitz et al., 2001). These are the latest papers related to abstraction published by Tommy Dreyfus and Rina Herkowitz (Elias & Dreyfus, 2022; Gilboa et al., 2019; Hershkowitz et al., 2023). In comparison, other countries still had under 20 articles published over the last 15 years. Apart from that, if we look at it based on single-country publications (SCP) and multiple-country publications (MCP) (see Figure 6b). Based on Figure 6b, the United Kingdom carries out the highest MCP, while the USA carries out the highest SCP. However, the USA publishes more articles than other countries, followed by the United Kingdom in second place. Based on Figure 6b, only India, Japan, and Norway publish articles with single-country publications, while the other countries have articles with multiple-country publications.

3.6. Keywords and Terms Analysis

Based on the word cloud results, the words that often appear in keywords are abstractions. Abstraction appeared 41 times in articles published from 2008 to 2020 on the theme of abstraction and abstraction in context. Moreover, the words mathematics appear 19 times, mathematics education 13 times, reflective abstraction 11 times, and geometry nine times. Furthermore, based on the relationship between keywords that appear can be seen in Figure 7.

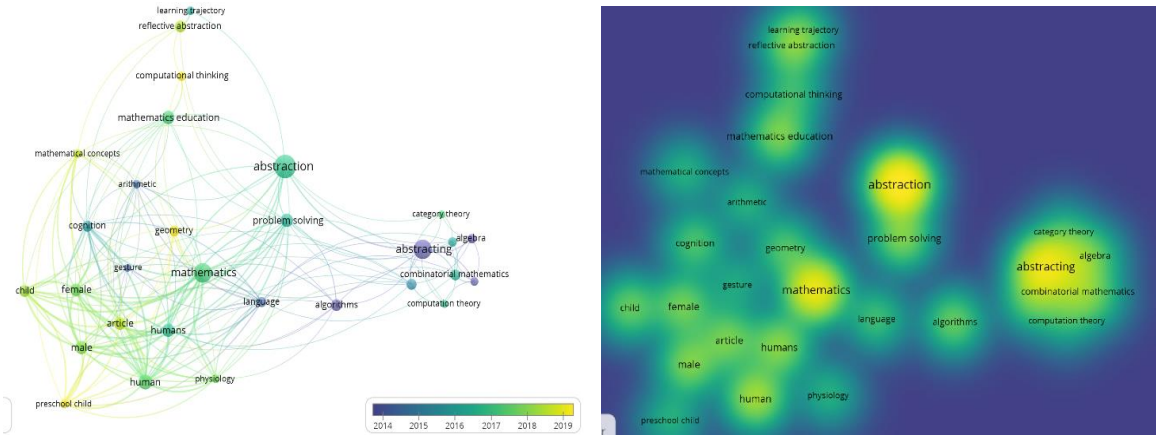


(a) (b)

Figure 7. Network visualisation: (a) Network with all research themes; (b) Network with other research clusters

Figure 7a shows three research clusters displayed with research clusters in red, blue, and green. However, the three clusters are interconnected, such as abstraction related to geometry and arithmetic. Figure 7b shows the relationship between abstractions and other themes or clusters.

Based on Figure 7b, abstraction is related to several research themes in other clusters, such as abstraction research about geometry, child, male, and female (red cluster). Apart from that, abstraction research is also associated with learning trajectory, arithmetic, and mathematical concepts (blue cluster). Themes directly related to abstraction indicate that there are already publications related to these themes. For example, in the green cluster, abstraction research is related to problem-solving (Kariadinata, 2021), algebra, category theory, and abstracting. In a blue cluster, abstraction research is related to arithmetic (Dvir & Tabach, 2017), learning trajectory, and mathematical concepts (Hodiyanto et al., 2024). In the red cluster, abstraction research is related to geometry (Breive, 2022; Hershkowitz et al., 2023), female and male (Borriello et al., 2022), physiology, and child (Breive, 2022). Thus, the next trend in abstraction research is research themes that are not directly related to abstraction, such as abstraction that is associated with gestures in the red cluster. Even though some of these research themes have been published, there are certainly few, so there is still chance for follow-up. However, to see the latest research trends (see Figure 8).



