

Review Article

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Numeracy Literacy Innovations in Primary Education: A Bibliometric Exploration of Future Trends and Directions

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Abstract

Background: This study aims to map the research landscape on numeracy literacy in primary education using bibliometric analysis to identify trends, influential works, thematic developments, and collaboration patterns.

Material/Method: Data were retrieved from the Scopus database using a set of defined keywords, limited to English-language journal articles published between 2013 and 2023, resulting in 242 eligible documents. Analysis was performed using VOSviewer and Biblioshiny to conduct performance analysis, co-word analysis, co-citation mapping, and thematic evolution tracking.

Results: The findings show a significant increase in research output over the past decade, with Australia, the United Kingdom, and the United States as the most productive countries, and Indonesia emerging among the top contributors. Thematic analysis revealed dominant clusters related to foundational numeracy and literacy skills and emerging topics such as gamification, AI-assisted personalized learning, and equity-focused interventions. Despite growing global interest, international collaboration remains limited.

Conclusion: This study contributes by integrating numeracy and literacy within primary education, highlighting innovation-driven themes and equity concerns. The results provide actionable insights for educators, policymakers, and researchers to design context-sensitive instructional strategies, strengthen cross-sectoral collaboration, and address underexplored research areas. This study identifies literature trends on numeracy literacy in primary education and offers important implications for instructional design, educational policy, and future research.

1. Introduction

Basic education is the main foundation in building literacy and numeracy skills that are the basis of 21st-century skills (Aini et al., 2024; Megawati & Sutarto, 2021; Setiyani et al., 2024; Sio Jyh Lih & Ismail, 2019). Literacy and numeracy are two basic skills that are very important in education, especially at the primary school level (Hong et al., 2020; Xiao et al., 2019). Literacy means being able to read and write and the ability to identify, understand, interpret, create, communicate, and calculate using printed and written materials related to various contexts in everyday life (Md-Ali et al., 2016). Literacy involves continuous learning to enable a person to achieve their goals, develop their knowledge and potential, and participate fully in the wider society, likewise with numeracy, which is not only a matter of counting, but also the ability to think logically (Iswara et al., 2022; Kumar & Behera, 2022; Napoli et al., 2021; Nguyen et al., 2016).

Despite their recognized importance, many students, particularly at the primary school level, struggle to attain adequate literacy and numeracy proficiency (Cooper & Dunne, 2000; Fery et al., 2017; Sepriyanti et al., 2022). Data from the OECD (2022) and various national assessments indicate that Indonesia continues to face challenges in achieving optimal literacy and numeracy outcomes. This persistent gap negatively impacts students' academic performance, limits their ability to engage in higher-order thinking, and affects their preparedness for future educational stages. The urgency of improving these foundational skills has driven educators, researchers, and policymakers to seek innovative and effective interventions.

However, although literacy and numeracy are considered important, the reality is that there are still many children who have not achieved these basic skills well (Cooper & Dunne, 2000; Fery et al., 2017; Sepriyanti et al., 2022). Various surveys and reports show that the level of literacy and numeracy of students in many countries, including Indonesia, still needs to be improved. (OECD, 2022). This encourages various parties to find solutions, one of which is by developing innovations in the field of education. As attention to literacy and numeracy increases, research in these areas also grows. Researchers from different countries are studying new teaching methods, utilizing technology, and creating more engaging approaches for students. However, with so much research, it's important to understand how these trends are evolving, what topics are most discussed, and where the research is headed.

With a myriad of topics to choose from, researchers must stay up-to-date with the latest developments in the field: leading authors, featured journals, and current topics. Today, this grueling task is greatly facilitated by technology, one of which is bibliometrics. Bibliometric tools can provide an advanced overview mapping, research evolution, citation impact, collaboration profiling, research positioning, and exhibition. (Ranjbar-Sahraei & Negenborn, 2017).

The bibliometric method is the right way to answer these questions. By analyzing data from scientific publications, this method can provide an overview of research trends, patterns of collaboration between researchers, and key emerging themes. This study aims to explore these trends in the context of literacy and numeracy innovations in primary education, so that it can provide new insights for teachers, researchers, and policymakers to improve the quality of education in the future.

Similarly, Cardona-Román & Sánchez-Torres (2017) show that through bibliometric studies, trends can be detected, and patterns that facilitate the identification of scientific progress and levels of development in a particular field, where various bibliometric indicators are used, can be established. Additionally, bibliometric analysis facilitates examining and evaluating large amounts of scientific data, providing insights into new areas and evolutionary intricacies within specific disciplines (Donthu et al., 2021). While Pritchard (1969) first coined the word 'bibliometric' to replace the term 'statistical bibliography,' the name first appeared in French as 'bibliométrie' by Paul Otlet in 1934.

Pritchard (1969) defines it as "the application of mathematics and statistical methods to books and other communication media" (Gozali et al., 2023).

Previous works on bibliometrics used bibliographies, citations, directories, and lists of unions as data sources. (Lawani, 1980). Since then, bibliometrics have been used to develop citation indexes. Garfield (2007) to determine productive writers, author collaboration profiles, and research networks (Hyland & Jiang, 2021).

Bibliometric methodology summarizes the application of quantitative techniques (i.e., bibliometric analysis e.g., citation analysis) to bibliometric data (e.g., Publication and Citation Unit) (Broadus, 1987). Wallin (2005) Wallin (2005).

To this end, conducting a bibliometric analysis provides a panoramic sketch of the trends of productive writers, leading journals, current topics, and the institutional origins of authors. It is hoped that the results of this study can help especially beginner numeracy literacy writers in the search for new research topics and potential publications.

Here are four relevant research questions for the topic "Innovations in Numeracy Literacy in Primary Education: A Bibliometric Exploration of Future Trends and Directions":

1. Descriptive: the most productive authors, institutions, journals, and countries, the most influential documents, authors, and journals as seen by the citation structure, as well as the keywords that most frequently appear in numeracy literacy research.
2. Conceptual structure: joint word analysis to find central themes and trends in numeracy literacy research, based on the relationships between keywords, as they appear in keywords provided by authors and by journals, in abstracts, and in titles.
3. Intellectual structure: analysis of joint citations to reveal the author's influence on others, as shown by the reference of articles written on numeracy literacy research.
4. Social structure: to reveal the collaboration between the state, authors and institutions of numeracy literacy research carried out during the pandemic.

Unlike previous bibliometric studies that examined literacy and numeracy as separate domains, this study integrates both within the context of primary education, providing a comprehensive view of their interconnection. Furthermore, it expands the scope by identifying innovation-driven themes such as gamification, AI-assisted personalized learning, and equity-focused interventions—topics that have received limited attention in prior research. By analyzing a decade-long dataset (2013–2023) from the Scopus database, this study offers an updated and nuanced understanding of global research trends, thematic developments, and collaboration patterns, thereby filling a critical gap in the literature.

By explicitly focusing on the intersection of literacy and numeracy innovations within primary education, this study contributes a unique perspective that bridges pedagogical, technological, and equity-focused dimensions. The findings are expected to inform curriculum designers, teacher educators, and policymakers in developing context-sensitive, evidence-based strategies to enhance foundational skills and reduce learning gaps across diverse educational contexts.

2. Literature Review

2.1. Definition and Dimensions of Numeracy Literacy

Literacy and numeracy are fundamental competencies that are the basis for the development of basic education around the world because they are the main foundation to support the learning process at a higher level. Literacy includes the ability to read, understand, and utilize information well, while numeracy includes logical thinking skills and problem-solving through the application of

number concepts. However, the results of evaluations such as PISA (Programme for International Student Assessment) and various national reports show that students' literacy and numeracy mastery, especially in developing countries, still need more serious attention (Kemdikbud, 2022; McComas, 2014; OECD, 2022). This triggered the birth of various innovations in the field of education that aim to improve these basic skills. Research shows that literacy and numeracy mastery at an early age play an important role in students' future academic success (Ni Mhurchu et al., 2010). However, the results of the 2021 National Assessment in Indonesia show that students' literacy and numeracy skills are still low, which requires learning innovation (Kemdikbud, 2022).

In the context of 21st-century skills, literacy also includes digital literacy, which is the ability to access, evaluate, create, and communicate information using digital tools (Ng, 2012; Eshet-Alkalai, 2012). The European Commission's DigComp framework describes five key dimensions: information and data literacy, communication and collaboration, digital content creation, safety, and problem-solving (Vuorikari et al., 2016). In primary education, these skills are increasingly seen as complementary to traditional literacy and numeracy in preparing students for future academic and professional demands (Falloon, 2020).

