Bridging the gap across global research on numeracy assessment in the digital era: Toward the development of diagnostic assessment

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Abstract. This research analyzed global research trends on numeracy assessment in the digital era to identify future directions for diagnostic assessment development. Numeracy is recognized as a key twenty-first century competency that supports problem-solving and lifelong learning; however, existing assessments predominantly focus on summative and formative purposes rather than diagnostic functions. To address this gap, a bibliometric analysis was conducted using 246 publications indexed in the Scopus database between 2020 and 2025. Data were processed using Biblioshiny and VOSviewer to examine publication trends, influential authors, institutions, journals, and keyword co-occurrence networks. The results indicate a consistent growth in publication productivity, with an annual increase of 8.92%, accompanied by strong international collaboration across institutions in Asia, Europe, and the Americas. Thematic mapping revealed four major research clusters: student achievement and learning, education policy and systems, numeracy assessment and design, and home-based learning. These clusters reflect a shift toward contextualized, learner-centered, and technology-enhanced approaches to numeracy education. Overall, the findings highlight a substantial gap in diagnostic-oriented numeracy assessments. This study contributes a conceptual and empirical foundation for advancing adaptive, data-driven diagnostic assessment frameworks that are responsive to digital learning environments.

1 Introduction

Numeracy refers to a fundamental competency required to function effectively in real-life contexts that involve mathematical elements, and it is often used interchangeably with terms such as quantitative literacy and mathematical literacy [1]. The concept of numeracy, which involves the ability to understand and apply mathematical concepts in everyday situations, has become a fundamental competency that individuals are expected to possess, particularly within academic contexts.[2][1].

In practice, many students continue to encounter challenges in developing a deep understanding of numeracy concepts and in connecting these concepts with scientific knowledge. Such difficulties often lead to low learning motivation and hinder the development of higher-order thinking skills, including analysis and evaluation [3]. Conversely, longitudinal studies indicate that children who acquire strong numeracy competencies tend to retain and even enhance these abilities into adulthood, enabling them to demonstrate more sophisticated problem-solving skills, particularly in technology-oriented environments. Furthermore, numeracy has been shown to play a crucial role in fostering critical thinking across disciplines, and the implementation of formative assessment strategies has been found to significantly strengthen students' mathematical reasoning [4][5], [6][7].

In the 21st century, numeracy has been widely acknowledged as a core competency necessary for individuals to engage effectively in contemporary society. International assessment frameworks, including the Programme for International Student Assessment (PISA), highlight numeracy as a fundamental dimension of mathematical literacy and a crucial foundation for problem-solving [8], [9][9]. The capacity to interpret quantitative information, reason logically, and apply mathematical concepts in authentic contexts is essential for preparing students to become lifelong learners. With the rapid advancement of digital technologies and reshaping educational practices across the globe, the evaluation of students' numeracy proficiency has gained increasing importance—not only as a measure of academic performance but also as a means of understanding students' cognitive processes in solving problems within technology-enriched learning environments [10] [11].

Recent developments in digital technology have facilitated the emergence of innovative assessment practices, such as computer-based testing, online assessments, and data-driven learning analytics. These innovations have transformed the landscape of educational evaluation by supporting more flexible,

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adaptive, and personalized assessments [12][13]. Technological advancements, together with their diverse functionalities, have enabled the implementation of high-quality assessments and played a crucial role in strengthening educational evaluation practices [14]. Consequently, a growing body of research has examined numeracy assessment within digital learning environments, reflecting increasing interest in the integration of technology into mathematics education. However, despite the expanding literature on digital assessment, most prior studies have predominantly focused on summative and formative assessments aimed at measuring students' performance, rather than offering diagnostic insights into students' conceptual understanding and misconceptions [15][16][17].

In numeracy learning, contextualization plays a crucial role, as numeracy requires the application of mathematical concepts across a variety of real-life situations. Accordingly, learning activities should integrate authentic contexts by providing students with meaningful problems derived from everyday situations, reading texts, or public information to strengthen their quantitative reasoning [18].

