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The role of numerical and scientific literacy in preparing students for the challenges of the 21st century: A systematic review and bibliometrics analysis

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Abstract: This study aims to identify research trends on the topic of numerical and scientific literacy. This study uses the Systematic Literature Review (SLR) and Bibliometric Analysis approaches. This review analyzes key themes, important concepts, and research gaps. Bibliometric analysis was conducted using software such as VOSviewer or RStudio. The findings reveal variations and fluctuations in the number of publications annually, with an increasing focus on scientific and numerical literacy as critical issues in both developed and developing countries. A thematic map highlights key research themes, particularly in scientific literacy, showcasing the diverse methodologies applied in this domain, including qualitative, review, mixed methods, quantitative, and research and development (R&D) approaches. The results underscore the importance of scientific understanding and numeracy skills in equipping individuals to navigate the complexities of scientific and numerical information. Additionally, the study emphasizes the integral role of instructional strategies, namely approach, model, method, assessment, and media. This research contributes to a deeper understanding of global trends and instructional practices in numerical and scientific literacy.

Keywords: *Bibliometric analysis, Numerical literacy, Scientific literacy, Systematic literature review.*

1. Introduction

In an increasingly complex and data-driven world, the importance of numerical literacy and scientific literacy is growing. Both competencies are essential not only for individual empowerment but also for the collective progress of society. As the global landscape evolves, individuals are often required to interpret, analyze, and apply quantitative and scientific information in a variety of contexts, from personal finance to public health and environmental sustainability. The World Economic Forum [1] emphasizes that the ability to understand and utilize numerical data is essential for effective decision-making in both personal and professional settings. This need is further emphasized by the rapid advancement of technology and the proliferation of information, which demands a workforce that is adept at critical thinking and problem solving.

Numerical literacy is defined as the ability to understand and work with numbers, playing a critical role in equipping individuals with the skills needed to navigate everyday tasks and challenges. According to the OECD [2] numerical literacy encompasses a range of skills, including the ability to interpret data, perform calculations, and make informed decisions based on quantitative information. These foundational skills are not only essential for managing personal finances, but also for engaging in broader societal issues such as economic inequality, access to health services, and environmental

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sustainability. Thus, improving numerical literacy is essential to fostering informed citizens who can contribute meaningfully to discussions and decisions that affect their communities.

Scientific literacy, on the other hand, refers to the understanding of scientific concepts and processes necessary for personal decision-making, participation in civic and cultural affairs, and economic productivity [1]. This form of literacy includes not only knowledge of scientific facts, but also an understanding of the scientific method, the ability to evaluate scientific claims, and the capacity to engage with scientific issues critically. In an era marked by significant challenges such as climate change, public health crises, and technological advancements, scientific literacy is essential to enable individuals to make informed choices and advocate for evidence-based policies.

The intersection between numerical and scientific literacy is particularly pronounced in the context of education and workforce development. As the economy shifts to a knowledge-based industry, the demand for individuals with strong analytical skills and a solid understanding of scientific principles is increasing. Educational institutions are therefore charged with the responsibility to foster these competencies among students, ensuring that they are well-prepared for the challenges of the future. Integrating numeracy and science literacy into the curriculum can provide students with the tools they need to thrive in a rapidly changing world, fostering not only academic success but also lifelong learning and civic engagement.

Numeracy and science literacy are integral to preparing individuals for the complexities of modern life. As society continues to evolve, prioritizing these competencies will be essential to cultivating informed citizens who are able to face the challenges and opportunities that lie ahead. Therefore, this article aims to identify research trends on the topic of science and mathematics literacy. It is hoped that this article will uncover areas that are under-researched, both in terms of content and methodology, and provide recommendations for further research.

The research questions are:

1. What are the trends in science and mathematics literacy research from 2013 to September 2024?
2. Which 10 countries conduct the most science and mathematics literacy research?
3. What is the network analysis of science and mathematics literacy research?
4. What research methods are used in conducting science and mathematics literacy research?
5. What are the indicators of science and mathematics literacy that support 21st century learning competencies?

