

Teacher's Pedagogical Literacy as a Foundation for Enhancing Students' Mathematical Literacy: A Systematic Literature Review and Bibliometric Analysis

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Article History:

Received: 12-01-2025

Revised: 15-02-2025

Accepted: 01-03-2025

Abstract:

This bibliometric review explores the significance of teachers' pedagogical literacy as a foundation for enhancing students' mathematical literacy. In recent years, the growing focus on improving mathematical skills has highlighted the critical role of teachers in shaping students' understanding and application of mathematical concepts. Teachers' pedagogical literacy, encompassing content knowledge and effective teaching strategies, is essential for creating an environment conducive to learning. This study analyzes academic publications to identify key trends, methodologies, and findings related to the relationship between teachers' pedagogical literacy and students' mathematical literacy. The results indicate that teachers with strong pedagogical knowledge are better equipped to design engaging, student-centered learning experiences promoting mathematical problem-solving skills. Furthermore, research suggests that ongoing professional development in pedagogical literacy contributes to more effective teaching practices, ultimately enhancing students' mathematical outcomes. This review highlights the growing need for teacher education programs to emphasize the integration of pedagogical literacy to improve students' mathematical literacy. The study also identifies future research directions, particularly in teacher training, curriculum development, and assessment strategies. By understanding the link between teachers' pedagogical literacy and students' mathematical performance, educators and policymakers can better address challenges in mathematics education and implement more effective strategies to enhance students' mathematical literacy.

Keywords: Teacher pedagogical literacy, mathematical literacy, teacher education, teaching strategies, professional development.

1. Introduction

The ability to effectively teach mathematical concepts in secondary education has become increasingly critical in the face of rapidly evolving global challenges [1]. Mathematical literacy equips students with the skills necessary for problem-solving, critical thinking, and decision-making in various contexts [2]. However, achieving high levels of mathematical literacy among students remains a persistent challenge, particularly in middle and high school education [3]. This issue underscores the importance of exploring pedagogical approaches that enhance the ability of teachers to facilitate meaningful learning experiences [4]. One such approach is the development of pedagogical literacy—an educator's ability to critically understand, evaluate, and implement effective teaching strategies tailored to their students' needs [5].

Pedagogical literacy is the theoretical foundation for designing and implementing instructional practices that promote student engagement and learning outcomes [6]. It encompasses a teacher's knowledge, beliefs, and practices related to teaching and learning [7]. In mathematics education, pedagogical literacy enables educators to create learning environments that address diverse student abilities while fostering mathematical understanding [8]. Despite its significance, the relationship between pedagogical literacy and enhancing students' mathematical literacy remains underexplored in the existing literature [9]. This gap highlights the need for a comprehensive review of this relationship's theoretical and practical underpinnings [8].

Bibliometric analysis has emerged as a powerful method for systematically examining the development of scholarly knowledge within a particular domain [10]. Tools such as VOSviewer allow researchers to visualize and analyze trends, relationships, and thematic patterns within large datasets of academic publications [11]. By employing bibliometric techniques, it is possible to identify key research areas, influential authors, and emerging topics in the field of education [12]. This study utilizes bibliometric analysis to investigate the intersection of pedagogical and mathematical literacy, providing insights into the evolution of research on this critical topic and offering directions for future inquiry [13].

This SLR and bibliometric review aims to explore the theoretical and empirical landscape of pedagogical literacy as a foundation for enhancing mathematical literacy in secondary education [14]. Using VOSviewer, the study seeks to map the trends, collaborations, and research hotspots that define this domain [15]. By synthesizing insights from existing literature, this article aims to highlight the role of pedagogical literacy in empowering teachers to develop effective instructional strategies that improve students' mathematical literacy [16]. The findings are expected to inform researchers and practitioners, contributing to the broader discourse on advancing educational quality in mathematics [17].

2. Methods

2.1. Study design

This study employed a systematic literature review (SLR) and bibliometric analysis to describe the role of teacher's pedagogical literacy in enhancing students' mathematical literacy and to reveal its bibliometric profile. In some references, this approach is also referred to as systematic literature network analysis (SLNA). Several researchers have utilized SLNA to uncover research trends by combining a systematic literature review with bibliographic analysis (BA). In this context, the SLR followed the PRISMA guideline, which outlines the systematic process of identification, source filtering, and screening. The process is illustrated in Figure 1, detailing the flow from initial identification of sources to the final inclusion of relevant studies. The bibliometric analysis further aimed to identify research patterns, trends, and metadata visualization, offering insights into the development of pedagogical literacy and its impact on mathematical literacy enhancement.