Although numeracy is recognized as a fundamental right for all students and a vital component of their academic development, its instruction remains challenging due to variations in learners' prior knowledge and engagement [19] [9].

This research emphasizes a continuing challenge in mathematics education: although digital innovations have expanded the accessibility and efficiency of assessment practices, they still fall short of adequately addressing the crucial need to identify learners' misconceptions and cognitive pathways. This limitation is significant, as the absence of diagnostic insight hinders educators from adapting instruction to individual learning needs and from fostering a deeper conceptual grasp of numeracy. Hence, exploring how contemporary research integrates diagnostic perspectives into numeracy assessment becomes vital for enhancing pedagogical practices and guiding evidence-based educational policymaking.

This imbalance indicates a significant gap in the current body of knowledge. While numerous international studies have examined the efficiency, validity, and accessibility of digital assessment tools, only a limited number have investigated their development from a diagnostic perspective. Furthermore, there is a lack of comprehensive mapping that outlines global research trends in numeracy assessment, particularly in terms of how the field has evolved, which areas remain insufficiently explored, and where future diagnostic innovations may emerge[20][21], [22] [22] [23] existing research also tends to treat assessment primarily as a tool for measuring learning outcomes rather than as a process for identifying students' conceptual errors and learning challenges [24]. Therefore, a systematic and data-driven overview of the global landscape of numeracy assessment research is essential to support the advancement of diagnostic assessment models in mathematics education.

Recognizing this gap in the existing body of knowledge, the present study aims to examine global research trends on numeracy assessment in the digital era and identify thematic directions that may inform the development of future diagnostic assessment models. Employing a bibliometric research mapping approach, this study analyzes publication trends, influential authors, contributing countries and institutions, sources of publication, keyword networks, and emerging thematic clusters. The insights derived from this analysis are expected to link current developments in numeracy and digital assessment with future research needs, thereby narrowing the existing research gap. Furthermore, this study provides a scholarly foundation for the development of diagnostic-oriented numeracy assessment tools aligned with international frameworks such as PISA.

This research contributes by presenting a systematic and globally oriented synthesis of research on numeracy assessment within the digital era. It maps the evolution of publication trends, identifies influential scholars, and highlights the key sources that have shaped the scholarly landscape of the field. Moreover, the study establishes a bibliometric groundwork for advancing diagnostic-focused approaches in numeracy education, thereby facilitating the development of assessment frameworks that reveal students' conceptual understanding and underlying learning processes. Accordingly, the study is guided by the following research questions:

RQ1: What are the primary bibliometric characteristics of global research on numeracy assessment in the digital era, including annual publication trends, leading authors, countries, institutions, publication sources, and the most highly cited documents?

RQ2: How do current research trends in numeracy assessment reveal existing gaps and future directions in the field?

Understanding the global landscape of numeracy assessment research is crucial for analyzing how the field has evolved and identifying areas where meaningful innovation is still required. By systematically mapping research trends and thematic developments, this study offers a comprehensive overview of current scholarly contributions while highlighting underexplored areas that warrant further investigation. Ultimately, the findings are expected to contribute to enhancing numeracy education and strengthening assessment frameworks that better capture students' learning processes and conceptual understanding.

2 Method

2.1 Database selection

This study utilized data retrieved from the Scopus database, which is widely recognized as one of the most reliable and comprehensive sources for bibliometric analysis. Scopus offers broad multidisciplinary coverage and consistent metadata quality, thereby ensuring analytical accuracy and reproducibility [25][26]. The search process employed Boolean

operators applied to the title, abstract, and keyword fields to identify relevant publications. The retrieved documents consisted of journal articles, conference papers, and review papers, which were exported in CSV format for further analysis using Biblioshiny and VOSviewer software [27] .

