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Visual Literacy Research Trends in Science Learning 2014-2024

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Abstract

Visual literacy is a crucial competency in science learning in the digital era because it helps students understand abstract scientific concepts through various visual representations. However, the development of research on visual literacy in science learning has not been comprehensively mapped. This study aims to analyze trends in visual literacy research in science learning during the 2014–2024 period based on publication distribution, research methods, subject characteristics, subject context, and geographic distribution. The study used the Systematic Literature Review (SLR) method with reference to the PRISMA guidelines. Data were collected through Publish or Perish software connected to the Google Scholar database using the keywords visual literacy AND science education and visual skills AND science learning. Based on a selection process according to inclusion and exclusion criteria, 37 articles were obtained and analyzed descriptively and thematically. The results of the study indicate that visual literacy research publications have increased in the past five years, indicating increasing attention to this topic. Mixed-method and quasi-experimental approaches are the most commonly used methods. Research subjects are dominated by undergraduate and high school students, while the research context is mostly conducted in biology, followed by integrated science and chemistry. Geographically, research is concentrated in Asia and the Americas, with Indonesia and the United States as the primary contributors. These findings indicate that visual literacy is increasingly recognized as a critical component of 21st-century science learning. However, further research is needed across educational levels, disciplines, and geographic regions to support the development of more effective, inclusive, and visually-based learning strategies.

Introduction

In the digital era, marked by the rapid development of information and communication technology, various aspects of life are undergoing significant transformations, including education (Fischer et al., 2020). Digitalization has transformed the way information is produced, disseminated, and consumed in various contexts. This demands a high degree of adaptability from all educational stakeholders (Khan & Husain, 2024). In the context of learning, technology integration is essential to create more effective, interactive, and relevant learning experiences to meet the demands of the 21st century (Al Bahjah et al., 2025).

Science learning, as a key pillar of education, plays a strategic role in equipping students with critical, analytical, and evidence-based thinking skills. The increasing complexity of scientific concepts demands more innovative learning approaches (Zaynitdinovna & Jamshidovna,

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2025). Conventional approaches are considered insufficient to optimally explain scientific phenomena. Therefore, technology integration in science learning is a crucial element in improving the quality of student understanding and engagement.

However, science learning practices in the field still face various complex problems. One of the main challenges is students' difficulty understanding abstract concepts, which are often presented symbolically or mathematically (Munawwaroh et al., 2025). Furthermore, the limited availability of learning strategies that adapt to technological diversity and student learning readiness also poses a barrier (Al Bahjah et al., 2025). The limited use of representative media results in a less meaningful learning process and suboptimal development of higher-order thinking skills (Evagorou et al., 2015). Therefore, a learning approach is needed to enhance understanding of abstract scientific concepts and higher-order thinking skills.

In this context, visual literacy is a crucial competency to develop in science learning. In the digital age, visual information such as infographics, graphs, and diagrams plays a role in facilitating the understanding of complex concepts (Kalaf, 2023; Rubtsova et al., 2025; Domínguez & Bobkina, 2025). However, the effectiveness of using visual media depends heavily on students' ability to understand, interpret, and critically evaluate visual information (Alabi, 2024; Haq & Madany, 2025; Ibrahim, 2025). Visual literacy is also an integral part of scientific literacy, supporting informed decision-making.

Various studies have shown that integrating visual literacy into science learning can improve conceptual understanding and encourage active student engagement (Huilcapi-Collantes et al., 2023). However, its implementation in learning still faces various challenges. Several factors include students' limited ability to interpret scientific representations and educators' readiness to systematically integrate visual aspects into learning (Amin et al., 2020; Avraam, 2020). In the context of complex science learning that demands higher-order thinking skills, visual representations play a crucial role in bridging students' understanding of abstract concepts (Evagorou et al., 2015). Visualization not only supports understanding but also encourages the development of scientific reasoning skills (Yeo et al., 2021; Yoon et al., 2021). However, teachers limited visual competence and students' low levels of visual literacy are obstacles to its implementation (Sotsaka & Singh-Pillay, 2020; Adi et al., 2023).