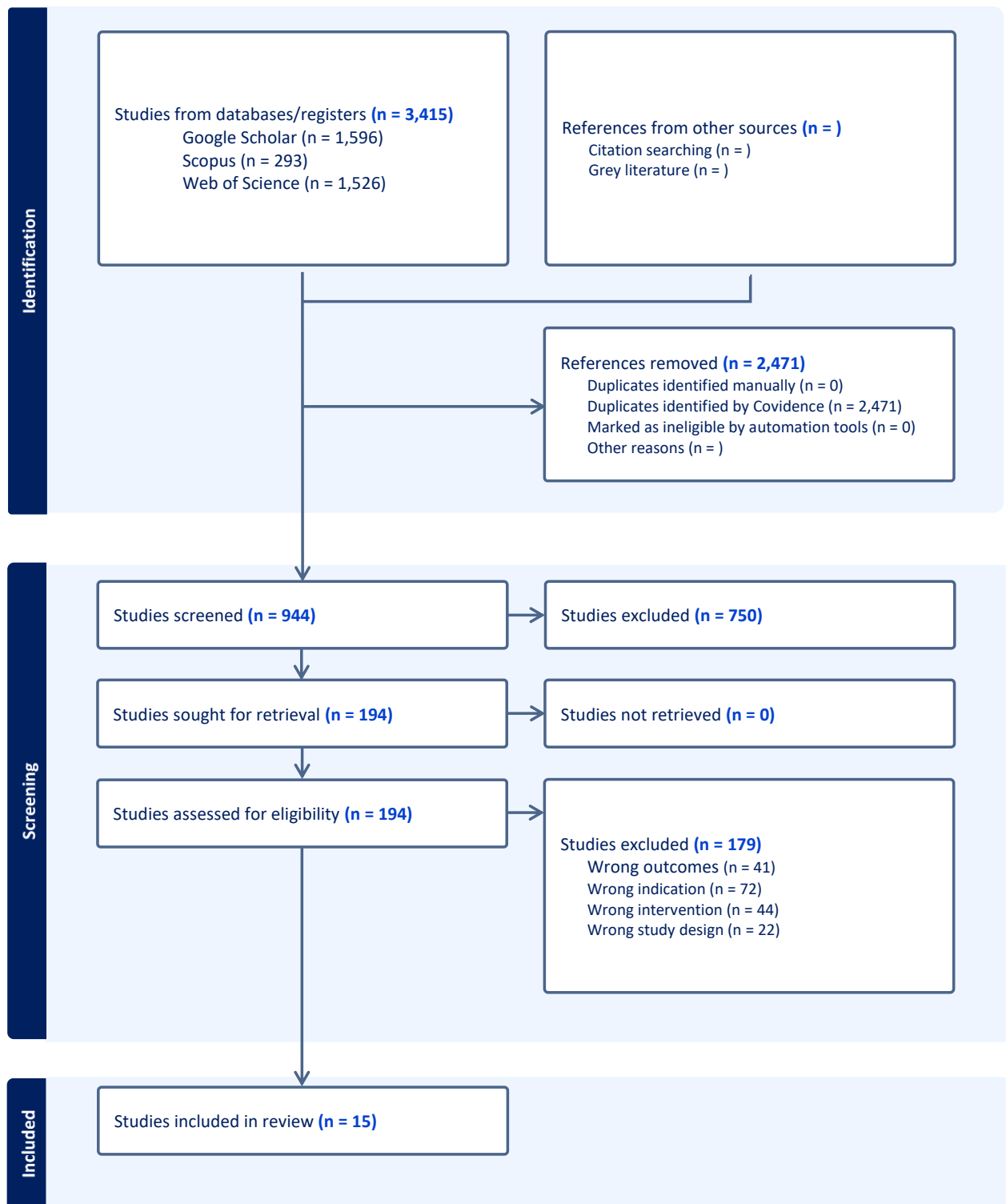


Figure 1. Diagram of the PRISMA. PRISMA, preferred reporting items for systematic reviews and meta-analyses.