What strategies have been widely implemented to improve science and mathematics literacy?

2. Methodology

This study uses the Systematic Literature Review (SLR) and Bibliometric Analysis approaches. The SLR approach is used to conduct a critical review of relevant literature on scientific and numerical literacy, while bibliometric analysis is conducted to explore research trends, citation patterns, collaborations between researchers, and publications related to the topic.

In conducting this research, we set inclusion and exclusion criteria as presented in Table 1.

Table 1.
Inclusion and exclusion criteria.

Aspect	Inclusion Criteria	Exclusion Criteria
Year of publication	2013 to September 2024.	< 2013 and September 2024
Content	Focus on scientific and numerical literacy in the context of 21st century education.	Does not study literacy and numeracy.
Language	English	Non English

The data collection procedure was carried out through the following stages (see Figure 1):

1. Identification
   Articles were collected from the Scopus database using the Boolean Operator keywords TITLE-ABS-KEY (numeracy AND scientific AND literacy) AND PUBYEAR > 2012 AND PUBYEAR <

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2025 AND (LIMIT-TO (LANGUAGE, "English")). At this stage, 67 articles were obtained.

2. Screening
   After the articles were collected, the initial selection process was carried out by reading the title and abstract. Irrelevant articles were eliminated at this stage. At this stage, 61 articles were obtained.
3. Included
   Articles that passed the abstract selection were read in full to ensure their relevance and quality in accordance with the research objectives. At this evaluation stage, 46 articles were obtained.