Although research on visual literacy in science learning has grown, previous studies still exhibit several limitations. Most studies focus on specific contexts, either in terms of educational level or scientific field. This situation results in the lack of a comprehensive overview of global research trends. Furthermore, studies mapping the distribution of publications, research methods, subjects, subject contexts, and geographic distribution are still relatively limited (Solen, 2022). Based on these limitations, a study is needed that systematically maps the development of visual literacy research in science education to identify research trends, remaining gaps, and future research directions.

To address these limitations, this study uses a Systematic Literature Review (SLR) approach. This approach allows researchers to systematically identify research trends, evaluate methodologies, and map research gaps. Unlike previous studies, which tend to be partial, this study presents a more comprehensive mapping spanning the period 2014–2024. Thus, this research is expected to provide a more complete picture of the development of visual literacy in science learning. Specifically, this study aims to analyze various important aspects of the study of visual literacy in science learning (Ramulumo, 2022; Bodén, 2023; Ramulumo, 2024). These aspects include publication distribution, research methods, subject characteristics, subject context, and geographic distribution of research. The analysis was conducted to identify

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the direction of development and existing research trends. The results of this study are expected to provide theoretical and practical contributions to the development of more effective and contextual science learning strategies (Abu et al., 2023; Maftuh et al., 2023; Thamrin et al., 2024).

Method

Research Design

This study employed a Systematic Literature Review (SLR) approach to identify, evaluate, and analyze research trends concerning visual literacy in science learning. The review focused on publications released over a ten-year period, from 2014 to 2024. The SLR approach was selected because it provides a systematic and transparent procedure for synthesizing existing scholarly evidence and identifying dominant research themes, methodological tendencies, research gaps, and potential directions for future studies.

The systematic review process was guided by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework. The PRISMA framework was used to organize the literature identification, screening, eligibility assessment, and data extraction processes in a transparent and reproducible manner.

Literature Search Strategy

The literature search was conducted using Publish or Perish software, with Google Scholar serving as the primary source of bibliographic information. Google Scholar was selected because it provides broad multidisciplinary coverage of scholarly publications relevant to education and science learning. The search was restricted to publications published between 2014 and 2024.

Several structured keyword combinations were used to obtain relevant studies. The primary search strings included “visual literacy” AND “science education” and “visual skills” AND “science learning.” The search strategy was designed to capture studies addressing visual literacy, visual skills, and the use or interpretation of visual representations within science education and learning contexts.

Only studies that were available in full text and written in English were considered for further screening. The search results obtained through Publish or Perish were subsequently reviewed to determine their relevance to the objectives of the study.

Inclusion and Exclusion Criteria

The selection of literature was conducted using predetermined inclusion and exclusion criteria. The inclusion criteria consisted of: (1) articles that explicitly discussed visual literacy or visual skills within the context of science learning or science education; (2) articles for which the full text was accessible; and (3) articles written in English and published during the 2014–2024 period.

Studies were excluded when they met one or more of the following criteria: (1) the full text was not accessible; (2) the article was written in a language other than English; or (3) the study was not relevant to science education or science learning. Studies focusing primarily on visual communication in fields such as art, graphic design, advertising, or other non-educational contexts were also excluded.

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Literature Selection Procedure

The literature selection procedure followed the four major stages of the PRISMA framework: identification, screening, eligibility, and inclusion. During the identification stage, relevant publications were collected from Google Scholar using the predetermined search strings. The bibliographic information of the identified publications was organized using Publish or Perish.

In the screening stage, duplicate records were removed, followed by an examination of the titles and abstracts. This process was conducted to determine whether the studies were potentially relevant to the research focus. Articles that did not address visual literacy, visual skills, science learning, or science education were excluded at this stage.