2.2. Data search and identification

Initial keyword development for this study focused on constructing comprehensive search terms related to teacher's pedagogical literacy and its role in enhancing students' mathematical literacy. The keywords include terms such as "pedagogical literacy AND mathematical literacy AND teacher competencies," "teaching strategies AND mathematics learning AND student outcomes," and "teacher professional development AND mathematical problem-solving AND critical thinking." This systematic approach ensured a robust search strategy for identifying relevant studies. After compiling the search keywords and retrieving articles using databases such as Scopus, Google Scholar, and Web of Science, the collected literature was meticulously screened and analyzed. This process involved evaluating the influence of pedagogical literacy on students' mathematical literacy, focusing on key aspects such as problem-solving skills, critical thinking, mathematical reasoning, and student engagement.

Database searches included articles published between 2005 and 2025 to capture recent developments and significant contributions to the field. Initially, 3,415 articles were identified. The data cleaning and sorting process involved removing duplicates, assessing abstracts and titles for topic relevance, and applying predefined inclusion and exclusion criteria. Following rigorous screening, only high-quality studies directly addressing the role of pedagogical literacy in enhancing mathematical literacy were included. The final dataset underwent systematic review and bibliometric analysis to identify patterns, trends, and research gaps. Metadata visualization highlighted key themes, influential publications, and collaboration networks within the field. The findings provide valuable insights into the importance of teacher pedagogical literacy as a foundation for improving mathematical literacy and offer a robust basis for developing targeted educational strategies.

2.3. Data extraction

This study identified Scopus-indexed publications and journals related to the role of teacher's pedagogical literacy in enhancing students' mathematical literacy. The analysis was restricted to peer-reviewed articles, excluding letters, editorials, conference papers, and short communications. Initially, 194 articles were identified, of which the top 15 articles were selected. These top articles were then used as core materials for systematic literature review (SLR). Additionally, the entire dataset of 3,415 articles was employed for bibliometric analysis to identify broader research patterns and trends. The selection of the 15 best publications involved a meticulous review process conducted independently by researchers to ensure reliability and relevance. Divergent opinions during the review were resolved through consensus, guaranteeing the validity of the selected materials. This rigorous approach ensured that the articles used in the analysis were of high quality and aligned with the study's objectives. The findings provide valuable insights into the existing body of research, highlighting key contributions to the development of teacher pedagogical literacy and its impact on mathematical literacy enhancement.

2.4. Statistical analysis

In this study, the 15 best publications were selected to address teacher's pedagogical literacy and its role in enhancing students' mathematical literacy. These publications were analyzed based on topics, journals, institutions, key concepts, analysis methods, and future research directions [18]. The bibliometric analysis utilized bibliometric theory, which applies mathematical and statistical

approaches to analyze research across various fields, including education [19]. This study employed the VOSviewer application to perform bibliometric analysis. VOSviewer is a widely used program for building and visualizing bibliometric maps, focusing on creating detailed graphical representations [20]. Its features allow for intuitive exploration of large bibliometric datasets, including metadata visualization of co-authorship, co-citation, and the relevance of bibliographies [21]. The application facilitated a comprehensive visualization of research trends, collaboration networks, and key themes related to pedagogical literacy and mathematical literacy, providing a deeper understanding of the field's current state and future directions [22].

3. Results and Findings

Table 1. Presents the Citation Analysis of Journals with the Highest Number of Publications in International Publications Indexed by Google Scholar

No	Article	Author(s)	Journal	Citations
1	Teachers' mathematical knowledge, cognitive activation in the classroom, and student progress	[23]	American Educational Research Journal	3327
2	Professional Competence of Teachers: Effects on Instructional Quality and Student Development	[24]	Journal of Educational Psychology	2191
3	Teacher Collaboration in Instructional Teams and Student Achievement	[25]	American Educational Research Journal	1259
4	Pedagogical Language Knowledge: Preparing Mainstream Teachers for English Learners in the New Standards Era	[26]	Review of Research in Education	783
5	Learning for STEM Literacy: STEM Literacy for Learning	[27]	School Science and Mathematics	643
6	The Association between Adverse Childhood Experience (ACE) and School Success in Elementary School Children	[28]	Aces And Elementary School Success	598
7	Mathematics Learning and Participation as Racialized Forms of Experience: African American Parents Speak on the Struggle for Mathematics Literacy	[29]	Mathematical Thinking and Learning	465