2.2. Teaching Numeracy and Literacy in Primary Education

In the last two decades, research related to literacy and numeracy innovations has shown significant development. Various new approaches have begun to be implemented, including project-based learning, contextual approaches, and collaborative learning, which have proven effective in improving student understanding (Ni Mhurchu et al., 2010). In addition, the use of digital technology such as learning applications, gamification, and e-learning is also a major trend in teaching literacy and numeracy. This technology helps to overcome the limitations of access to education in various regions and increase student engagement in the learning process (Higgins, 2010; UNESCO, 2021).

Various innovations have been applied in improving students' literacy and numeracy skills. One of them is the use of digital technology that allows the learning process to be more interactive and flexible. Platforms such as Google Classroom, Kahoot!, and GeoGebra have helped improve students' literacy skills through more engaging and streamlined methods. (Ho et al., 2023a). In addition, the Project-Based Learning (PBL) approach is also increasingly popular. This method encourages students to understand literacy and numeracy through real problem-solving and collaborative work, which has been proven to improve students' critical thinking skills. (To et al., 2020). Another relevant approach is Contextual Teaching and Learning, which relates literacy and numeracy materials to the context of daily life, making it easier for students to understand (Johnson, 2002). Intervention programs such as the School Literacy Movement (GLS) also play an important role in fostering reading habits and numeracy comprehension in school (Kemdikbud, 2022).

However, the challenges in improving literacy and numeracy are still significant. Gaps in access to education, especially in remote areas, often limit the availability of resources such as books, technology, and competent educators. (UNESCO, 2021). The lack of teacher training in implementing innovative methods is also an obstacle, considering that teachers have an important role in the development of students' basic skills. (Kemdikbud, 2022). In addition, the COVID-19 pandemic has further worsened the quality of learning, especially in developing countries that still rely on face-to-face learning (World Bank, UNESCO, UNICEF, USAID, FCDO, 2022).

Integrating digital literacy pedagogy into literacy and numeracy instruction requires both infrastructure readiness and teacher professional development. Previous research emphasizes that sustained training in digital pedagogy is essential for effective integration of technology in classrooms (Instefjord & Munthe, 2017; Tondeur et al., 2018).

2.3. Previous Studies on Bibliometric Analysis in Literacy and Numeracy

Not only that, innovation also occurs in the aspect of assessment, where competency-based assessment approaches such as AKM (Minimum Competency Assessment) are used to measure students' understanding of literacy and numeracy in a more in-depth and meaningful way (Andrade & Heritage, 2017; Kemdikbud, 2022).

Through bibliometric exploration, it can be seen that the research trend in literacy innovation has increased significantly in the last decade. The focus of the research is more directed at the integration of technology in learning, innovative teaching methods, and the development of formative assessment systems. (Ho et al., 2023a). This study also shows an increase in collaboration between researchers in various countries, especially in an effort to understand global challenges in basic education. (Ahmad et al., 2021; Oecd, 2021). However, several challenges still need to be overcome, such as the gap in access to technology in developing countries and the limited capacity of teachers to implement these innovations in the field (UNESCO, 2021).

Future research directions in the field of literacy and numeracy are expected to focus on the development of artificial intelligence (AI)-based technologies to support more personalized learning, an interdisciplinary approach that incorporates 21st-century skills, as well as efforts to create a more inclusive education (OECD, 2022). In addition, collaboration between researchers, educational institutions, and governments is key in creating innovations that can be applied effectively to improve the quality of basic education around the world. By understanding this trend, it is hoped that innovative solutions will emerge that can support the continuous improvement of literacy and numeracy.

3. Methodology

3.1. Study Design

This study aims to analyze research articles on numeracy literacy in basic education using a bibliometric approach, which was taken from the Scopus database from 2013 to 2023. Bibliometric analysis, compared to systematic literature review or meta-analysis, is the design of choice, as it can handle a large set of research data on a broad topic, allowing for both quantitative and qualitative interpretations (Donthu et al., 2021).

Bibliometrics is a statistical method for measuring and assessing the increase in trends in a particular area of study. (Agapiou et al., 2017). This goal is achieved by assessing relevant patterns of excellence and emerging research areas. This study uses the design of a bibliometric analysis method using the VOSviewer and Biblioshiny applications. This design is used to identify research related to the theme of numeracy literacy from various aspects. Publications related to numeracy literacy are taken from the Scopus database.

3.2. Data Collection

Data were obtained from the Scopus database, chosen for its comprehensive coverage and high-quality indexing (Baas et al., 2020). The search process involved several stages:

1. Keyword Selection – A combination of terms such as "literacy numeracy", "numeracy skill", "literacy and numeracy", and "literacy numeracy skill" was used in conjunction with educational context terms like "elementary school", "primary school", and "primary education".
2. Search Filters – Limits were applied to include only final-stage journal articles in English, published between 2013 and 2023. Conference papers, book chapters, and reviews were excluded.
3. Data Retrieval – The final search was conducted on November 22, 2024, yielding 342 documents. After applying the exclusion criteria, 242 journal articles were retained.

4. Data Cleaning – The retrieved metadata (authors, titles, abstracts, keywords, and references) were exported in CSV format and refined to remove duplicates, incomplete records, and irrelevant entries.

3.3. Instruments and Software

Two main bibliometric tools were used:

1. VOSviewer: For network visualization, including co-authorship, keyword co-occurrence, and co-citation mapping.
2. Biblioshiny (R-based bibliometrix package): For descriptive statistics, thematic mapping, and conceptual structure analysis.

The bibliometric indicators analyzed included publication count, citation count, h-index, g-index, m-index, and collaboration index. Network mapping parameters were set with a minimum occurrence threshold for keywords and citations to ensure relevance.

3.4. Data Analysis Technique

The data analysis consisted of four stages:

1. Descriptive Analysis: Identifying the most productive authors, institutions, countries, journals, and most cited documents.
2. Conceptual Structure Analysis: Conducting co-word analysis to identify major research themes and their interrelationships.
3. Intellectual Structure Analysis: Performing co-citation analysis to reveal influential works and journals shaping the field.
4. Social Structure Analysis: Mapping co-authorship networks to examine patterns of national and international collaboration.

All results were visualized in the form of network maps, thematic diagrams, and frequency tables, which were then interpreted in relation to existing literature and current educational priorities.

4. Results

A summary of the main features of the data obtained is presented in Table 1.

Table 1. Summary of the Data Obtained

Description	Results
MAIN INFORMATION ABOUT DATA	
Timespan	1989:2025
Sources (Journals, Books, etc.)	184
Documents	242
Annual Growth Rate %	0
Document Average Age	8
Average citations per doc	15.37
References	10823

Description	Results
DOCUMENT CONTENTS	
Keywords Plus (ID)	592
Author's Keywords (DE)	732
AUTHORS	
Authors	762
Authors of single-authored docs	58
AUTHORS COLLABORATION	
Single-authored docs	58
Co-Authors per Doc	3.39
International co-authorships %	19.42
DOCUMENT TYPES	
article	242

4.1. Descriptive Analysis

4.1.1. The Most Productive Authors, Institutions, Countries, and Journals

In the first part of the descriptive analysis, a list of the ten most productive aspects, such as authors, institutions, journals, and countries in numeracy literacy research, is presented in Figure 1. For the ten most prolific authors, as shown in Figure 1, 589 authors have been identified. At the top of the chart is He Vy with 3 publications, followed by Su Jy with three, and Zin Nam with two publications.