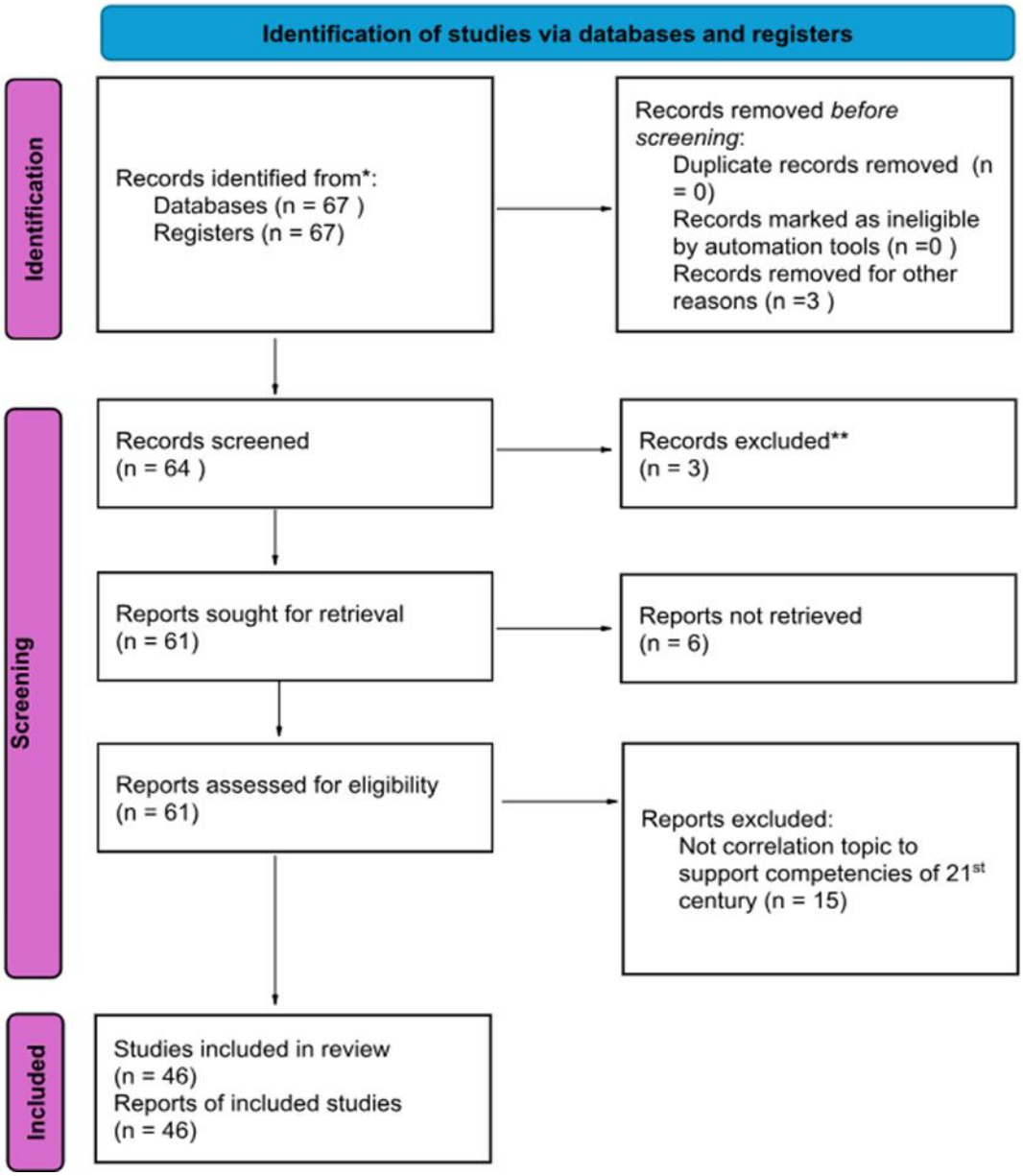

Figure 1.
PRISMA Flowchart.
Source: Page, et al. [3].

Data analysis was conducted in two stages, namely SLR and bibliometric analysis. Selected articles were systematically analyzed using the PRISMA Protocol (Preferred Reporting Items for Systematic Reviews and Meta-Analyses). The articles were analyzed based on important aspects such as methodology, sample, research results, and their contribution to the development of scientific and numerical literacy. This review will identify key themes, important concepts, and research gaps. Bibliometric analysis was conducted using software such as VOSviewer or RStudio to identify publication trends by year, country, and institution, analyze collaboration networks between researchers and institutions, and evaluate citation patterns and links between articles.

3. Result

3.1. Research Trends in Scientific and Numerical Literacy

Research on scientific and numerical literacy shows variations in the number of publications each year or experiences fluctuations (see Table 2). Based on the review results, the highest increase occurred in 2021 (19.57%). This shows that interest in the topic increased that year, which could be due to the increasing need for scientific and numerical literacy skills to face the challenges of 21st-century learning [4, 5]. However, in 2017, no relevant research was found on the topic. This shows that in that year, scientific and numerical literacy had not become the focus of research. However, in that year, people started to think about the importance of literacy and numeracy looking at needs such as our climate changing and that these changes are caused by human activities [6]. This fluctuation can be influenced by various factors such as research policies, community needs, or other factors that influence research priorities each year.

Table 2.
Number of publication.

Year	Frequencies (N)	Percentage (%)
2013	2	4.35
2014	3	6.52
2015	4	8.70
2016	2	4.35
2017	0	0.00
2018	2	4.35
2019	4	8.70
2020	6	13.04
2021	9	19.57
2022	4	8.70
2023	6	13.04

3.2. Countries Scientific Production

The ten countries that publish the most publications on scientific and numerical literacy are the USA (26.63%), Australia (16.67%), Canada (9.26%), Indonesia (8.33%), UK (6.48%), Germany (3.70%), India (3.70%), Netherlands (3.70%), Spain (3.70%), and Belgium (2.78%) (see Figure 2). The United States leads with the highest publication contribution, followed by Australia and Canada. It indicates that scientific and numerical literacy are of major concern in these countries, perhaps due to their need for a scientific and numerically literate workforce to support the development of a knowledge-based economy [7]. The distribution of these publications shows that scientific and numerical literacy are not only important issues in developed countries but are also increasingly becoming a concern in developing countries.