The remaining articles were subsequently assessed for eligibility through full-text examination. At this stage, each article was evaluated against the predetermined inclusion and exclusion criteria. Studies that satisfied all eligibility requirements were included in the final review and subjected to systematic data extraction and analysis.

Data Extraction

Data extraction was conducted systematically from the selected articles. Information extracted from each study included publication year, methodological approach, participant characteristics, scientific discipline or subject area, and geographic region of the study. Additional information concerning the main focus and findings of each article was also considered to support the thematic analysis.

The extracted information was organized to facilitate comparison among studies and to identify patterns in the development of visual literacy research in science learning. The data were subsequently categorized according to publication characteristics, research methodology, participants, disciplinary focus, and geographical distribution.

Data Analysis

The data analysis combined descriptive quantitative analysis and qualitative thematic analysis. Descriptive analysis was used to identify publication trends across the 2014–2024 period, including the distribution of studies by publication year, methodological approach, participant characteristics, scientific discipline, and geographic region.

Qualitative thematic analysis was then conducted to identify recurring themes and dominant research focuses related to visual literacy in science learning. The analysis also examined the ways in which visual literacy and visual skills were conceptualized and investigated across different science learning contexts. Based on these patterns, the review identified research gaps and areas that remain insufficiently explored. The findings were subsequently synthesized to formulate potential directions for future research on visual literacy in science education.

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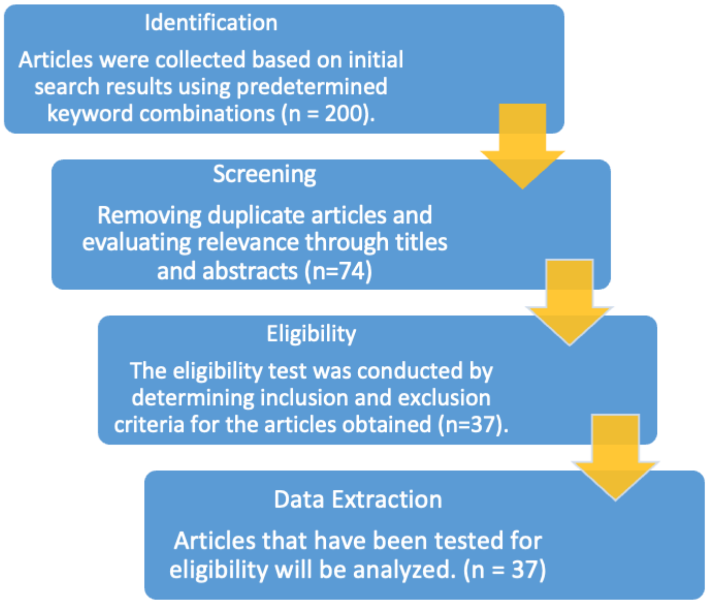

Result and Discussion

Publication Trends of Visual Literacy Scientific Articles in Science Learning Based on Publication Year