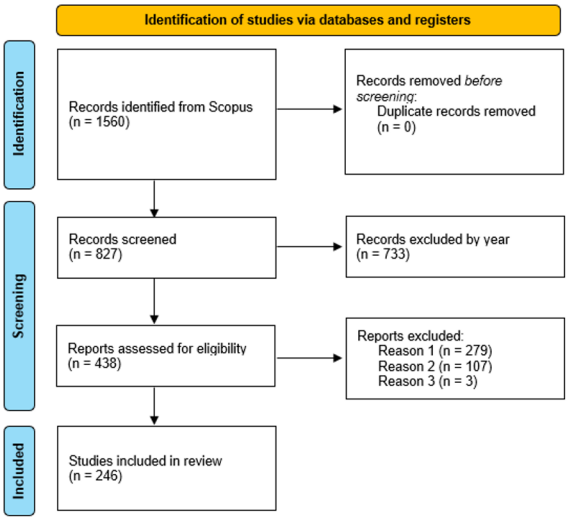

Fig. 1. PRISMA diagram of data collection and selection criteria [28].

2.2 Selection criteria

The criteria for selecting relevant documents were established carefully to ensure that the collected data were accurate and aligned with the objectives of this study. The data search was conducted in the Scopus database using the following Boolean search string applied to the TITLE-ABS-KEY field: ("numeracy" OR "numeracy skills") AND ("assessment*" OR "diagnostic assessment") AND ("digital" OR "learning" OR "technology"). This search query was systematically constructed to identify publications related to numeracy assessment in the digital era. The inclusion criteria consisted of: (a) publications from 2020 to 2025, (b) removal of duplicate records, (c) limitation to relevant subject areas, (d) document type restricted to journal articles, and (e) English-language publications. In addition, only open-access documents were included to ensure transparency and data verification. These criteria were applied to obtain a dataset that accurately represents current and relevant research on numeracy assessment in the context of digital transformation.

2.3 Data analysis

Data analysis in this study was carried out using two primary tools, namely RStudio and VOSviewer. RStudio was employed to conduct bibliometric analysis using the Bibliometrix package, which systematically processed bibliographic data, including annual publication trends, document types, sources of publication, and the distribution of authors and affiliations. The Biblioshiny interface was additionally utilized to generate interactive visualizations, enabling a clearer exploration of publication trends and collaboration networks in global research on numeracy assessment [26] [29].

VOSviewer, on the other hand, was used to examine research foci and relationships between keywords through co-occurrence analysis [30]. The visualizations generated by VOSviewer helped identify thematic clusters and emerging keywords, providing insight into the conceptual structure and evolutionary direction of research in numeracy assessment. The combined use of RStudio and VOSviewer offered a comprehensive, transparent, and replicable analytical framework that enabled an in-depth understanding of the development of numeracy assessment and diagnostic innovation in the digital era.

3 Results and discussion

3.1 Main information

The analysis of main information provides an overview of the characteristics of the documents included in this study, encompassing publication distribution, sources, contributing authors, and levels of collaboration and citation [31]. Based on the bibliometric results (Figure 2), a total of 246 documents were published between 2020 and 2025 across 133 sources. The annual growth rate of 8.92% indicates a consistent increase in scholarly interest in this topic. A total of 1,062 authors contributed to these publications, of which only 18 were single-authored documents. The average of 4.79 authors per publication suggests a strong tendency toward collaborative research, while the international collaboration rate of 33.74% reflects the presence of active cross-country research networks. Additionally, 859 author keywords were identified, demonstrating diversity in research focus and methodological approaches. A total of 2,170 references were cited, with an average document age of 2.18 years, indicating that most studies draw upon relatively recent literature. Furthermore, the average of 6.83 citations per document signifies a moderate but meaningful level of scholarly impact within the academic community. Overall, these findings suggest that research on numeracy assessment continues to develop dynamically and exhibits strong relevance to current educational discourse.

Fig. 2. Main information.

