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A Bibliometric Analysis (2015-2025): Research on the Implementation of Problem-Based Learning Using Visual Media in Physics Education

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Abstract – *The rapid growth of digital technology has encouraged physics education to adopt more student-centered and visually supported learning approaches, particularly because many physics concepts are abstract, mathematically complex, and difficult for students to understand through conventional instruction. Problem-Based Learning (PBL) supported by visual media has been widely recognized as a promising approach for improving conceptual understanding, problem-solving skills, and student engagement; however, the development of this research area has not been comprehensively mapped. This study aims to analyze research trends on the implementation of PBL using visual media in physics education during the 2015-2025 period. A bibliometric method was employed using Scopus-indexed publications as the data source. A total of 137 selected documents were exported as CSV files and analyzed using VOSviewer to examine publication trends, country contributions, document types, relevant authors, keyword co-occurrence networks, thematic clusters, overlay visualizations, and highly cited documents. The findings show a consistent increase in publications, with the United States, China, and Indonesia emerging as the most productive contributing countries. The keyword analysis identified eight major research clusters, indicating that studies in this field are strongly associated with physics education, students, simulations, augmented reality, virtual reality, artificial intelligence, image processing, and learning outcomes. The overlay visualization revealed a thematic shift from conventional visual media toward more interactive, immersive, and computational technologies. The novelty of this study lies in its integrated bibliometric mapping of PBL, visual media, and physics education over the last decade. This study concludes that visual media play an important role in strengthening PBL-based physics learning and provides evidence-based directions for future research and instructional innovation in physics education.*

Keywords: *bibliometric study; digital learning; physics education; problem-based learning; visual media.*

I. INTRODUCTION

The rapid advancement of digital technology has significantly transformed contemporary educational practices, particularly in the ways instructional content is delivered, represented, and experienced by students. Technology integration in education has shifted learning practices from teacher-centered instruction toward more interactive environments that encourage active student participation, inquiry, and engagement (OECD, 2021). His transformation requires instructional innovation that is responsive to the characteristics of digital-era learners and supports the development of essential twenty-first-century competencies, including critical thinking, problem-solving, collaboration, and digital literacy (Lintangesukmanjaya et al., 2025b; Sari et al., 2025). In science education, physics occupies an important position because it provides conceptual and analytical foundations for understanding natural phenomena and technological applications in everyday life (Laili & Nisa', 2025). However, physics is often perceived as a difficult subject because many of its concepts are abstract, mathematically structured, and not readily observable in real-world contexts (Latifah et al., 2024). Consequently, students frequently encounter difficulties in developing deep conceptual understanding and connecting physics concepts with contextual problems (Banda & Nzabahimana, 2021).

These difficulties have been widely reported in recent studies of physics education. A systematic review by Pratiwi et al. (2025) indicates that students often experience misconceptions and conceptual barriers in fundamental physics topics, particularly electricity and magnetism. Similarly, Jannah et al. (2022) and Syahril and Jarnawi (2023) report that students frequently struggle to identify relevant information, select appropriate formulas, and construct coherent problem-solving strategies. These challenges reflect weaknesses not only in conceptual knowledge but also in procedural and strategic knowledge. Ismail et al. (2022) further confirm that many students have difficulty applying analytical reasoning when solving physics problems, even when cooperative learning strategies are implemented (Yusal et al., 2021). In addition, studies based on Polya's problem-solving stages show that students' difficulties occur across multiple phases, especially in planning solutions and evaluating results (Evendi et al., 2025). These findings suggest that physics learning should not only emphasize formula application but also support students in developing conceptual reasoning, structured problem analysis, and reflective evaluation. In this regard, PBL has been identified as a promising framework for analyzing and improving students' problem-solving skills in physics learning (Sinensis et al., 2021).