(a) (b)

Figure 8. Overly and density visualisation: (a) Overly visualisation; (b) Density visualisation

Based on Figure 8a, brighter indicates new research, and darker suggests that the study has not been researched for a long time. Apart from that, Figure 8a shows that abstraction related to geometry, computational thinking and preschool is a trend. To show how much research has been carried out (see Figure 8b).

The brighter the research theme shown in Figure 8b, the more research has been conducted, and the darker the research theme shown, the less research has been carried out, such as abstraction being brighter than gesture. This indicates that there is more research on abstraction compared to gesture. Thus, the dark theme displayed in Figure 8b provides researchers with opportunities for further research. Research themes related to abstraction that have yet to be widely carried out are gesture, preschool child, arithmetic, physiology, mathematical concepts, computational thinking, geometry, language and cognition. Abstraction research has bright colours, which means there have been many studies with the theme of abstraction. However, that does not imply that abstraction research is no longer worthy of research. We need to look for new research and trends related to abstraction that can be carried out now. Abstraction research has much to do with other research themes, either indirectly, like in Figure 7a, or directly, like in Figure 7b. Abstraction research is currently trending if abstraction is linked to geometry and preschool (see Figure 8a) because these two themes are trendy if they relate to abstraction. In addition, if geometry is related to gesture or preschool in abstraction, its novelty will be more visible than other themes because more research on gestures still needs to be done (see Figure 8b), especially if it relates to abstraction. Several abstraction studies are associated with embodiment or gesture (Boonstra et al., 2023; Breive, 2022; Reinboth & Farkaš, 2022). Figure 8b shows that abstraction is still a trend when carried out on kindergarten children, but abstraction research can still be carried out on undergraduate students. Several previous abstraction studies have been conducted on undergraduate students (Hershkowitz et al., 2023; Hodiyanto et al., 2024).

4. CONCLUSION

This research shows that abstraction research is exciting because it will still trend until 2022. Moreover, the papers published are also, on average, in the Scopus database with quartile one. Therefore, the results of this research can be used as a reference by future researchers who wish to conduct abstraction research based on the research trends reported in this paper. This research uses bibliometric analysis from the Scopus database to investigate the abstraction research published in the last 15 years. Significant findings from this research are as follows: There were 271 publications during the previous 15 years, but the article citation index still needs to be improved. This means that high citations of articles do not follow the high number of publications; Educational Studies in Mathematics is the journal that contributes the most to publishing articles in the field of abstraction; Martin A. Simon from New York University is the most influential author in publishing articles, especially reflective abstraction, while Tommy Dreyfus and Rina Herkowitz from Tel Aviv University focus on studying abstraction in context; New York University is the most productive universities; The United States is the most productive country compared to other countries and is among the countries with the most authors, while the United Kingdom is the country with the highest multiple country publications; The publications in the abstraction tend to be of high quality, as a significant number of articles are published in journals with high percentile rankings.

In the last decade, abstraction studies related to geometry, computational thinking, and preschool are trend and abstraction studies related to gesture, preschool child, arithmetic, physiology, mathematical concepts, geometry, language, and cognition are few. Thus, the future direction of this research can be focused on geometry, gesture, computational thinking, mathematical concepts, and preschool children, but the possibility of this being done at a higher level, for example, with undergraduate students, still needs to be considered. The results of this research can provide an overview of future research related to trends in abstraction research so that more abstraction research is reviewed, especially the latest abstraction studies. In addition, this study provides information that abstraction research still needs to be further researched, both based on research trends and the still minimal research results. This data only uses the Scopus database, so further research can be combined with the WoSCC database. In addition, the papers taken from Scopus data are only from the last 15 years.

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Declarations

Author Contribution : H: Conceptualisation, Writing-Original Draft, Visualisation, Data Curation, and Methodology; MTB: Conceptualisation, Investigation, and Supervision; RE: Conceptualisation, Data Curation, Writing-Original Draft, Formal analysis, and Methodology; GS: Writing-Review & Editing, Investigation, Visualisation, Resources, and Validation; JK: Validation, and Formal analysis; DMRB: Writing-Review & Editing, Resources, and Validation.

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Conflict of Interest : The authors declare no conflict of interest.

Additional Information : Additional information is available for this paper.

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