3.2 Growth Patterns

The analysis of publication trends was conducted to observe the development of research interest over time in the topic under investigation. Identifying such patterns is essential to understanding the progression and dynamics of scholarly attention within the field [32][31]. Based on figure 3, the publication data from 2020 to 2025 reveal a consistent upward trend. In 2020, a total of 30 documents were published, followed by a slight increase to 31 publications in 2021. A notable rise occurred in 2022 with 36 publications, marking the beginning of a growing research focus on this topic. The period of 2023–2024 represents the peak years in publication productivity, with 51 and 52 documents, respectively—the highest output recorded within the analyzed timeframe. Although the data for 2025 do not yet represent a full year, the 46 publications recorded thus far indicate that scholarly interest in numeracy assessment within the digital context remains strong and stable.

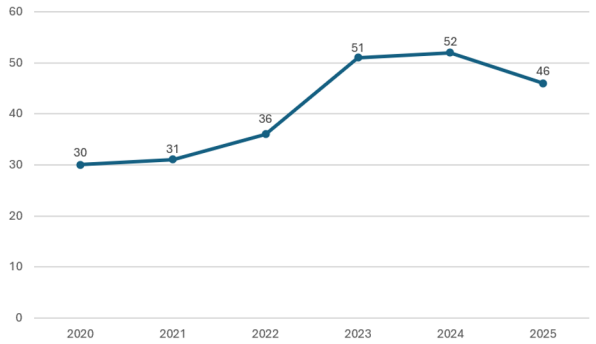

Fig. 3. Annual scientific production.

3.3 Most Global Cited Document

Based on the results presented in Table 1, the articles with the highest citation counts can be grouped into two dominant thematic areas: (1) the impact of the COVID-19 pandemic on basic learning and numeracy, and (2) digital transformation and new literacies in education. Most of the highly cited studies—such as Estimation of Learning Loss, PISA-like Task Design, and Complementary Basic Education in Ghana—emphasize the decline in foundational learning skills caused by prolonged school closures. This thematic cluster contributes to a deeper understanding of learning loss, learning poverty, and various strategies for educational recovery. The Normalized TC values of these articles indicate that research on learning recovery and diagnostic assessment has attracted significant attention across different countries. The second theme, Digital Transformation and New Literacies in Education, is represented by studies such as Higher Education Students' Perceptions of ChatGPT, which marks the emergence of a new research focus on the integration of artificial intelligence (AI) in learning and assessment. With the highest Normalized TC (31.19), this study highlights that technology-based literacy and numeracy have become rapidly expanding research frontiers in the post-pandemic era.

Table 1. Top 10 global cited document.

Paper	TC	TC per Year	NTC
Estimation of the fundamental learning loss and learning poverty related to COVID-19 pandemic in Mexico	90	22.50	9.36
Numeracy, adult education, and vulnerable adults: a critical view of a neglected field	76	12.67	5.47
Potential effects of COVID-19 school closures on foundational skills and Country responses for mitigating learning loss	49	9.80	3.59
Youth well-being predicts later academic success	47	11.75	4.89
Designing PISA-like mathematics task using a COVID-19 context (Pisacomat)	47	9.40	3.44
Practice makes perfect: Practice engagement theory and the development of adult literacy and numeracy proficiency	41	6.83	2.95
Higher education students' perceptions of ChatGPT: A global study of early reactions	40	40.00	31.19
Welcome to the era of vague news: a study of the demands of statistical and mathematical products in the COVID-19 pandemic media	40	10.00	4.16
Using educational transitions to estimate learning loss due to COVID-19 school closures: The case of Complementary Basic Education in Ghana	40	8.00	2.93
Short-term effects of a classroom-based STEAM program using robotic kits on children in South Korea	38	12.67	5.84

*TC: Total citations
*NTC: Normalized total citations

In addition, studies focusing on adult numeracy and practice engagement theory underscore the relevance of lifelong learning approaches and the connection between numeracy skills and social well-being. This broader perspective extends the scope of numeracy research from the school setting to community and workforce contexts. Overall, these patterns reflect a paradigm shift from viewing numeracy solely as a cognitive skill toward understanding it as a multidimensional construct shaped by social, technological, and global educational policies.