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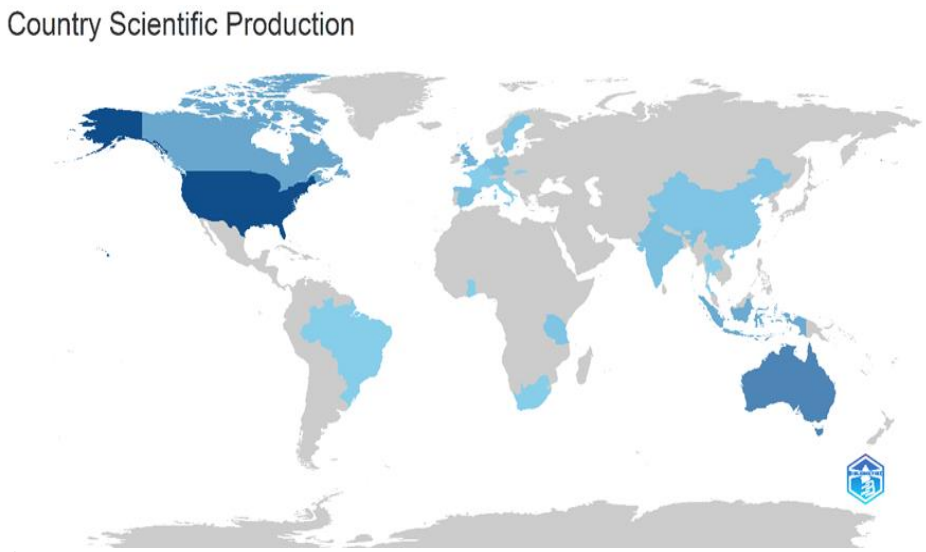

Figure 2.
Output of country scientific production from Biblioshiny.

3.3. Network Analysis

Based on the VOSViewer output, a network co-occurrence analysis with four clusters is displayed (see Figure 3). These clusters indicate research focus and related topics [8]. The red color indicates key terms such as human, humans, health literacy, attitude to health, health disparity, education, procedures, review, health care system, systematic review, selfcare, health knowledge, attitude and Australia. The key terms in these colors indicate that the focus in developing scientific literacy began with research in the health sector, then developed in the education sector. Both are related to humans who are the main actors in developing scientific literacy. In these key terms, numerical literacy has not been a center of attention in research. The second cluster is marked with green which consists of several key terms such as human experiment, article, questionnaire, child, literacy, female, male, adult, major clinical study, cohort analysis and academic achievement. These key terms indicate that literacy development begins to review in terms of technique, gender and the age of students to improve academic achievement. The third cluster is marked with blue which includes key terms such as numeracy, decision making, communication, decision support techniques, data visualization and statistics. In this cluster, numerical literacy has begun to become the focus of research, starting from techniques, data visualization to its application in the field of statistics. The fourth cluster is marked in yellow, including the key term perception. In this cluster, studies have begun to be conducted regarding how perceptions in the development of scientific and numeracy literacy have been carried out and for future research.