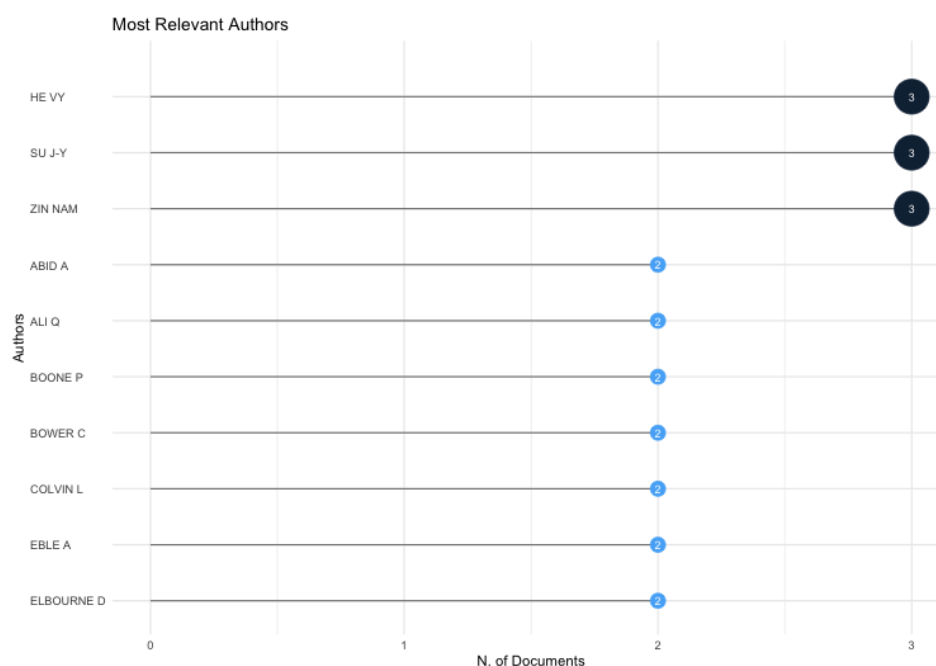


Figure 1. Top Ten Most Productive Authors

This result indicates that research on numeracy and literacy in primary education is driven by a small number of prolific authors, whose works significantly influence the development of the field.

The search for the ten most productive affiliates is filtered by limiting the number of publications to a minimum of one. The search returned 181 institutions. In Table 2, it can be seen that the University of Western Australia is first with 17 publications, followed by the London School of Hygiene and Tropical Medicine with 14 publications, and the University of London is third with 13 publications.

Table 2. Top Ten Most Productive Affiliations

Affiliation	Articles
UNIVERSITY OF WESTERN AUSTRALIA	17
LONDON SCHOOL OF HYGIENE AND TROPICAL MEDICINE	14
UNIVERSITY OF LONDON	13
CHARLES DARWIN UNIVERSITY	11
UNIVERSITY OF MELBOURNE	11
POPULATION COUNCIL	10
DURHAM UNIVERSITY	9
QUEENSLAND UNIVERSITY OF TECHNOLOGY	9
AUSTRALIAN CATHOLIC UNIVERSITY	8
MACQUARIE UNIVERSITY	8

Table 3 also reveals the top ten most productive countries. The list is topped by Australia (NP = 47), the United Kingdom (NP = 31), and the USA (NP = 17).

Table 3. Top Ten Most Productive Countries

Country	Articles
AUSTRALIA	47
UNITED KINGDOM	31
USA	17
IRELAND	11
INDONESIA	10
SOUTH AFRICA	9
MALAYSIA	4
CANADA	3
JAPAN	3
NETHERLANDS	3

The geographical analysis shows Australia, the United Kingdom, and the United States as the

leading contributors, with Indonesia emerging among the top five countries. However, international co-authorship rates remain below 20%.

Finally, the ten most productive journals in numeracy literacy are also presented in Table 4. The search is limited to journals that publish a minimum of three articles. The International Journal of Educational Development leads the list with nine articles, followed by Education 3-13 with five articles, and Irish Educational Studies, which publishes a total of 5 articles.

Table 4. Top Ten Most Productive Journals

Sources	Articles
INTERNATIONAL JOURNAL OF EDUCATIONAL DEVELOPMENT	9
EDUCATION 3-13	5
IRISH EDUCATIONAL STUDIES	5
BRITISH EDUCATIONAL RESEARCH JOURNAL	4
AUSTRALIAN JOURNAL OF EDUCATION	3
BMC PUBLIC HEALTH	3
ECONOMICS OF EDUCATION REVIEW	3
EDUCATIONAL RESEARCH	3
FRONTIERS IN PSYCHOLOGY	3
INTERNATIONAL JOURNAL OF PHYTOREMEDIATION	3

The top journals publishing research in this domain include International Journal of Educational Development, Education 3-13, and Irish Educational Studies. These journals serve as the main platforms for disseminating innovations in numeracy literacy teaching. The data shows that high-impact journals in education and technology dominate the publication of numeracy and literacy studies, suggesting that this topic is increasingly recognized as relevant to both educational theory and digital pedagogy.

In addition to measuring the productivity element by authors, institutions, countries, and journals in numeracy literacy research, the impact and influence of publications also need to be assessed through the measurement of citations and h-index (Donthu et al., 2021), where the h-index calculates the number of publications that have been cited at least h times (Hirsch, 2005). As a result, the analysis of the number of citations was carried out to find the most influential authors, journal articles, and countries of origin for published numeracy literacy research.

For authors, a total of 631 authors (with citation data) from the database were identified. Table 3 lists the top ten authors with details related to their h-index, total citations, number of publications, and institutions. Following the h-index, the most prominent author in numeracy literacy is proven to be He Vy, with h-index ($n = 3$), number of publications ($NP = 3$), and total citation time ($TC = 38$). He was followed by Su J-y (h-index ($n = 3$), ($NP = 3$), ($TC = 38$)), Wolf S, with h-index ($n = 3$), ($NP = 3$), ($TC = 35$)) coming in third.

Tabel 5. Top Ten Authors by H-Index

Author	h_index	TC	NP
HE VY	3	38	3
SU J-Y	3	38	3
WOLF S	3	35	3
ABID A	2	25	2
ALI Q	2	25	2
AUNIO P	2	45	2
BOONE P	2	6	3
BOWER C	2	20	2
COLVIN L	2	20	2
ELBOURNE D	2	6	3

Meanwhile, the top ten impact journals based on the h-index are shown in Table 6. The International Journal Of Educational Development topped the list with an h-index of 5, followed by the British Educational Research Journal with an h-index of 4, and Irish Educational Studies, which also had an h-index of 4. For journals, the h-index implies that the author has published h articles and has been cited at least h times. The g index signifies at least g² citations for the top g articles arranged in descending order by number of citations (Egghe & Rousseau, 2006). For example, a g-index of 9 means that the journal has nine articles that have all been cited 400 times. Finally, the m-index is the normalization of the h-index; i.e., the H-Index divided by the number of years of the author's publication activity.

Table 6. Top Ten Journals by H-Index

Source	h_index	g_index	m_index	TC	NP
INTERNATIONAL JOURNAL OF EDUCATIONAL DEVELOPMENT	5	9	0,5	93	9
BRITISH EDUCATIONAL RESEARCH JOURNAL	4	4	0,16	95	4
IRISH EDUCATIONAL STUDIES	4	5	0,36363636	34	5
BMC PUBLIC HEALTH	3	3	0,2	70	3
EDUCATION 3-13	3	4	0,23076923	19	5
RESEARCH PAPERS IN EDUCATION	3	3	0,1	18	3
AUSTRALIAN EDUCATIONAL RESEARCHER	2	2	0,15384615	40	2
AUSTRALIAN JOURNAL OF EDUCATION	2	3	0,25	40	3
DEVELOPMENTAL PSYCHOLOGY	2	2	0,33333333	31	2
ECONOMICS OF EDUCATION REVIEW	2	3	0,33333333	24	3

Table 7 reveals the top ten most cited articles. A glance at the title and source reveals that four out of ten are articles related to technology (Articles 1, 2, 5, and 9), and four are related to psychological aspects, such as learning pleasure, anxiety, and affective factors (Articles 3, 4, 6, and 7).