3.4 Most productive affiliation

Based on the analysis results in Table 2, Nanyang Technological University emerged as the most productive institution with 23 publications, followed by Sriwijaya University (22 publications), Semarang State University (21), and Jakarta State University (20). The involvement of internationally recognized institutions such as the University of Cambridge (16 publications), along with other contributors including Padang State

University, the University of Cape Town, Queensland University of Technology, Malang State University, and Universiti Teknologi MARA (each contributing between 10 and 11 publications), reflects the global reach of research in this field. The strong representation of Asian institutions, particularly from Indonesia, highlights the growing role of universities in this region in advancing research on numeracy and digital assessment. This trend also suggests increasing regional engagement in international collaboration and knowledge production.

Table 2. Top 10 productive afflitiation.

Affiliation	Articles
Nanyang Technological University	23
Universitas Sriwijaya	22
Universitas Negeri Semarang	21
Universitas Negeri Jakarta	20
University Of Cambridge	16
Universitas Negeri Padang	11
University Of Cape Town	11
Queensland University of Technology	10
Universitas Negeri Malang	10
Universiti Teknologi Mara	10

3.5 Most productive source

Based on the analysis results presented in Table 3, *Frontiers in Education* (Q2, Switzerland) is the most productive journal, publishing 11 articles related to the topic. This is followed by the *International Journal of Educational Development* (Q1, United Kingdom) and *PLoS One* (Q1, United States), each with 10 publications. Other notable sources that made substantial contributions include *Early Childhood Research Quarterly* and *Social Sciences and Humanities Open*, each with 7 articles, as well as the *Journal on Mathematics Education* (Q3, Indonesia) with 6 articles. The dominance of publications in Q1 and Q2 journals indicates that studies in this field are widely disseminated through reputable academic outlets, with strong contributions from Europe, the Americas, and Asia.

3.6 Most productive researcher

Based on the analysis results presented in Table 4, two researchers from Sriwijaya University, R. I. I. Putri and Zulkardi, were identified as the most productive authors, each contributing six publications. This finding underscores Indonesia's notable role in advancing research in numeracy and mathematics education. Other leading contributors include Pirjo Aunio from Finland with five publications, followed by Mellony Holm Graven (South Africa), Steven J. Howard (Australia), David J. Purpura (United States), and Pauline M. Rose (United Kingdom), each with four publications. Additionally, researchers such as Adi Nur Cahyono, Aidan Clerkin, and Iddo Gal contributed three publications each, further enriching global scholarly output in this field. Overall, the participation of authors from diverse geographical regions reflects strong international collaboration and growing global interest in numeracy assessment research.

Table 3. Top 10 productive sources.

Sources	SQ	Country	Articles
Frontiers in Education	Q2	Switzerland	11
International Journal of Educational Development	Q1	United Kingdom	10
PLos One	Q1	United States	10
Early Childhood Research Quarterly	Q1	United Kingdom	7
Social Sciences and Humanities Open	Q1	United Kingdom	7
Journal on Mathematics Education	Q3	Indonesia	6
Economics of Education Review	Q1	United Kingdom	5
International Review of Education	Q2	Netherlands	5
Journal of Numerical Cognition	Q1	Germany	5
South African Journal of Childhood Education	Q3	South Africa	5

Table 4. Top 10 productive researcher.