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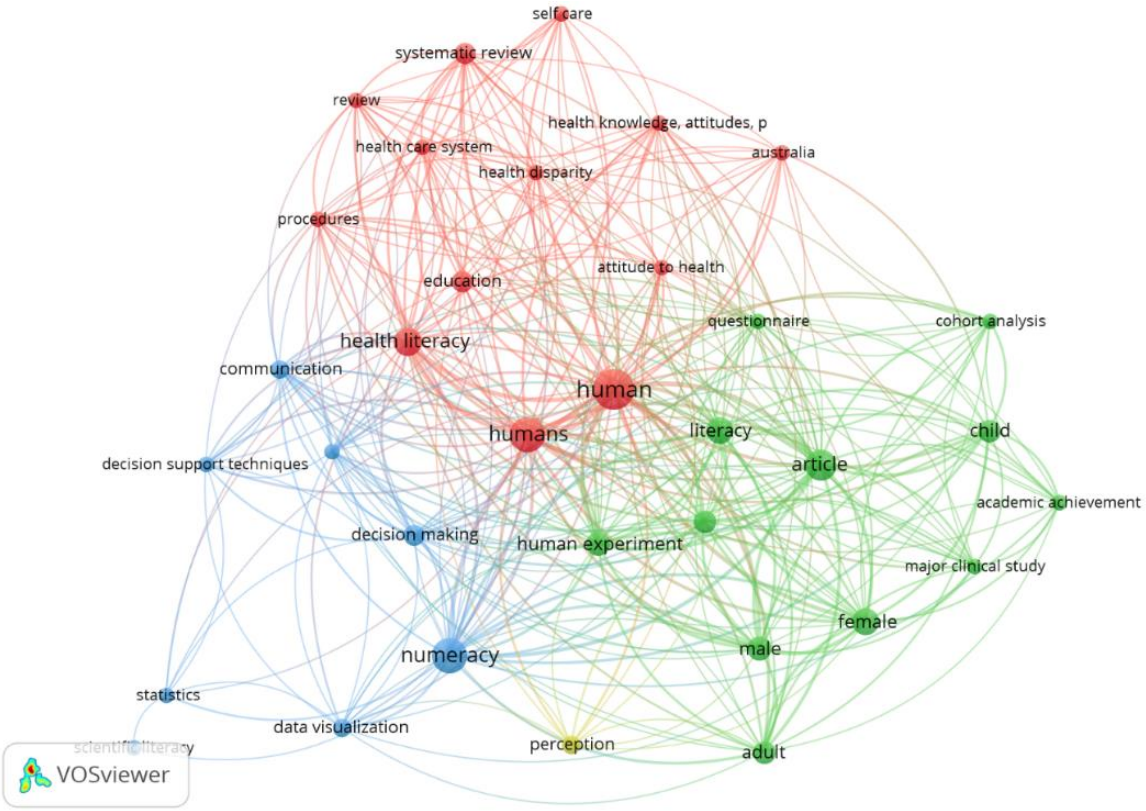

Figure 3.
Output of Network Co-Occurences Analysis from VOS Viewer.

Thematic map shows a visual display of important themes in the research [9]. Referring to the keywords used, thematic analysis can produce keyword groups and identify research themes [8]. This thematic map uses two dimensions, namely the x-axis shows centrality and the y-axis shows density. Centrality shows how important a theme is, and density refers to the development of the research theme [10]. Based on the four quadrants of the thematic map, each will display keyword bubbles according to the theme.

In this study (see Figure 4), there are three quadrants that are filled, namely motor themes, niche themes and emerging or declining themes. In the upper right square (motor themes), keywords such as human, article, female, risk, decision making, health education, academic achievement, major clinical study, and tanzania appear. This theme shows a very developed and significant theme in the field of science literacy and numeracy and has a strong appeal for further research. The upper left quadrant (niche themes) shows the keyword scientific literacy. This theme shows a specific theme and high relevance but is limited to a topic, namely science. The bottom left quadrant (emerging or declining themes) shows the keywords students and systematic literature review. This theme explains that the themes in this quadrant tend to emerge or are declining in popularity but still have the potential to be studied. In addition to the square, there is one theme in the bottom middle with the keyword mapping. This shows a balance between centrality and research density.