Table 7. Top Ten Most Cited Articles

Document Title	Authors	Journal Title	Total Citations
Effects of the home learning environment and preschool center experience upon literacy and numeracy development in early primary school	Edward C. Melhuish & Mai B. Phan	Journal of Social Issues	498
The effects of environmental and classroom noise on the academic attainments of primary school children	Bridget M. Shield & Julie E. Dockrell	The Journal of the Acoustical Society of America	322
Literacy, numeracy, and learning in school-aged children identified as having speech and language impairment in early childhood	Linda J. Horrison, Sharynne McLeod, Donna Beerthelsen & Sue Walker	International Journal of Speech-Language Pathology	77
Preschool and primary school influences on the development of children's early numeracy skills between the ages of 3 and 7 years in Germany	Yvonne Anders, Christiane Grosse, Hans-Gunther Rossbach, Susanne Ebert & Sabine Weinert	School Effectiveness and School Improvement	74
Using a brief preschool early numeracy skills screener to identify young children with mathematics difficulties	David J. Purpura, Erin E. Reid, Michael D. Eiland & Arthur J. Baroody	School Psychology Review	73
Literacy and Numeracy are more heritable than intelligence in primary school.	Yulia Kovas, Ivan Voronin, Andrey Kaydalov, Sergey B. Malykh, Philip S. Dale & Robert Plomin	Association for Psychological Science	71
Small Poppies: Highly gifted children in the early years	Miraca U.M. Gross	Roeper Review	71
Implementation and Challenges of English Language Education Reform in Malaysian Primary Schools	Hazita Azman	3L: The Southeast Asian Journal of English Language Studies	67
Inquiring into children's experiences of teacher feedback: reconceptualising assesment for learning	Eleanore Hargreaves	Oxford Review of Education	62
Teachers' thinking about information and communications technology and learning: beliefs and outcomes	Steve Higgins & David Moseley	Teacher Development	59
Total Citation			3720

Table 8. Top Ten Most Cited Countries by Corresponding Authors

Country	Articles	SCP	MCP
AUSTRALIA	47	45	2
UNITED KINGDOM	31	24	7
USA	17	12	5
IRELAND	11	9	2
INDONESIA	10	7	3
SOUTH AFRICA	9	7	2
MALAYSIA	4	4	0
CANADA	3	2	1
JAPAN	3	3	0
NETHERLANDS	3	3	0

In terms of relevant countries based on corresponding authors, it can be seen from Table 6 that authors from Australia produced the highest number of cited articles (n = 47), of which 45 were published by authors who were only affiliated in Australia. Two were written by at least one co-author from another country. The next most cited countries are the United Kingdom (n=31) and the USA (n=17).

In the last part of the descriptive analysis, the keywords of the top ten authors, as shown in Table 7, are also presented to look at the more prominent keywords used by literacy and numeracy writers of students in elementary school.



Figure 2. Top Ten Most Frequently Occurring Authors' Keywords

The image above displays a word cloud visualization that identifies the main keywords in research related to literacy and numeracy. It seems that the most frequently followed by "child" and Terms such as "literacy," "child," and "education" take center stage, highlighting the primary focus on children's basic learning. Words such as "female" and "male" indicate a concern for gender differences in educational attainment, while the terms "primary education" and "primary school" underline the context of primary education as the focus of the study.

4.2. Conceptual Structure

To determine the most relevant themes and concepts that have been researched in numeracy literacy in primary education, as well as the inter-relationship between the two, a co-word analysis was conducted to reveal a map of the co-occurrence network (Aria & Cuccurullo, 2017; Sharma et al., 2021). The analysis can be done using abstracts, author keywords, plus keywords (provided by journals), and titles as units of analysis.

The visualization for the results of the author's keyword co-occurrence analysis is shown in Figure 3. The node's size represents the frequency of occurrence, and the intensity of the connecting line reflects the frequency of co-occurrence between two keywords.

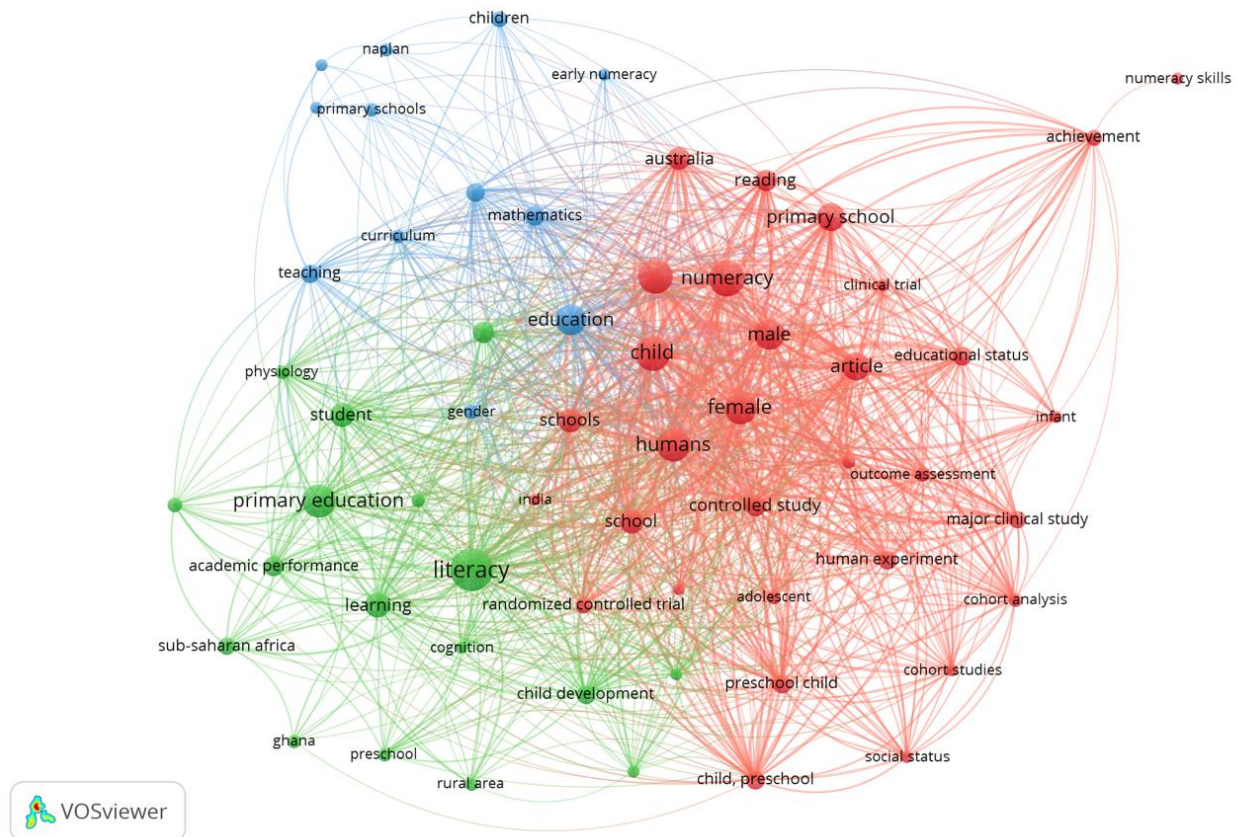


Figure 3. Co-Occurrence Analysis Network of Authors' Keywords

This co-occurrence-based visualization shows the relationship between keywords often used in literacy and numeracy research. Key keywords such as "numeracy," "literacy," "education," "child," and "primary school" appear as the largest nodes, suggesting that this theme has taken center stage in many studies. The clusters that form are colored differently to indicate the focus of a particular theme. The red cluster, for example, focuses on "numeracy" which is closely related to topics such as "primary school," "achievement," and "educational status," reflecting the focus of research on numeracy academic achievement at the elementary school level. Meanwhile, the green cluster highlighted "literacy" related to themes such as "learning," "primary education," and geographic contexts such as "sub-Saharan Africa" and "Ghana," indicating a focus on developing education in developing countries. The blue cluster emphasizes a pedagogical approach, with keywords such as "mathematics," "teaching," and "curriculum."

In addition, this visualization reflects the use of data-driven research methodologies, as indicated by keywords such as "controlled study," "randomized controlled trial," and "cohort analysis." The relationships between the nodes, indicated by the lines, indicate a strong correlation between several themes, such as between "numeracy" and "achievement" as well as "literacy" and "academic

performance." Geographical context is also a concern, as evidenced by keywords such as "sub-Saharan Africa," "India," and "Ghana," which indicate the research's focus on educational challenges in a particular region. Social factors such as "social status" and "educational status" highlight the importance of socio-economic dimensions in literacy and numeracy achievement. Thus, this visualization illustrates that literacy and numeracy research has a multidimensional focus, covering aspects of education, socio-economy, and geographical context, as well as providing guidance for further research development in the future.