Authors	Affiliation	Country	Articles	AF
Putri, R. I.I.	Universitas Sriwijaya	Indonesia	6	1.56
Zulkardi, Zulkardi	Universitas Sriwijaya	Indonesia	6	1.56
Aunio, Pirjo	Helsingin Yliopisto	Finland	5	0.94
Graven, Mellony Holm	Rhodes University	South Africa	4	1.83
Howard, Steven J.	University of Wollongong	Australia	4	0.56
Purpura, David J.	College of Health and Human Sciences	United States	4	0.87
Rose, Pauline M.	University of Cambridge	United Kingdom	4	0.87
Cahyono, Adi Nur	Universitas Negeri Semarang	Indonesia	3	0.73
Clerkin, Aidan	Dublin City University	Ireland	3	0.73
Gal, Iddo	University of Haifa	Israel	3	1.08

*AF: Articles Fractionalized

3.7 Focus research

Figure 4 illustrates the keyword co-occurrence network constructed using VOSviewer, revealing the semantic relationships among recurring terms in numeracy assessment studies. The color differentiation identifies

thematic clusters that organize the intellectual structure of the field.

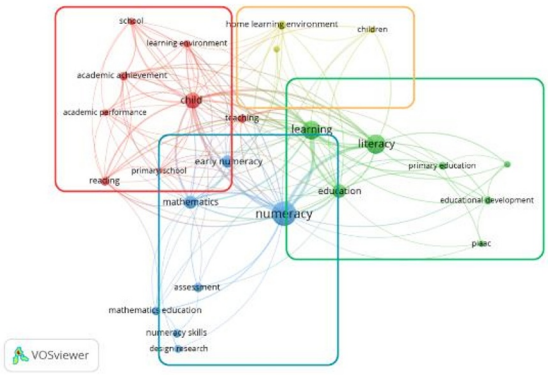

Fig 4. Visualization of co-occurance keywords.

Based on the figure 4 obtained from the VoSviewer analysis, four clusters were identified, as shown in the following Table 5:

Table 5. Cluster classification based on color-coded grouping.

Keywords	Color name	Group name
Academic achievement, Academic performance, Child, Learning environment, Primary school, Reading, School, Teaching	Red	Student Achievement and Learning
Education, Education policy, Education development, Learning, Literacy, Piaac, Primary education	Green	Education Policy and System
Assessment, design research, early numeracy, mathematics, mathematics education, numeracy, numeracy skills	Blue	Numeracy Assessment and Design
Children, home learning environment, home numeracy environment	Blue	Home-Based Learning

The red cluster, labeled "Student Achievement and Learning," reflects research focusing on student learning outcomes and classroom learning contexts. Keywords such as *academic achievement*, *learning environment*, and *teaching* indicate attention to instructional strategies, classroom conditions, and factors that influence learning performance, particularly at the primary school level. This cluster emphasizes the crucial role of teachers and school environments in supporting the development of students' numeracy competencies [1][33][34].

The green cluster, titled "Education Policy and System," encompasses studies related to educational policy frameworks and systemic influences on numeracy learning. The presence of keywords such as *education policy*, *education development*, and *PIAAC* suggests research concentration on international education policies, literacy standards, and how systemic structures shape the implementation of numeracy learning and assessment. This cluster highlights the significant influence of educational policy in directing instructional practices and improving numeracy outcomes at both national and international levels [35].

The blue cluster, labeled "Numeracy Assessment and Design," represents the core theme of this research field. This cluster includes keywords such *as assessment, design research, early numeracy, and mathematics education, which indicate a strong research emphasis on the development and refinement of diagnostic assessmen*t instruments. Studies in this cluster focus on designing assessment tools capable of identifying students' strengths and weaknesses in numeracy, particularly in the context of digital learning environments.

The yellow cluster, titled "Home-Based Learning," highlights the influence of the family environment on children's numeracy development. Keywords such as *children*, *home learning environment*, and *home numeracy environment* reflect the view that numeracy learning extends beyond formal schooling and is also shaped by everyday interactions at home. This cluster underscores the crucial role of parental involvement in fostering foundational numeracy skills from an early age [36].