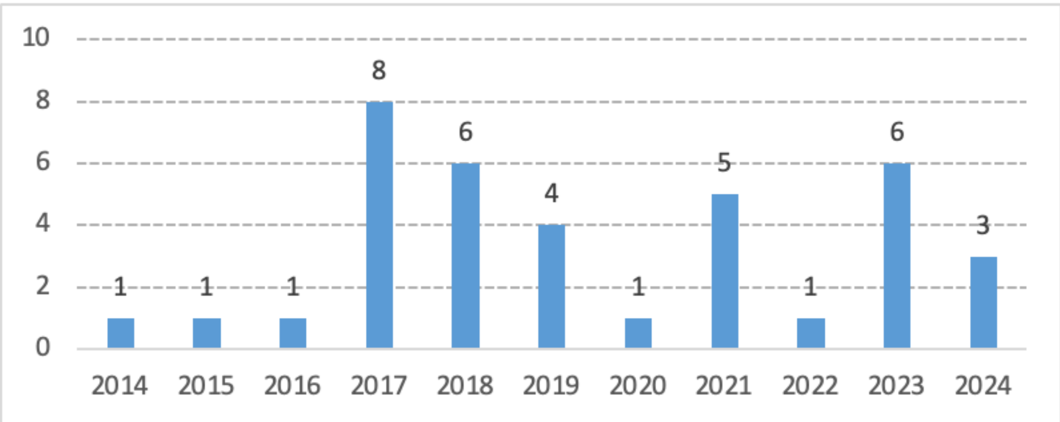

Figure 1

The distribution of scientific publications on visual literacy in science learning from 2014 to 2024 shows a dynamic trend reflecting increasing academic attention to this topic. During this period, 37 articles were published, with variations in the number reflecting the influence of research trends, developments in educational technology, and global conditions.

At the beginning of the period (2014–2016), the number of publications was still low, with only three articles, indicating that visual literacy was still in its early exploration stage and had not yet become a primary focus in science learning. A significant increase began in 2017 and

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again in 2023, while a decline in the number of publications occurred in 2020 and 2022. Overall, this trend indicates that visual literacy is gaining increasing attention as a key topic in science education research. The increasing number of publications reflects growing academic awareness of the importance of students' ability to understand, interpret, and utilize various visual representations to support the learning of complex scientific concepts.

This phenomenon aligns with the theory of Avgerinou & Pettersson (2011), which states that visual literacy is the ability to access, interpret, evaluate, create, and communicate information through various visual representations. In science learning, this ability is becoming increasingly important because many scientific concepts are abstract and therefore require visual aids such as images, diagrams, graphs, models, and animations. Therefore, the increasing research trend over the past decade indicates that visual literacy is no longer viewed merely as a learning support medium but has evolved into a competency that needs to be developed in science education.

This research finding is supported by research by Pem (2019), which showed that the use of motion graphics in biology learning can improve students' visual literacy skills and learning outcomes. These results indicate that systematically designed visualizations can help students understand complex biological concepts through more accessible visual representations. Furthermore, research by Oktariya et al. (2023) also explains that the use of problem-based e-LKPD (Student Worksheets) assisted by Canva significantly improves students' visual literacy skills compared to conventional learning. Both studies reinforce the finding that increased attention to visual literacy is driven by the development of innovative visual-based media and learning tools. Although there was a decrease in the number of publications in 2020 and 2022, likely influenced by the shift in focus of educational research during the COVID-19 pandemic, the publication trend has increased again in subsequent years. This condition indicates that visual literacy remains a relevant field of study in science education. Thus, the increase in publications during the 2014–2024 period not only reflects an increasing number of studies but also demonstrates the growing recognition of visual literacy as a competency that supports conceptual understanding, scientific reasoning, and more effective science learning.

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Publication Trends of Visual Literacy Scientific Articles in Science Learning Based on Research Methods