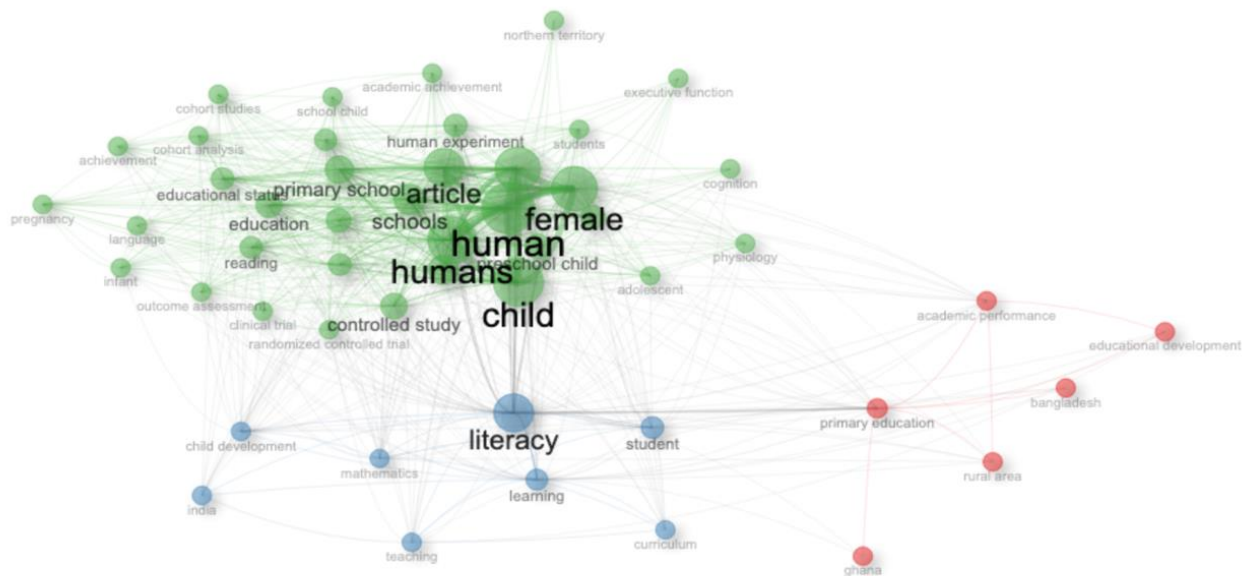


Figure 4. Co-Occurrence Network

The image is a network visualization resulting from bibliometric analysis to understand the relationship between keywords in research related to literacy and numeracy. Key keywords such as "human," "child," "literacy," and "primary school" are at the center of the network, suggesting that the main focus of the research is on children's education at the primary level. The terms "female" and "male" are also prominent, reflecting the attention to gender differences in literacy and numeracy research.

The network indicates a close relationship between "literacy," "education," and "academic performance," illustrating how literacy is directly correlated with student academic achievement. Terms such as "controlled study" and "cohort analysis" are linked to themes such as "reading" and "educational status," highlighting the importance of a data-driven approach to evaluating the effectiveness of educational programs. Other thematic groups are seen in the network, such as concepts related to child development (e.g., "child development," "preschool child"), technical aspects of education such as "mathematics," "learning," and "curriculum," as well as geographic contexts such as "Bangladesh," "Ghana," and "rural areas," which describe educational challenges in developing countries and remote areas.

In addition, the research methodologies used often involve empirical study designs, such as "randomized controlled trials" and "clinical trials," which suggest that data-driven approaches are a cornerstone of literacy and numeracy research. The presence of geographical locations such as "Bangladesh," "Ghana," and "Australia" highlights that the study covers a global context, with special attention to countries facing educational challenges. This visualization provides insight into the main focus and trends of research in literacy and numeracy, by uncovering the relationships between key themes, methodological approaches, and relevant geographic contexts.

Deep factorial analysis is also performed to represent the co-occurrence network in different ways. The double correspondence analysis (MCA) method was chosen, using the Author Keyword as the field. The results of the MCA map are shown in Figure 4, which shows two different clusters.

This bibliometric visualization map shows the relationship between various keywords that are relevant in the fields of education, child development, and academic performance. In the red area, clustering keywords such as child development, education, academic performance, and literacy can be seen, indicating the focus of the research on aspects of child development and educational achievement. Keywords such as social status, cohort studies, and outcome assessment on the left side show the relationship with longitudinal studies and the influence of social factors on education. In contrast, on the right side, terms such as rural area, primary education, and teaching highlight the educational context in a particular area, including challenges and efforts to improve literacy and numeracy. This map reveals how factors such as social status, teaching methods, and geographical conditions are intertwined in shaping educational outcomes, providing important insights for data-driven policy formulation and more targeted educational interventions.

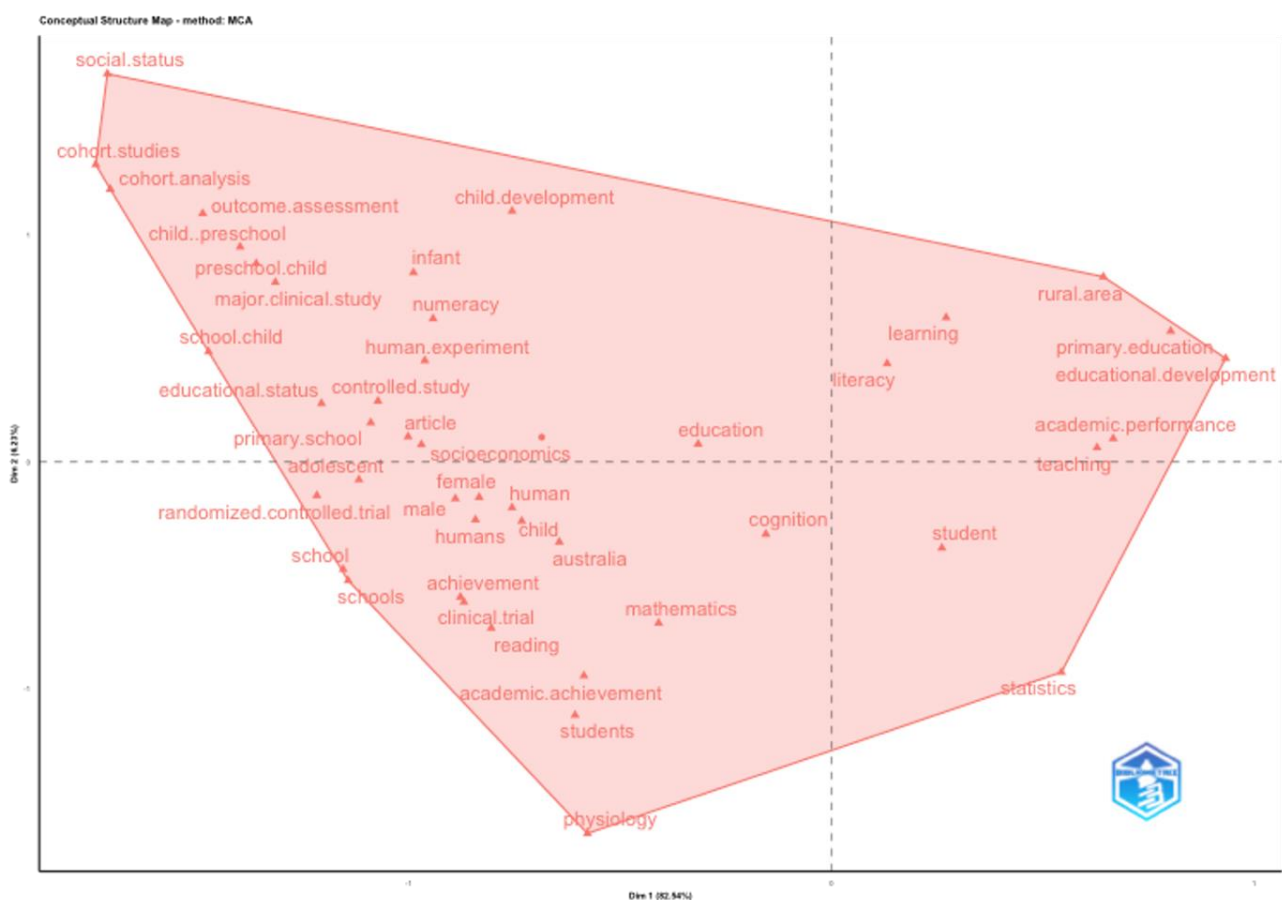


Figure 5. Conceptual Structure Map With MCA Method on Authors' Keywords

Thematic analysis can reveal the interconnection of a unit, such as author keywords, plus keywords, abstracts, or titles, to find themes mapped using density and centrality parameters (Agbo et al., 2021). Depending on the degree of correlation between topics (centrality) and cohesiveness between nodes (density), themes in their groups are mapped along four quadrants. The quadrant in the top right (Q1) represents the theme of the bike; the bottom right (Q2) represents the basic theme; the top left (Q3) represents the niche theme; and the bottom left (Q4) represents the theme that appears or decreases.