One factor contributing to students' difficulties in physics is the continued use of conventional instructional practices that emphasize knowledge transmission, lecture-based explanations, and routine exercises. Although such approaches may help students practice procedural calculations, they often provide limited opportunities for inquiry, exploration, conceptual negotiation, and higher-order thinking. Instruction dominated by teacher explanation and repetitive problem-solving tends to restrict students' opportunities to engage deeply with scientific problems and develop advanced reasoning skills (Haris et al., 2025; Hattie, 2020). Therefore, physics education requires instructional approaches that actively stimulate students' cognitive engagement and encourage them to construct knowledge through meaningful learning experiences. Problem-Based Learning (PBL) is considered relevant in this context because it positions contextual problems as the core of learning activities and encourages students to analyze, investigate, discuss, and reflect on possible solutions (Muslimin & Purwaningsih, 2023). In physics education, PBL can help students connect theoretical concepts with phenomena encountered in everyday life. Empirical studies have also shown that PBL, particularly when supported by appropriate media and instructional strategies, can improve learning outcomes (Purwati & Mundilarto, 2021; Karmila et al., 2021), increase student engagement through teaching aids (Pujiyanti et al., 2021), and strengthen problem-solving competencies in various physics contexts (Wulansari et al., 2025).

Although PBL has strong potential to improve physics instruction, its implementation is not always fully effective when students are required to solve abstract problems without adequate representational support. Physics concepts often involve phenomena that are difficult to observe directly, such as electric fields, microscopic interactions, wave propagation, energy transformation, and dynamic motion. When such phenomena are presented only through verbal explanation or mathematical symbols, students may experience cognitive difficulties in forming accurate mental representations. One major challenge in PBL implementation is the limited availability of learning media to help students visualize complex and abstract physics concepts (Lintangesukmanjaya et al., 2025a; Padilla, 2009). Recent studies have attempted to address this challenge by using various visual tools, including Powtoon-based animations (Wati et al., 2025) and other visual media platforms that have demonstrated effectiveness in physics instruction (Mazidah et al., 2026). Visual media such as infographics, animations, simulations, and interactive digital tools are widely used because they can present abstract physics concepts in more concrete, accessible, and understandable forms (Mayer, 2020; Zulianto et al., 2025).

The development of digital and immersive technologies has further expanded the role of visual media in physics education. Augmented reality, virtual laboratories, simulations, and interactive digital tools enable students to observe, manipulate, and analyze physical phenomena in more dynamic, exploratory learning environments. Augmented reality (AR), for example, has been recognized as a promising technology for enhancing learning engagement and conceptual understanding, although challenges related to usability, accessibility, and implementation remain (Akçayır & Akçayır, 2017; Wang et al., 2025). Within PBL environments, visual media can support several stages of learning, including problem orientation, exploration, hypothesis testing, conceptual clarification, and solution evaluation. Several studies have reported that visual media-assisted PBL can improve learning outcomes and cognitive abilities (Ningsih et al., 2021; Koto et al., 2021; Sulistiyo, 2021), strengthen students' critical thinking skills (Juniantari & Suniasih, 2023), and enhance learning through audio-visual media in PBL settings (Febriyani et al., 2025). These findings indicate that visual media are not merely supplementary instructional aids but can function as cognitive tools that support students' reasoning and problem-solving processes in physics learning.

Despite the growing number of studies on PBL supported by visual media in physics education, the research landscape remains fragmented across journals, educational levels, physics topics, media types, and methodological approaches. Most previous studies have focused primarily on classroom effectiveness, such as measuring students' conceptual understanding, problem-solving skills, critical thinking, motivation, or learning outcomes after implementing specific forms of visual media within PBL. While these studies provide valuable empirical evidence, they do not fully explain how the broader research field has developed over time. Broader analyses of publication trends, thematic development, collaboration patterns, and future research opportunities are still limited (Zhang et al., 2022; Donthu et al., 2021). More specifically, no previous study has comprehensively examined the growth of publications, collaboration networks, dominant themes, and emerging opportunities in visual media-assisted PBL research in physics education using Scopus-indexed publications over the last decade. Therefore, a structured bibliometric analysis is needed to provide clearer directions for future research and educational practice. Therefore, a comprehensive mapping of research on visual media-assisted PBL in physics education is needed. Bibliometric studies are useful for identifying publication trends, dominant research topics, and the evolution of educational innovation in science and physics education (Nurazmi & Bancong, 2024; Nurazmi et al., 2025).