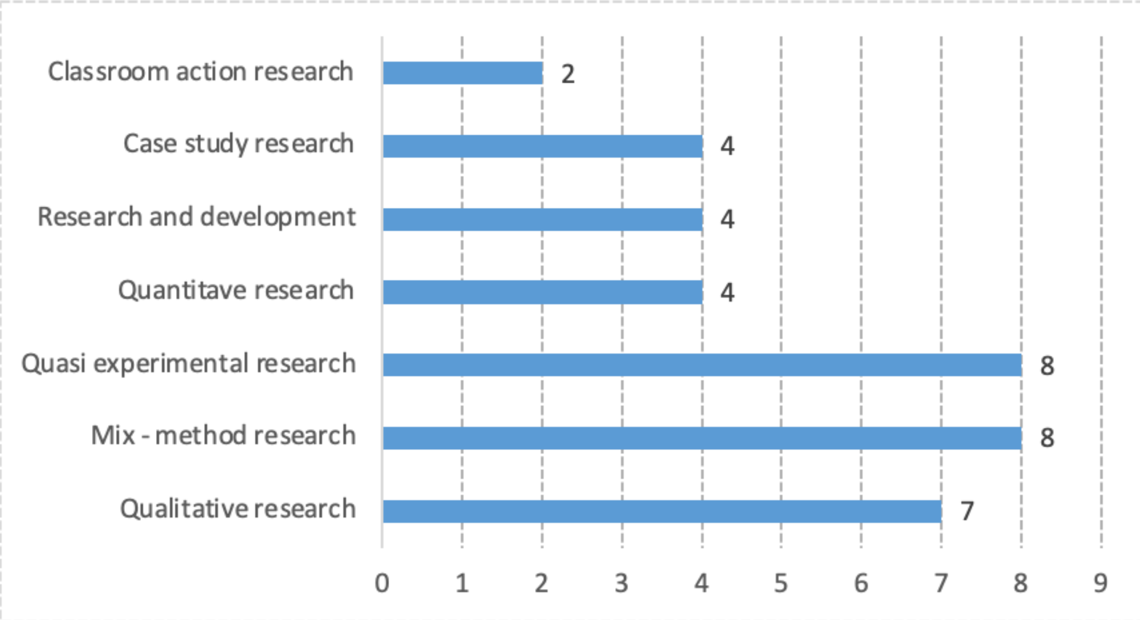

Figure 2

mixed methods and quasi-experimental approaches were the most widely used in visual literacy research in science learning during the 2014–2024 period. This was followed by qualitative research, quantitative research, research and development (R&D), case studies, and classroom action research. The dominance of these two methods indicates that visual literacy research is not solely directed at measuring the effectiveness of visual-based learning media or strategies but also seeks to understand the process by which students interpret various visual representations during learning. This demonstrates that research on visual literacy is evolving from descriptive research to research capable of providing empirical evidence regarding the effectiveness of implementing various learning innovations.

The dominant use of mixed methods aligns with research by Schoonenboom (2018), which states that integrating quantitative and qualitative data enables researchers to gain a more comprehensive understanding of a phenomenon than using a single approach alone. In visual literacy research, a quantitative approach is generally used to measure improvements in students' visual literacy skills after a learning intervention, while a qualitative approach is utilized to explain how students understand, interpret, and use visual representations during the learning process. Therefore, the use of mixed methods provides more in-depth information regarding the effectiveness and process of visual literacy development.

These findings are supported by research by Sulaiman & E. Nyong (2018), who used a quasi-experimental design to analyze the effect of visual literacy on biology learning in high school students. The study showed that students who received instruction emphasizing the interpretation of biological diagrams performed better in understanding biological processes and developing scientific reasoning than students who received conventional instruction. Furthermore, research by Dickson et al. (2017) used a qualitative approach to explore first-year students' ability to produce visual representations of basic chemistry concepts. The results showed that analyzing student drawings revealed levels of conceptual understanding not

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always evident in written tests, thus providing complementary information to the quantitative results.

Overall, the dominance of mixed methods and quasi-experimental approaches indicates that visual literacy research in science learning is not only oriented toward theory development, but also toward testing the effectiveness of various media, models, and visual-based learning tools in real-life learning situations. Meanwhile, the presence of qualitative research, R&D, case studies, and classroom action research complements our understanding of the development and implementation of visual literacy in various learning contexts. This distribution demonstrates a tendency to utilize methods that are not only descriptive, but also applicative and transformational. This aligns with the complexity and practical needs of visual literacy research in science learning in today's digital era.