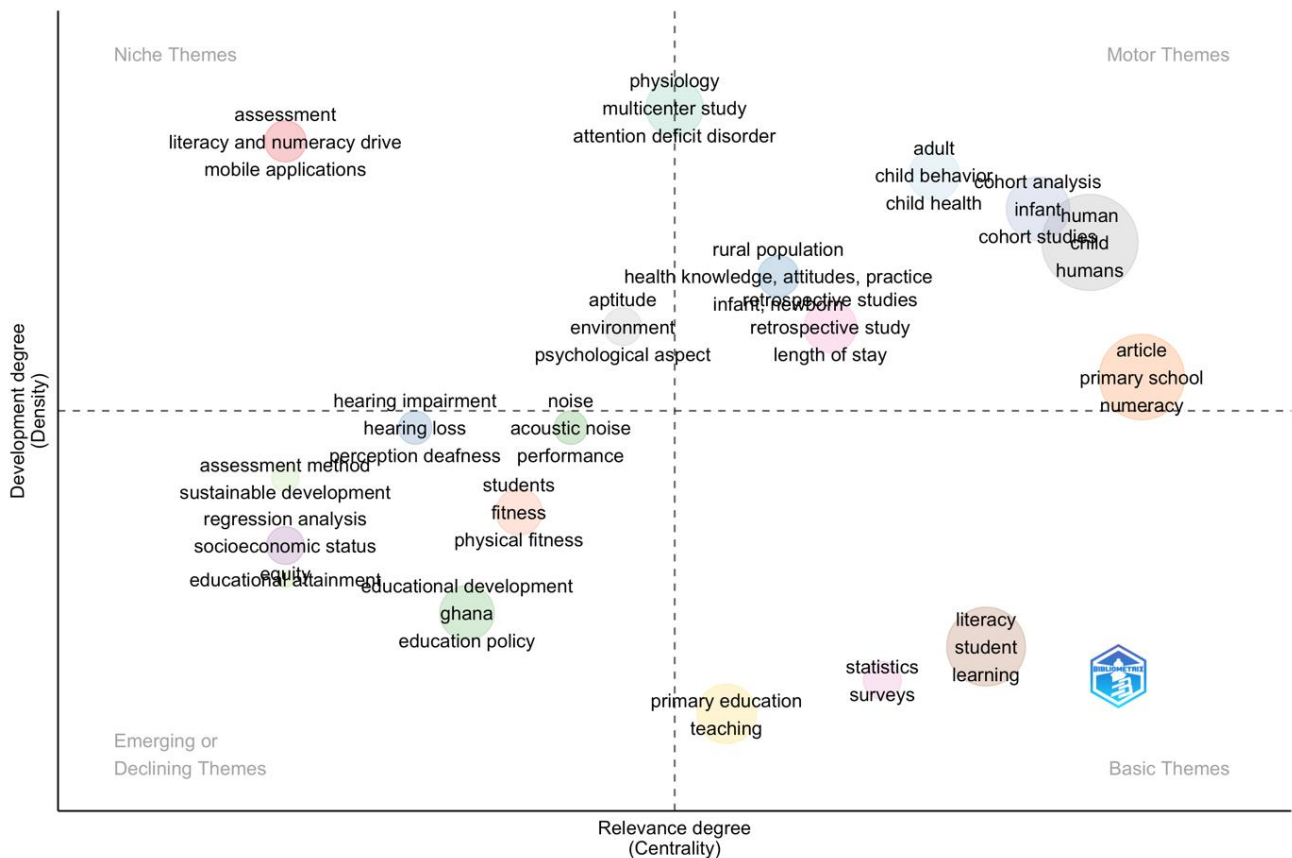


Figure 6. Thematic Map on Authors' Keywords

Based on the analysis of the images and the theme of your research on numeracy literacy, here are the connections:

1. Literacy and Numeracy Position

- a. On the "Niche Themes" Quadrant: Numeracy literacy has developed enough in certain contexts, but its relevance to other themes is still limited. This means your research has great potential to bridge this gap, by linking numeracy literacy to other broader themes, such as:
- b. Teaching and Primary Education (quadrant "Basic Themes"): Numeracy literacy can be an important part of the teaching approach or elementary school curriculum.
- c. Cohort Studies and Child Behavior (quadrant "Motor Themes "): You can explore how numeracy literacy affects children's behavior or development in long-term studies.

2. Research Opportunities to Increase Relevance

The numeracy literacy theme can be expanded by:

- a. Technology integration: Mobile application themes (in the Niche Themes quadrant) can be linked to research on the effectiveness of digital applications in improving numeracy literacy.
- b. Data-based approach: Using statistics or surveys (Basic Themes quadrant) to analyze the impact of numeracy literacy on student learning outcomes.
- c. Educational policy perspective: Linking numeracy literacy research with the theme of educational policy or sustainable development (Emerging/Declining Themes quadrant).

3. Strategies to Maximize the Impact of Your Research

- a. Focus on Practical Applications: Your research can explore the application of numeracy literacy in elementary schools (primary school themes and numeracy in the Basic Themes quadrant).
- b. Improving Interthematic Relationships: Combine numeracy literacy with student learning and child health (in the Motor Themes quadrant) to demonstrate a broader impact.
- c. Build Relevant Themes: If possible, relate numeracy literacy to global issues such as equity or socioeconomic status.

With this strategy, your research not only strengthens the position of numeracy literacy as a niche theme but also increases its relevance in education, making it more suitable for publication in highly reputable journals such as JME.

Intellectual Structure

The intellectual relationship between the author, the source (journal), and the work (article) is shown as the intellectual structure of the field. It is revealed through co-citation analysis (Aria & Cuccurullo, 2017). This is based on the principle that a common theme will be shared by two documents cited together in the next article (Sharma et al., 2021). The node size reflects the number of citations received by the reference, while the intensity of the line between the nodes indicates the strength of the link between the two references.

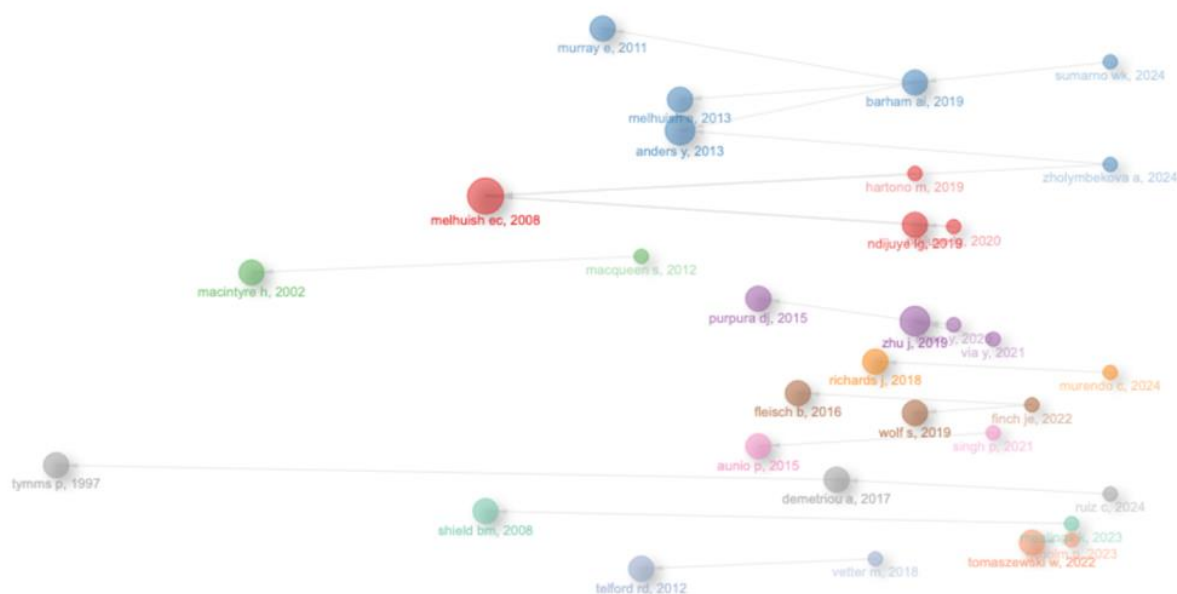


Figure 7. Co-Citation Network of Papers (References)

The visualization analysis of the citation network on the collection of articles studied resulted in a pattern of literature linkages that form several thematic clusters in Figure 6. Each node in the network represents one article, while the connecting line between the nodes indicates a citation relationship between those articles. The results of the analysis show that the *Melhuish EC (2008)* Siraj-Blatchford et al. (2008). It acts as a hub for the network, with strong connections to various other articles, both earlier and newer. This article is an important reference point in research that focuses on the influence of early childhood education on children's long-term development. Melhuish (2008) states that *"high quality early childhood education has significant long-term effects on cognitive and social outcomes"*. These findings made his publication a strong foundation for many future studies.