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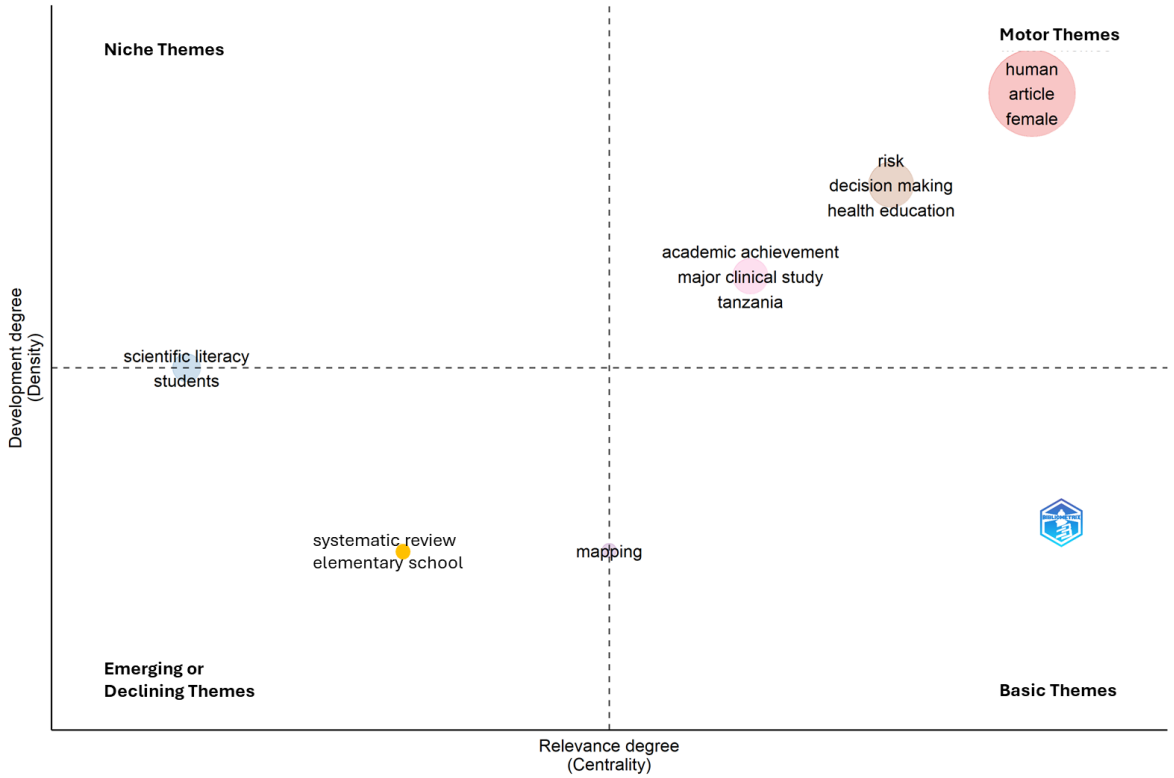

Figure 4.
Output of Thematic Map from Biblioshiny.

3.4. Method of Studies

This study identifies the methods used in research related to scientific literacy and numeracy. There are five research methods such as qualitative, review, mixed method, quantitative and research and development (RnD) which are most widely used to investigate the theme (see Figure 5). Qualitative methods are used to investigate perceptions, experiences and contexts in scientific literacy and numeracy which usually involve observation techniques, interviews or content analysis [11, 12]. Review methods include literature review analysis such as systematic literature reviews and meta-analyses to find trends and gaps in previous research Paul and Barari [13]. Mixed methods are used to gain a comprehensive understanding by combining quantitative and qualitative methods [14]. Quantitative methods investigate findings based on numerical data and statistical analysis to test a hypothesis such as increased scientific literacy and numeracy influenced by a treatment [15]. RnD methods focus on developing a product to improve scientific literacy and numeracy and testing the effectiveness of the product in its implementation [16]. By utilizing these various methods, research in the field of scientific and numerical literacy can encompass a more comprehensive perspective, both in terms of theory and practical application.