Publication Trends of Visual Literacy Scientific Articles in Science Learning Based on Research Subjects

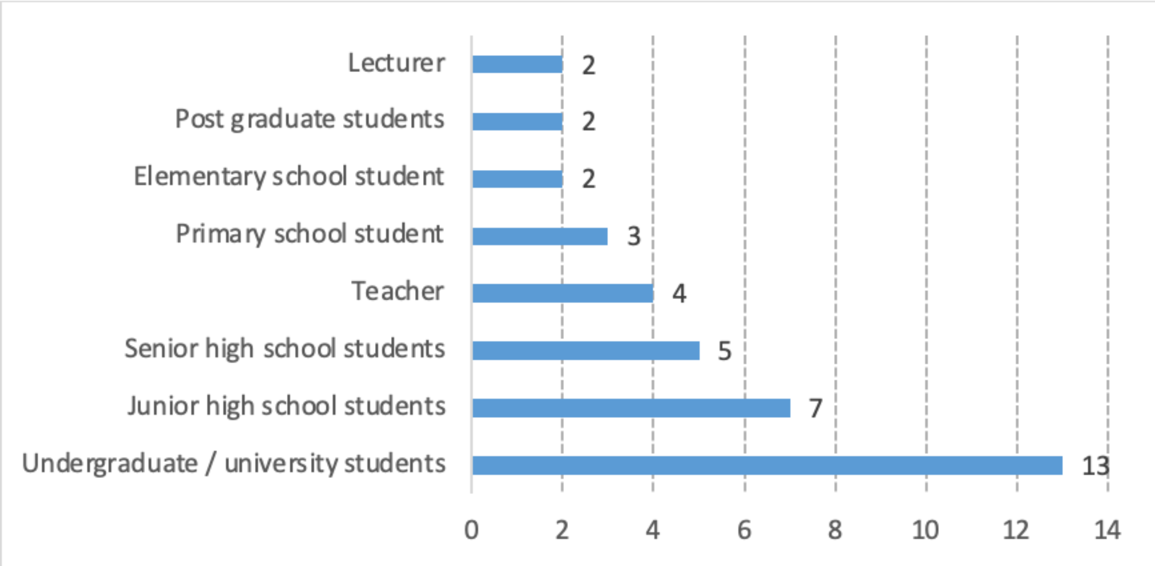

Figure 3

Research subjects are a crucial component in visual literacy studies because they reflect the broad application of this approach across various levels of education. Based on an analysis of 37 articles, undergraduate students were the most frequently studied subjects. The next group included high school and junior high school students. Conversely, research involving elementary school students, teachers, lecturers, and graduate students is relatively limited.

This predominance of students indicates that visual literacy research focuses more on groups accustomed to interacting with various scientific representations, such as graphs, diagrams, conceptual models, simulations, and digital visualizations, which are widely used in science learning. (Avgerinou & Pettersson, 2011) explain that visual literacy relates not only to the ability to understand images but also to the ability to critically use visual information to construct, integrate, and communicate knowledge. Therefore, university students are the most frequently studied group because at this level, they interact more frequently with complex scientific representations and are required to interpret various visual forms in the science learning process.

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Guntara et al. (2023) developed a Visual Thinking Strategy in Augmented Reality (ViTSAR) on magnetic fields, involving university students as research subjects. This study demonstrated that integrating augmented reality with visual thinking strategies helped students connect three-dimensional representations with abstract magnetic field concepts, thereby developing their visual literacy skills through the process of observing, interpreting, and evaluating visual representations in greater depth. Kaniawati et al. (2024), through their research involving university students in open-ended inquiry-based astronomical observation activities, demonstrated that observation activities supported by digital media encouraged students to interpret astronomical visual data, evaluate observation results, and communicate their findings through scientific visual representations. These results demonstrate that students not only act as users of visual information but also as builders of knowledge through digital visual representations.

These findings reinforce the research findings that university students are the most dominant subjects because the characteristics of learning at the tertiary level demand higher visual literacy skills than at other levels of education. On the other hand, the limited research on elementary school students, teachers, and lecturers indicates that there are opportunities for further research to develop visual literacy more evenly across various levels of education.