Blue-colored clusters that include articles by Karoly et al. (2013), Constrained et al. (2019), and Murray et al. (2015). It seems to focus on longitudinal and comparative aspects of the cross-border early childhood education system. For example, Constrained et al. (2019) menegaskan bahwa *"variations in early childhood education quality contribute significantly to children's academic trajectories"*. On the other hand, the purple cluster led by Purpura et al. (2011) and Zhu & Chiu (2019) focuses on developing early numeracy literacy. Zhu & Chiu (2019) state that *"early numerical competencies are critical predictors of later mathematical achievement, "reinforcing the importance of measuring numeracy skills from an early age.*

Meanwhile, Richards J's 2018 article on orange clusters contributed to data-driven studies and interventions on numeracy literacy gaps. Richards writes that *"data-driven instruction plays a pivotal role in closing early learning gaps."* This article shows a shift towards an evidence-based approach in learning design. Some recent articles, such as Sumarno WK, 2024, and Murnedo C, 2024, have not yet established many connections in the network, but show the current research direction that integrates technology and artificial intelligence in the context of basic education. The articles by Macintyre H (2002) and Tymms P (1997) appear more isolated, yet they still serve as an initial theoretical reference. For example, Tymms et al. (1997) emphasize the importance of longitudinal evaluation by stating that *"long-term tracking of students offers insights beyond what short-term gains can reveal."*

Overall, the results of this analysis show that the Melhuish EC (2008) article significantly influences the direction of further research. The network also illustrates the emergence of new trends and the integration of cross-disciplinary approaches in developing early childhood literacy and numeracy.

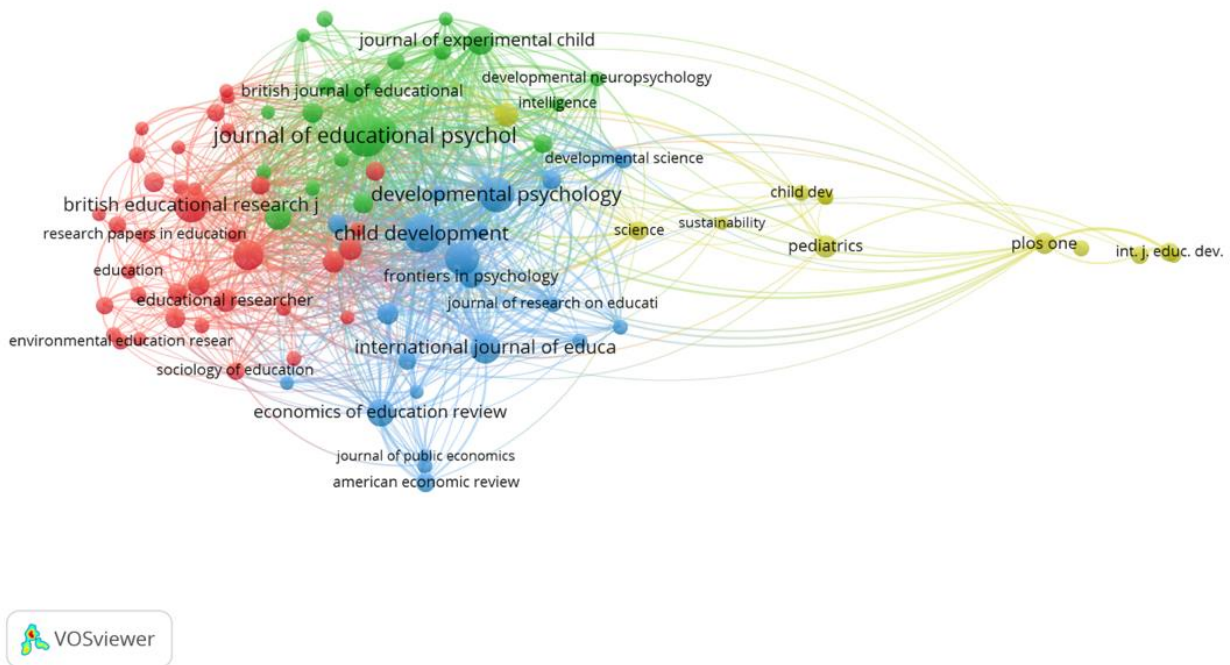


Figure 8. Co-Citation Network of Sources (Journals)

Similarly, the visualization of the analysis of the joint citation (journal) source is shown in Figure 7. Results of a bibliometric network visualization using VOSviewer, illustrating the citation relationships among academic journals that contribute to research on child development and education. The visualization maps the strength of bibliographic coupling and clusters journals based on their thematic and citation linkages.

Several distinct clusters are identified by color:

1. The red cluster is dominated by education-focused journals such as *British Educational Research Journal*, *Educational Researcher*, and *Research Papers in Education*, indicating a concentration on educational research and policy.
2. The green cluster includes educational and developmental psychology journals, such as the *Journal of Educational Psychology* and the *Journal of Experimental Child Psychology*. This cluster highlights the role of developmental psychology in early childhood learning.
3. The blue cluster features multidisciplinary journals like *Developmental Psychology*, *Child Development*, and *Frontiers in Psychology*, reflecting the intersection of various disciplines in studying child development.
4. The yellow cluster, positioned somewhat separately, consists of journals such as *PLOS ONE*, *Pediatrics*, and the *International Journal of Educational Development*. This cluster appears to bridge child health, science, and global development topics.

The *Journal of Educational Psychology* is a key node at the center of the visualization, connecting the psychological, educational, and developmental research domains. This network map illustrates that early childhood development and education research is inherently interdisciplinary, involving collaborations across education, psychology, health, and public policy.

Social Structure

The analysis of social structure (co-author) reveals collaboration between countries, institutions, and authors.

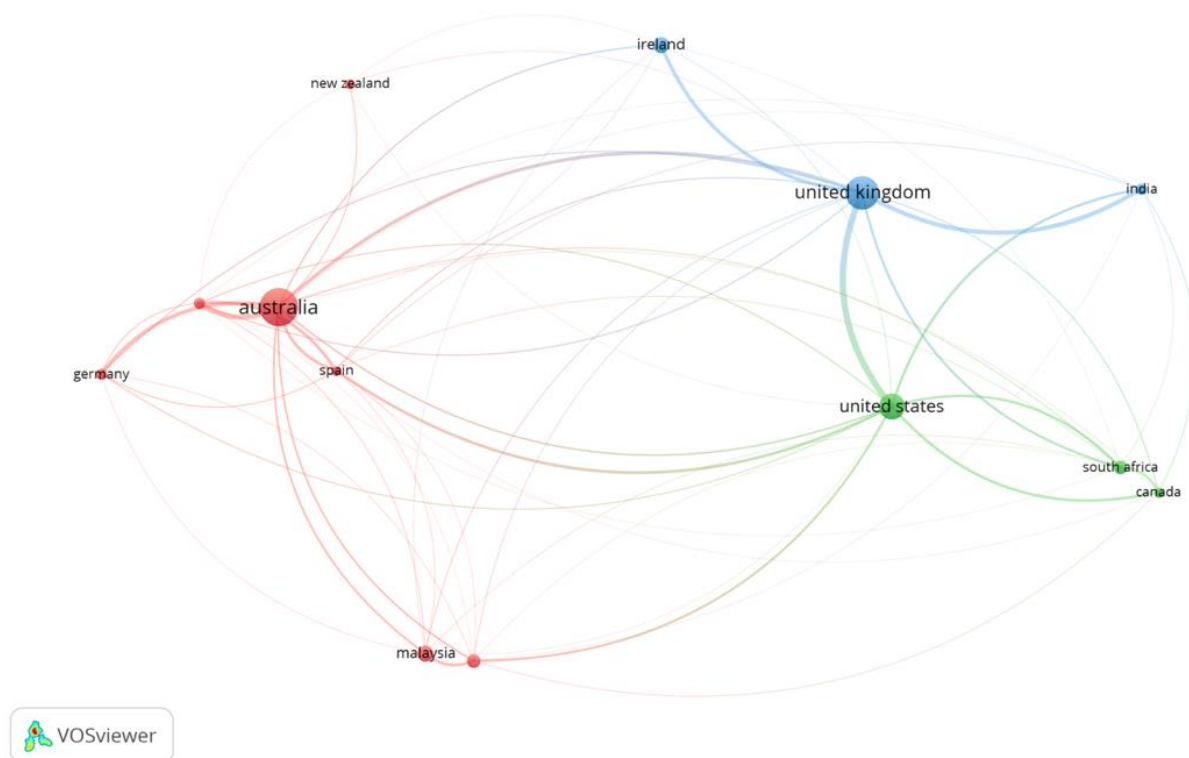


Figure 9. Country Collaboration Network

Figure 8 illustrates the international collaboration network of scholarly publications in early childhood education and development, visualized using VOSviewer. Each node represents a country,

while the lines connecting them indicate co-authorship or collaborative research links. The thickness of the lines reflects the strength and frequency of the collaboration.