8	STEM Education: A review of the contribution of the disciplines of science, technology, engineering and mathematics	[30]	Science Education International	399
9	The relationship between ICT and student literacy in mathematics, reading, and science across 44 countries: A multilevel analysis	[2]	Computers & Education	383
10	The Digital Learning Classroom: Improving English Language Learners' academic success in mathematics and reading using interactive whiteboard technology	[31]	Computers & Education	349
11	Closing the gaps e Improving literacy and mathematics by ict-enhanced collaboration	[32]	Computers & Education	338
12	The relationship between teachers mathematical content and pedagogical knowledge, teachers' perceptions, and student achievement	[1]	Journal for Research in Mathematics Education	330
13	Using realistic mathematics education and the DAPIC problem-solving process to enhance secondary school students' mathematical literacy	[3]	Kasetsart Journal of Social Sciences	302
14	Improving teaching and learning of basic maths and reading in Africa: Does teacher preparation count?	[5]	International Journal of Educational Development	291
15	Teachers' knowledge base for implementing response-to-intervention models in reading	[4]	Reading and Writing	265

The citation analysis reveals several key insights into the scholarly discourse surrounding pedagogical literacy and mathematical literacy. Table 1 showcases the most frequently cited articles in this domain, highlighting influential works and their contributions to the field. For instance, the article by [23], published in the American Educational Research Journal, leads with 3,327 citations, emphasizing teachers' mathematical knowledge and cognitive activation in student progress. Similarly, [24] focus

on professional competence and its impact on instructional quality and student development, further underlining the importance of teacher effectiveness.

Articles such as those by [25], [26] explore collaborative practices and pedagogical language knowledge, offering diverse perspectives on enhancing educational outcomes. Additionally, works by [2], [27] integrate STEM literacy and ICT's role in student achievement, reflecting the interdisciplinary nature of this research area. These highly cited publications guide current pedagogical practices and provide a foundation for future studies to build upon.

The analysis also underscores the diversity in research themes, ranging from STEM education [27], [30] to addressing equity in mathematics education [29]. Furthermore, studies such as those by [3], [28] delve into the socio-emotional and contextual aspects of learning, enriching the understanding of factors influencing mathematical literacy. The findings from this analysis highlight the dynamic and multifaceted nature of research in this field, emphasizing the critical need for continued exploration and innovation in pedagogical literacy to enhance mathematical literacy in diverse educational contexts.