Publication Trends of Visual Literacy Scientific Articles in Science Learning Based on Science Subjects

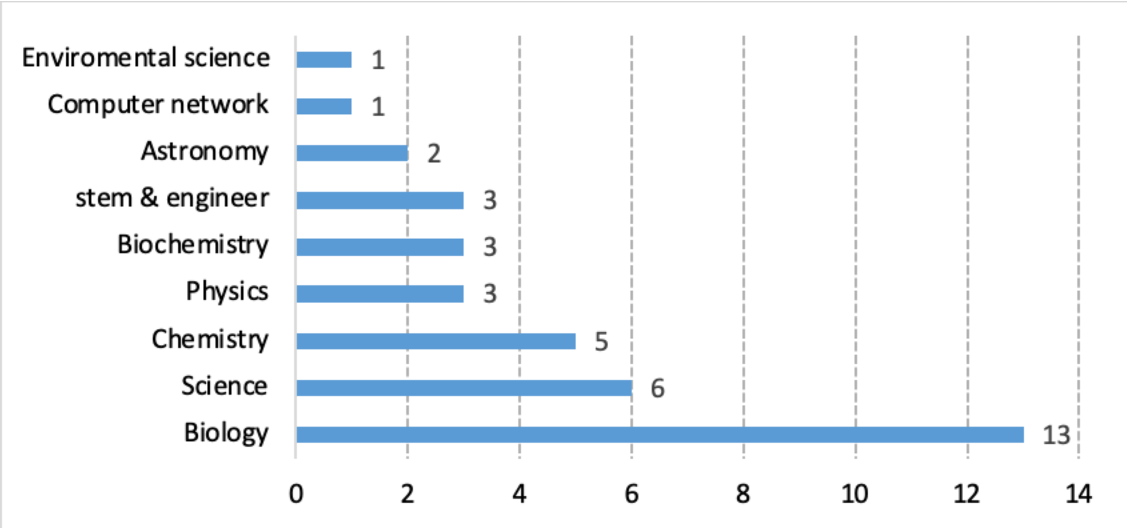

Figure 4

studied subject in visual literacy research in science learning during the 2014–2024 period, with 13 studies, followed by integrated science (6 studies), chemistry (5 studies), and physics, biochemistry, and STEM & Engineering (3 studies each). Meanwhile, astronomy was only found in 2 studies, while computer networks and environmental science each had only 1 study. The dominance of biology indicates that visual literacy research is more directed at subjects that contain abstract and microscopic concepts, requiring various forms of visual representation to help students build conceptual understanding. Concepts such as cell structure, plant anatomy, organ systems, genetics, and physiological processes cannot be observed directly, thus requiring images, diagrams, models, and digital visualizations as learning media.

Avgerinou & Pettersson (2011) state that visual literacy is the ability to observe, interpret, evaluate, and communicate visual information in various learning contexts. In biology learning,

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this ability is crucial because students are not only required to recognize visual forms but also to connect visual information to underlying scientific concepts. Therefore, subjects rich in visual representations, particularly Biology and Chemistry, are more frequently used as research contexts because learning success depends heavily on students' ability to interpret visual information.

Susiyawati & Treagust (2021) examined students' visual literacy in plant anatomy learning. The results showed that most students still lacked optimal visual literacy skills, particularly in interpreting plant anatomy photographs, understanding visual information, and constructing explanations based on visual representations. The study also found that low visual literacy is related to a lack of conceptual understanding, making it difficult for students to integrate plant anatomy knowledge with the visual representations they observe. Therefore, photographs and visual representations should be used not only as illustrations but also as information sources that train students' observation, interpretation, and knowledge construction skills.