The visualization reveals three major clusters: The red cluster, centered on *Australia*, includes strong connections with *Malaysia*, *Spain*, *Germany*, and *New Zealand*. Australia is a central hub in this network, indicating its prominent role in regional and international research collaborations. The blue cluster is led by the *United Kingdom*, which is closely linked with *Ireland* and *India*. This cluster reflects the strong academic ties rooted in historical, linguistic, and institutional connections. The United States dominates the green cluster, showing strong collaborative ties with *Canada* and *South Africa*. The United States appears to be a major global player in this research field, with links extending across multiple regions.

Overall, the map demonstrates that international collaboration in early childhood education research is extensive and often follows patterns of geographical proximity, linguistic similarity, and shared research priorities. Countries such as Australia, the United States, and the United Kingdom act as key nodes, bridging multiple regions and fostering global scholarly exchange.



Figure 10. Collaboration Network of Universitas

Finally, Figure 9 illustrates collaboration between institutions. The visualization of this university's collaborative network shows four academic entities or research institutions, namely the Faculty of Education, Monash University (green), the Faculty of Information Science (yellow), Effective Intervention, London (red), and the Paediatric Intensive Care Unit (blue). Each entity forms a distinct cluster, indicating no direct relationship between them in the analyzed dataset. The absence of a connecting line between nodes indicates that their research or publication fields are separate, or there is no significant cooperation between them.

Nevertheless, there is potential for collaboration to be developed. For example, the Faculty of Education, Monash University, can collaborate with the Paediatric Intensive Care Unit in developing educational programs for medical personnel or parents about pediatric intensive care. In addition, the Faculty of Information Science can collaborate with the Faculty of Education in developing a technology-based digital learning platform. Meanwhile, Effective Intervention, London, can establish partnerships with educational and health institutions to test the effectiveness of evidence-based intervention strategies in various areas. This visualization shows that the four institutions have different research areas and are not yet directly connected.

5. Discussion

The bibliometric analysis conducted in this study reveals a significant growth in publications on numeracy literacy in primary education over the past decade, confirming the increasing scholarly and policy attention toward foundational skills. This finding is consistent with prior studies (Aunio & Niemivirta, 2010; OECD, 2022) that highlight numeracy and literacy as predictors of long-term academic achievement. The upward publication trend observed here aligns with the global commitment to Sustainable Development Goal 4, which emphasizes quality education for all (UNESCO, 2021).

A comparative view with earlier bibliometric works (Ho et al., 2023a; Donthu et al., 2021) shows that while previous research predominantly examined literacy and numeracy as separate domains, the present study positions them at the intersection, focusing on innovations in numeracy literacy within the primary education context. This integrated focus expands upon Purpura et al. (2011), who underscored the predictive value of early literacy for numeracy development by revealing thematic trends such as gamification, AI-based personalized learning, and equity-focused interventions.

In terms of geographical distribution, the dominance of Australia, the United Kingdom, and the United States as leading contributors parallels findings from other bibliometric studies in education (Sugimoto et al., 2017). However, this study adds value by identifying Indonesia among the top five contributing countries, suggesting an emerging role in the global numeracy literacy research landscape. The relatively low percentage of international co-authorships (19.42%) indicates that, despite global interest, institutional collaborations remain underdeveloped—an observation also noted by Ahmad et al. (2021) in a broader bibliometric context.

The conceptual structure analysis confirms the centrality of keywords such as "numeracy," "literacy," and "primary education," which correspond to foundational themes found in prior research. Yet, identifying niche but under-connected themes—such as mobile learning applications and socio-economic equity—suggests untapped opportunities for cross-disciplinary integration. These results resonate with Lu et al. (2023), who demonstrated the potential of AI-driven tools to improve numeracy outcomes in underserved communities, reinforcing the practical implications of integrating technology into literacy programs.

From an intellectual structure perspective, the persistent influence of works by Melhuish et al. (2008) and Purpura et al. (2011) underscores the enduring relevance of early childhood education and early skill measurement in shaping subsequent research. Nonetheless, the emergence of newer, technology-focused studies indicates a gradual thematic shift toward innovation-driven strategies, supporting calls for more adaptive and inclusive pedagogical frameworks (Kim & Kwon, 2023a).

Overall, this study contributes to the academic dialogue by offering a consolidated view of how numeracy literacy research is evolving, where thematic gaps remain, and how global collaboration patterns shape knowledge production. The findings emphasize the need for stronger cross-sectoral partnerships—particularly between education, technology, and policy stakeholders—to address innovation and equity challenges. By situating numeracy literacy innovations within broader educational and socio-economic contexts, this research provides actionable insights for designing interventions that are both evidence-based and context-sensitive.

6. Conclusion

This study provides a comprehensive bibliometric analysis of research on numeracy literacy in primary education from 2013 to 2023. Integrating literacy and numeracy within the same analytical framework contributes to the literature by revealing dominant research themes, emerging innovation-driven topics, and patterns of global collaboration. The findings highlight the prominence of countries such as Australia, the United Kingdom, and the United States, while also recognizing

Indonesia as an emerging contributor to the field. The thematic analysis underscores both well-established foundations in numeracy education and the growing role of technological innovations such as gamification and AI-assisted learning.

Despite these contributions, the study has certain limitations. The dataset is restricted to English-language journal articles indexed in Scopus, which may exclude relevant studies in other languages or databases. Additionally, the reliance on bibliometric tools limits the depth of qualitative interpretation of the content of individual studies.

The practical implications of this research are threefold. First, educators can draw upon the identified themes to design instructional strategies that balance foundational skills with technology-enhanced learning. Second, policymakers may use the collaboration patterns identified here to foster greater cross-institutional and international partnerships, particularly in regions with lower research output. Third, researchers are encouraged to explore underdeveloped themes such as equity in digital access and the application of AI tools in numeracy instruction. Together, these actions can help bridge gaps in research, practice, and policy, ultimately advancing equitable and innovative numeracy literacy education in primary schools.

7. Recommendations

Based on the findings and analysis, several recommendations can be made. First, international and institutional collaboration should be strengthened through targeted funding schemes, policy incentives, and collaborative platforms that enable researchers from different regions to work together effectively. Second, the digital divide in primary education must be addressed by investing in ICT infrastructure, ensuring equitable access to digital devices in underserved areas, and providing continuous professional development for teachers in digital pedagogy. Third, emerging themes such as gamification, AI-assisted learning, and equity-focused interventions should be further integrated into practice, with instructional materials to balance foundational skills and innovative approaches. Finally, the scope of future research should be expanded by including non-English publications and data from other academic databases and combining bibliometric mapping with qualitative content analysis to provide a more comprehensive understanding of thematic developments in numeracy literacy research.

8. Limitations

This study has several limitations that should be acknowledged. First, the dataset is limited to journal articles indexed in the Scopus database and written in English, which may exclude relevant studies published in other languages or indexed in different databases. Second, bibliometric analysis relies heavily on the accuracy and completeness of database indexing, meaning that missing or misclassified records could affect the results. Third, while bibliometric tools effectively identify trends, networks, and thematic structures, they do not capture the nuanced qualitative aspects of individual studies, which may require in-depth content analysis. Finally, the temporal scope of the analysis (2013–2023) provides a decade-long overview, but trends emerging outside this range are not captured. These limitations should be considered when interpreting the findings, and future research could address them by broadening the dataset, incorporating multiple bibliometric databases, and combining quantitative mapping with qualitative synthesis.

Declarations

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