3.1 Classification based on the publication year

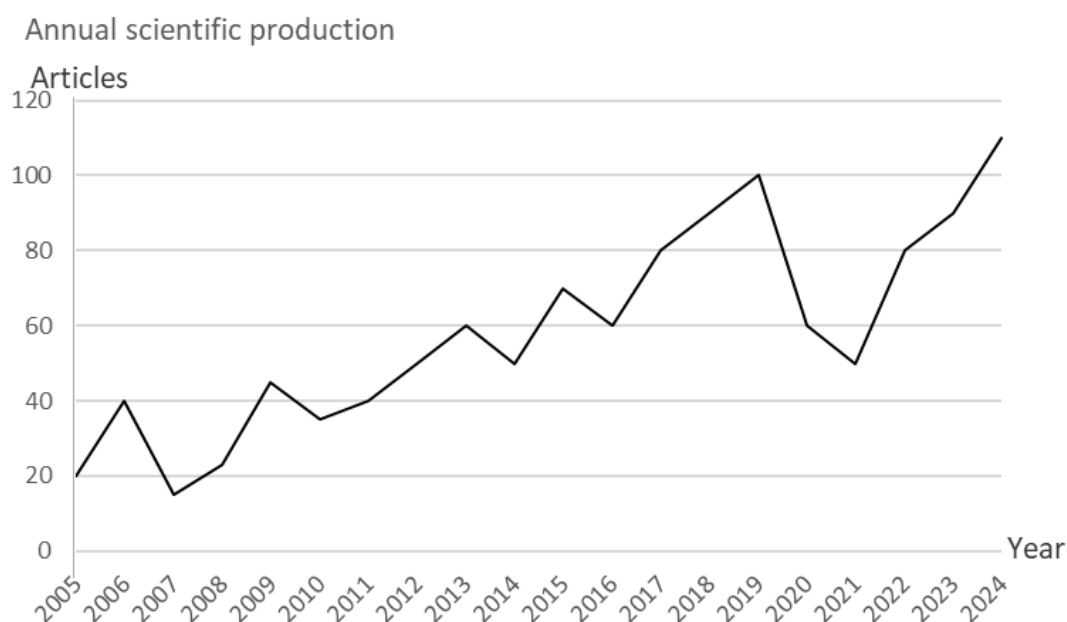


Figure 2. Total publications from 2020-2024

The annual scientific production graph in Figure 2 illustrates the steady growth in the number of articles published in pedagogical and mathematical literacy from 2005 to 2024. The upward trend indicates an increasing interest and attention toward this area of research over the years. Notable peaks in the number of publications occurred in 2018 and 2024, highlighting periods of heightened academic activity and possibly reflecting significant developments or increased funding in this domain.

The dip in 2021, followed by a resurgence in 2022, could be attributed to global disruptions such as the COVID-19 pandemic, which may have temporarily impacted research outputs. However, the strong recovery in subsequent years demonstrates the resilience of the academic community and the

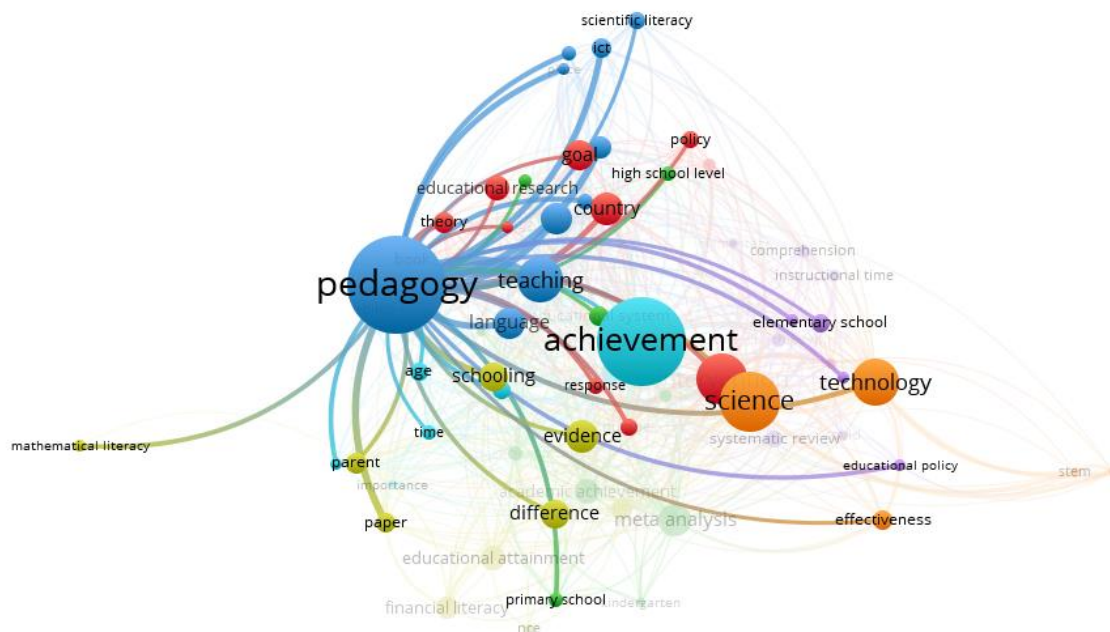


Figure 4. Correlation subject by pedagogy based on enhancing mathematical literacy approach

The visualization of the VOSviewer data results using the keyword "pedagogy" is depicted in Figure 4, illustrating the correlation between various educational concepts and their relationship with enhancing mathematical literacy. At the center of this network, the term "pedagogy" is prominently featured, indicating its pivotal role in shaping educational practices. Surrounding this core concept are related terms such as "achievement," "science," "educational policy," "evidence," and "schooling," which together create a comprehensive framework for understanding the dynamics of teaching and learning.