Demirezer & İlkörücü, (2024) showed that the use of Web 2.0 tools in science learning on cell material provides significant improvements to students' learning achievement, visual literacy, and spatial visualization abilities. The study utilized various digital visual media, such as Powtoon, Canva, Quiver (augmented reality), Learning Apps, Kahoot, and Jigsaw Puzzles, so that students can observe, compare, and connect various visual representations of biological concepts more interactively. These results indicate that the integration of visual-based technology can strengthen the understanding of abstract biological concepts while improving students' visual literacy competencies. This finding supports the SLR results that Biology is the most studied subject because the characteristics of the material are highly dependent on visual representations, while research on other subjects is still relatively limited, thus providing opportunities for future research development.

Publication Trends of Visual Literacy Scientific Articles in Science Learning Based on Geographical Distribution

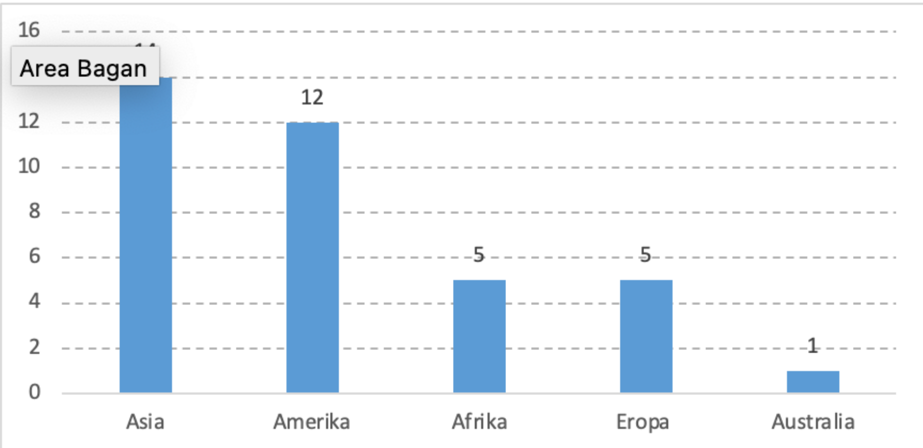

Figure 5

Strong focus on integrating visual media into science learning and improving 21st-century literacy. Furthermore, countries such as Japan (1 study) and Turkey (2 studies) also demonstrate their involvement in promoting the use of visualization in education.

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The Americas region recorded 12 studies, with the United States being the primary contributor (10 studies). This dominance reflects the strong tradition of educational research there, as well as the integrative approach to visual literacy in STEM learning contexts. Canada and Brazil also contributed one study each, demonstrating the diversity of cross-cultural approaches within the region.

Africa and Europe each contributed five studies. In Africa, research is predominantly conducted at the regional level, focusing on the use of visual media to address limitations in educational infrastructure. In Europe, Spain (3 studies), Germany (1 study), and Portugal (1 study) demonstrate a trend toward innovative, adaptive visual-based learning.

Australia contributed only one study, indicating its current low representation, despite the country's education system being known to support visual-based approaches. This indicates significant opportunities for future research, particularly in the context of strengthening visual learning in STEM fields.

Overall, the geographic distribution shows a concentration in Asia and the Americas, with more limited involvement from other regions. This disparity underscores the importance of expanding cross-national collaboration to enrich perspectives and develop a more contextualized and inclusive understanding of visual literacy globally.

Conclusion

Based on the SLR research conducted, it was found that the methodological approach in visual literacy studies is dominated by mixed-methods and quasi-experimental methods, which allow for in-depth exploration and contextual analysis. The research subjects mostly involved university and high school students, indicating a strategic focus of visual literacy at the secondary and tertiary levels of education. Biology was the most frequently studied subject context, followed by integrated science and chemistry, as it requires high-level visual interpretation skills. In terms of geographic distribution, visual literacy research is mostly conducted in Asia and the Americas, with Indonesia and the United States as the main contributors. This imbalance in representation indicates the need to expand research to other regions such as Europe, Africa, and Australia to strengthen understanding across cultural contexts and educational systems. The results of this study emphasize the importance of integrating visual literacy into the science curriculum, strengthening the visual competencies of educators and students, and broadening the scope of research.

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