The learning environment is therefore a crucial component in achieving learning objectives, as it shapes the teaching and learning process both inside and outside the classroom. The learning environment refers to the physical, social, and psychological contexts in which learning occurs. Within this environment, students not only acquire academic knowledge but also develop social competencies through interaction and engagement in meaningful learning experiences [37]

3.8 Keyword novelty

The results of the VOSviewer overlay visualization in Figure 5 reveal several yellow-highlighted areas that indicate emerging and increasingly popular keywords in recent studies, such as *academic achievement*, *academic performance*, *child*, *learning environment*, *school*, *teaching*, and *reading*. The presence of these keywords suggests a shift in numeracy research toward a broader understanding of contextual learning factors that influence students' numeracy outcomes, particularly at the elementary school level.

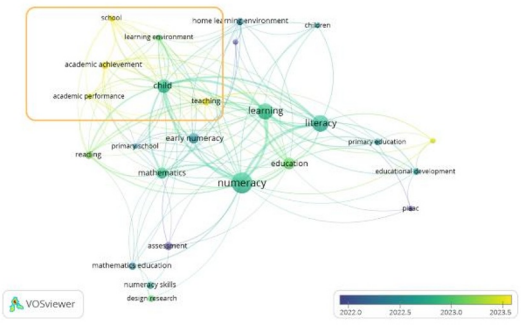

Fig. 5. Visualization of keywords novelty.

These findings indicate that current numeracy research is evolving beyond traditional assessments of mathematical ability and increasingly explores the

relationships among the learning environment, teaching practices, and students' academic achievement [38][39]. This shift reflects the growing recognition of numeracy as a multidimensional construct shaped by the interaction of social, pedagogical, and psychological factors. Consequently, this perspective opens new opportunities for the development of diagnostic numeracy assessments that not only evaluate cognitive skills but also incorporate affective dimensions, pedagogical support, and environmental influences on learning.

The causal relationship among these three components suggests that a supportive learning environment—both at school and at home—serves as a fundamental basis for the development of children's numeracy skills [40]. An environment that offers meaningful numeracy experiences, access to relevant learning resources, and a safe and engaging atmosphere can enhance students' motivation and cognitive readiness to learn mathematics [41]. Continuous and appropriately structured learning stimulation enables children to build stronger conceptual understanding of numbers and to engage in mathematical problem solving more effectively [42].

Furthermore, the teaching process plays a mediating role between the learning environment and students' academic achievement. Teachers who can adapt instructional strategies to students' characteristics and learning needs are better positioned to optimize numeracy learning outcomes [43] A diagnostic-oriented teaching approach enables early identification of learning gaps and conceptual misunderstandings, allowing for timely and targeted intervention [44]. Accurate assessment data enables teachers to implement remedial, or enrichment strategies tailored to students' individual learning profiles, thereby enhancing instructional effectiveness.

As a result of the dynamic interaction between the learning environment and the teaching process, children's academic achievement in numeracy develops cumulatively. When one of these components is weakened, such as an unsupportive learning environment or instructional practices that are not adaptive to students' numeracy development may be hindered. Therefore, a comprehensive understanding of the interrelationship among these three factors is crucial for designing diagnostic assessments that accurately capture students' learning profiles in numeracy.

In this perspective, diagnostic assessments in the digital era should not be viewed solely as tools for measuring learning outcomes but as instruments for identifying individual learning needs. When developed based on contextual understanding, diagnostic instruments enable teachers and researchers to identify the root causes of learning gaps in numeracy more precisely. They also provide a foundation for designing targeted, adaptive, and evidence-based learning interventions. Consequently, the research trajectory represented by this cluster offers a strategic contribution to advancing holistic diagnostic assessment models in numeracy that are responsive to the challenges of education in the digital age.