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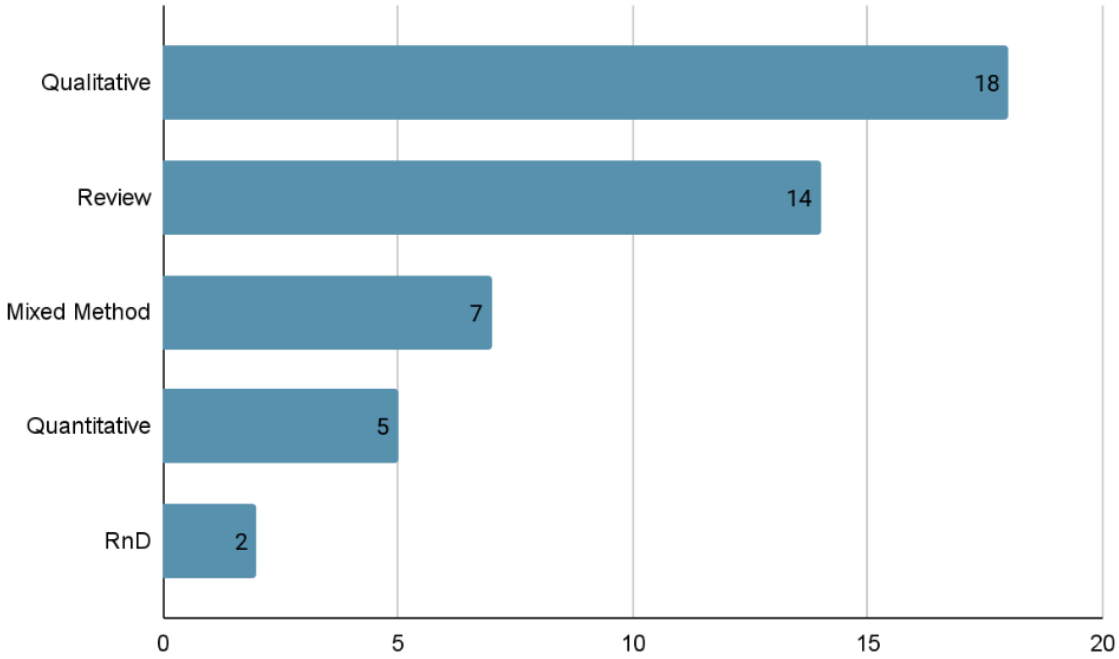

Figure 5.
Method of studies.

3.5. Research Supporting 21st Century Learning Competencies

Research on scientific and numerical literacy supports the development of 21st century competencies [17, 18]. In this study we refer to three skills, namely learning skills, literacy skills, and life skills. Learning skills include 4C skills, namely critical thinking, creativity, collaboration, and communication [19, 20]. Literacy skills include information literacy in data collection, experimentation and analysis [14]. Life skills refer to research that emphasizes flexibility, leadership, initiative, productivity and social skills. Research themes are dominated to support literacy skills (50%), arranged with learning skills (31.4%) and life skills (18.6%) (see Figure 6). Research findings show that there is a great deal of attention to scientific understanding and numeracy skills to equip individuals to navigate scientific and numerical information in a complex world. In addition, literacy development is also related to improving learning strategies that enable students to understand the subject matter more effectively. In addition, life skills also reflect an awareness of increasing literacy not only in academics but also in real everyday situations.

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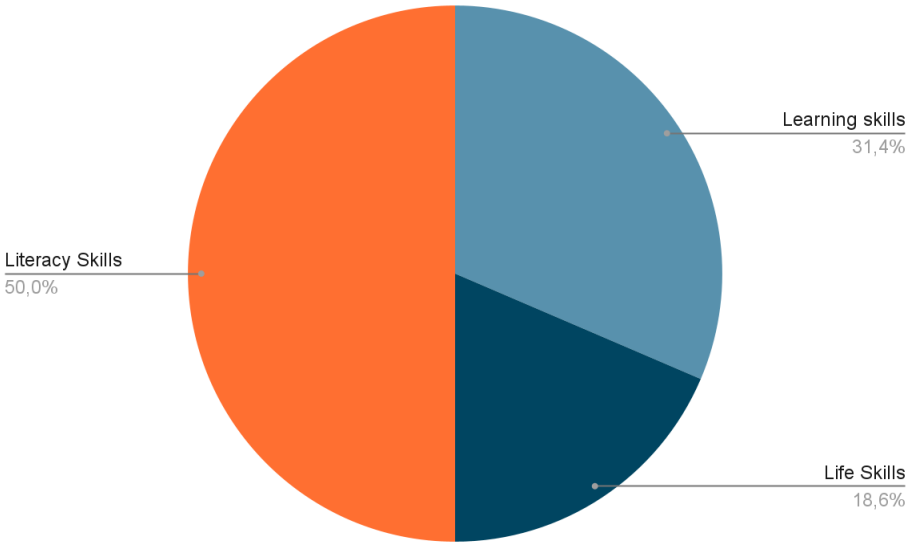