The visual representation employs colored nodes and interconnected lines to illustrate the complex web of associations between these different elements [34]. Terms like "mathematical literacy" and "scientific literacy" suggest a strong interconnection between these areas, highlighting the importance of pedagogical approaches in enhancing students' competencies in mathematics and science.

This analysis emphasizes the need for effective pedagogical strategies that address the challenges of teaching mathematical literacy, particularly in varying educational contexts such as elementary and high school. The relationships depicted in the visualization demonstrate that pedagogical methods are not isolated; they influence and contribute to educational achievement and policy.

By showing the interconnectedness of these concepts, the figure underscores the multifaceted nature of pedagogy and its impact on fostering essential skills like mathematical literacy [35]. The diversity of terms and their relationships advocate for a holistic and integrative approach to education, emphasizing the need to adapt teaching methods to meet the evolving demands of the academic landscape [36]. Overall, this figure provides a compelling representation of the complex interplay between pedagogy and mathematical literacy, highlighting the importance of innovative educational practices in cultivating students' mathematical understanding and skills.

Table 2. Keyword Term Clusters

Clusters	Keyword Term
Clusters 1 (12 items)	Book, chapter, country, educational research, goal, grade level, intervention, number, policy, predictor, response, theory
Clusters 2 (10 items)	Academic achievement, article, educational level, educational practice, educational system, high school level, higher education, kindergarten, meta-analysis, primary school
Clusters 3 (10 items)	Curriculum, ICT, language, pedagogy, place, scientific literacy, secondary school teacher, teacher education, teaching, way
Clusters 4 (10 items)	Difference, educational attainment, evidence, financial literacy, nce, paper, parent, pisa, schooling
Clusters 5 (10 items)	Case, comprehension, covid, educational policy, elementary, elementary school, instructional time, middle school, student achievement, systematic review
Clusters 6 (8 items)	Ability, achievement, age, educational outcome, home, importance, relation, time
Clusters 7 (5 items)	Effectiveness, engineering, science, stem, technology

The Table 2 presents different clusters of keyword terms related to educational research. Cluster 1 includes terms like "book," "chapter," "theory," and "policy," suggesting a focus on foundational aspects of educational studies, such as research frameworks and theoretical underpinnings. Cluster 2 highlights "academic achievement," "high school level," and "meta-analysis," indicating an emphasis on assessing educational outcomes and analyzing trends across different educational levels. Cluster 3 revolves around key elements in education such as "curriculum," "ICT," "pedagogy," and "teacher education," emphasizing the importance of teaching methods and technological integration. Cluster 4, with terms like "educational attainment," "evidence," and "PISA," focuses on factors influencing educational success and international assessments. Cluster 5 deals with "case," "comprehension," and "covid," reflecting the impact of external factors on education, including the pandemic and policy responses. Cluster 6 covers "ability," "achievement," and "educational outcome," which ties into understanding how various factors relate to student performance and success. Lastly, Cluster 7, consisting of "effectiveness," "engineering," and "STEM," points to the growing importance of science, technology, engineering, and mathematics in modern educational contexts. Together, these clusters illustrate diverse dimensions of educational research, from policy and theory to practical outcomes and challenges.

4. Conclusion

This article provides a bibliometric review of the role of teachers' pedagogical literacy in enhancing students' mathematical literacy. Through an analysis of relevant academic publications, the study highlights the growing recognition of the importance of teacher pedagogical competence in shaping students' mathematical abilities. The review reveals a clear connection between teachers' pedagogical knowledge, effective teaching strategies, and improved student performance in mathematics. It also underscores the need for teachers to be well-versed in mathematical content and pedagogical approaches that cater to diverse learning styles. The findings suggest that fostering teachers' pedagogical literacy is crucial for promoting mathematical literacy among students. Over the past years, research has increasingly emphasized the integration of pedagogical literacy into teacher development programs to boost students' mathematical skills. This bibliometric review contributes to a deeper understanding of how teachers' pedagogical literacy serves as a foundation for strengthening students' mathematical literacy and offers valuable insights for future educational policies and practices.

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