3.9 Comparison with other studies

This study is consistent with previous research [21] [22] and confirms a steady growth in publication output related to numeracy skill and assessment. As reflected in the annual scientific production, this trend illustrates that the enhancement of numeracy competencies, particularly within digital learning contexts, has become an increasingly prominent area of scholarly interest. The present study offers a broader perspective by revealing that diagnostic assessment approaches have received limited attention compared to earlier analyses. Unlike previous bibliometric reviews that primarily focused on technology integration and learning assessment, this research highlights the emergence of diagnostic-oriented approaches as a crucial research focus in the post-pandemic era. Moreover, the identification of research clusters, which include student achievement, educational policy, assessment design, and home-based learning, demonstrates the multidimensional expansion of numeracy research.

3.10 Implications and explanation of findings

The overall findings of this research present several important implications. The considerable increase in publication output and the expansion of international collaboration suggest that numeracy assessment has developed into a global and interdisciplinary area of study. The identification of emerging themes, including contextualized learning environments and technology-based assessment, indicates that researchers are progressively moving toward holistic frameworks that integrate learning processes, pedagogical approaches, and cognitive outcomes. This trend demonstrates that numeracy is no longer perceived merely as a technical competence but as a complex construct influenced by both environmental and affective factors.

At a practical level, the results emphasize the importance of incorporating diagnostic assessment principles within digital assessment frameworks. The frequent appearance of keywords associated with learning environments and teaching practices shows the potential of data-informed diagnostics to guide personalized feedback and support adaptive learning design. These findings offer meaningful directions for future studies aimed at developing assessment systems that go beyond measuring performance to reveal learning gaps and conceptual misconceptions.

3.11 Strengths and limitations

The primary strength of this research lies in its comprehensive bibliometric design, which employs data visualization tools such as Biblioshiny and VOSviewer to generate transparent, replicable, and multidimensional insights into global scholarship on numeracy assessment. The inclusion of recent publications covering the period from 2020 to 2025 enhances both the relevance and timeliness of the results, while the emphasis on diagnostic perspectives addresses a notable gap within the existing literature.

However, certain limitations should be recognized. This study is based exclusively on the Scopus database, which, despite its extensive coverage, may omit relevant works indexed in other databases, including the Web of Science and ERIC. Furthermore, the reliance on Scopus bibliometric data alone might not capture the full breadth of research on the topic. Future investigations could expand the dataset or adopt complementary analytical methods to strengthen contextual interpretation and provide a more holistic understanding of global trends in numeracy assessment research.

4 Conclusion

This study provides a comprehensive bibliometric overview of global research on numeracy assessment in the digital era. The findings reveal a steady increase in scholarly attention accompanied by robust international collaboration and substantial contributions from institutions across Asia, Europe, and the Americas. Current research trends demonstrate a growing emphasis on technology-enhanced and digital assessments; however, much of the existing literature continues to focus predominantly on summative and formative approaches rather than diagnostic purposes.

The mapping and keyword analyses highlight an emerging shift toward more contextualized and learner-centered perspectives, emphasizing how learning environments, teaching practices, and students' academic achievement interact to shape numeracy outcomes. These results point to a critical research gap—namely, the limited investigation into diagnostic-oriented assessment models capable of identifying students' conceptual understanding and learning difficulties.

By addressing this gap, the present study establishes both a conceptual and empirical foundation for the development of adaptive, data-informed, and diagnostically focused assessment frameworks in numeracy education. Beyond mapping the existing research landscape, this study provides strategic insights to guide future innovations toward more responsive, evidence-based, and equitable assessment practices that align with the evolving demands of digital-era learning.

This study contributes to a deeper understanding of the relationship between digital assessment and diagnostic approaches, emphasizing that numeracy should be examined through both cognitive and contextual lenses. Although the analysis is limited to data drawn from the Scopus database, the results nonetheless provide a clear global overview that can inform future investigations employing broader datasets or integrated analytical frameworks. Overall, the study underscores the importance of advancing research on diagnostic-oriented digital assessments to enhance the precision and adaptability of numeracy evaluation practices.

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