Figure 6.
Scientific and numerical literacy's studies to support 21st Century Learning Competencies.

3.6. Instructional Strategy

In the development of science literacy and numeracy, of course, it cannot be separated from instructional strategies. These strategies play a role in optimizing the learning process such as assessment, media, approaches, management, methods and learning models. The findings of this study indicate that the focus of research on literacy and numerical literacy is mostly on assessment (47.83%), then followed by learning media (23.91%), approach (15.22), management (6.52%); method (4.35%) and model (2.17%) (see Table 3). It shows that there are efforts to help optimize the scores of both literacies including in PISA. Better scores on these tests not only reflect learning success, but also indicate students' readiness to face global challenges that require critical thinking skills and strong numerical understanding.

Table 3.
Instructional Strategy to Enhance Scientific and Numerical Literacy.

Instructional Strategy	Article Code	Frequencies (N)	Percentage (%)
Assessment	P6; P7; P8; P10; P11; P12; P14; P18; P21; P22; P24; P26; P27; P28; P31; P35; P36; P40; P41; P44; P45; P46	22	47.83
Media	P1; P3; P4; P5; P17; P19; P29; P30; P32; P33; P39	11	23.91
Approach	P2; P13; P15; P16; P23; P25; P38	7	15.22
Management	P9; P42; P43	3	6.52
Method	P20; P37	2	4.35
Model	P34	1	2.17

Learning media also dominates the second after assessment. This shows that there is a need for media that can be used to optimize scientific and numerical literacy, be it digital tools [21] interactive platforms [22] or other media that are reviewed from various learning styles and promote active learning. The learning approach also plays a role in improving both literacies such as STEM learning [23] inquiry learning [24] and others. Effective classroom management emphasizes a conducive learning environment to enhance student academic performance [25]. In addition, learning methods such as experiments and lass discussions also support improving literacy and learning models such as project-based learning [26] problem-based learning [27] or others also contribute to improving scientific and numerical literacy. Based on the findings of this study, it is important to conduct further

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research to develop learning strategies that can improve students' literacy and numeracy so that they have an impact on 21st century skills as a nurturing effect.

In further research, research can be conducted that focuses on identifying problems that are still obstacles for students related to scientific literacy and numerical literacy. By identifying these barriers, researchers recommend targeted interventions and strategies to improve students' scientific and numerical literacy, ultimately equipping them with the skills to navigate and understand complex issues in the real world.

4. Conclusion

Research on scientific and numerical literacy reveals annual variations and fluctuations in the number of publications. The distribution of these publications highlights that scientific and numerical literacy are significant concerns not only in developed countries but also in developing nations. The thematic map provides a visual representation of key themes in the research, with a particular focus on scientific literacy. Various methods are employed in this field, including qualitative, review, mixed methods, quantitative, and research and development (R&D) approaches. The findings indicate a growing emphasis on scientific understanding and numeracy skills as essential tools for individuals to navigate complex scientific and numerical information in today's world. Furthermore, the development of scientific literacy and numeracy is closely linked to instructional strategies, such as assessments, media, approaches, management, methods, and learning models.

Transparency:

The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.

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