Bibliometric analysis is an appropriate approach to addressing this gap, as it enables researchers to examine publication trends, identify influential topics, map collaboration patterns, and reveal emerging areas for further investigation (Donthu et al., 2021). In education research, bibliometric analysis is useful for understanding how a field develops, which topics dominate scholarly attention, and which areas remain underexplored. Through bibliometric mapping, researchers can identify not only the volume of publications but also the intellectual structure and thematic evolution of a research domain. Therefore, bibliometric analysis is particularly relevant for mapping studies on PBL supported by visual media in physics education, where pedagogical models, digital technology, and subject-specific learning challenges intersect.

Based on the background and research gap described above, this study conducted a bibliometric analysis of research on the implementation of PBL supported by visual media in physics education during the 2015–2025 period, using the Scopus database. Specifically, this study aims to map publication trends, illustrate keyword networks, identify thematic clusters, and determine potential directions for future research. The findings are expected to provide practical references for physics teachers, curriculum developers, instructional designers, and researchers in selecting appropriate visual media, designing PBL-based instruction, and identifying priority areas for future innovation in physics learning. The novelty of this study lies in its focused bibliometric mapping of visual media-assisted PBL research in physics education over the past decade, thereby enabling the identification of publication patterns, collaboration trends, dominant themes, and emerging research topics in this increasingly important field.

II. METHODS

Research design

This study employed a quantitative descriptive approach, using bibliometric analysis, to systematically examine the development, structure, and research patterns of publications on the implementation of PBL supported by visual media in physics education. Bibliometric analysis is appropriate for this study because it enables researchers to quantitatively map the scientific literature using publication metadata, including publication trends, author productivity, country contributions, keyword relationships, citation patterns, and collaboration networks (Donthu et al., 2021). This approach provides an objective overview of how a specific research field has evolved over time and helps identify dominant themes, intellectual structures, and future research directions (Snyder, 2019; Donthu et al., 2020). In this study, bibliometric analysis was used not only to describe publication growth but also to interpret the thematic development of studies that connect PBL, visual media, and physics education.

To conduct the bibliometric analysis, this study used the Scopus database as the main data source. Scopus was selected because it is a widely recognized bibliographic database that indexes peer-reviewed publications across disciplines and provides structured metadata suitable for bibliometric studies. The use of Scopus also supports the dataset's reliability by allowing researchers to retrieve publication information, author affiliations, citation data, keywords, and source titles in a standardized format. The search process was conducted using the following search string: “Problem Based Learning” AND “Visual Media OR Visual Learning” AND

"Physics". This search string was designed to capture publications that explicitly addressed the intersection between problem-based learning, visual media, and physics education. To ensure the relevance and quality of the selected documents, the search was limited to Scopus-indexed publications written in English, published between 2015 and 2025, and categorized as journal articles or conference proceedings. Documents with irrelevant subject areas, incomplete bibliographic information, and duplicate records were excluded from the dataset.

VOSviewer was used as the primary software for visualizing and analyzing bibliometric networks. This software was selected because it facilitates the construction and visualization of co-authorship networks, keyword co-occurrence relationships, citation structures, and thematic clusters in a research domain (Aria & Cuccurullo, 2017; Moral-Muñoz et al., 2020). In this study, VOSviewer was used to analyze bibliographic data exported from Scopus in CSV format. The analysis focused on identifying publication trends, keyword relationships, research clusters, and the temporal development of research themes. The use of VOSviewer enabled the findings to be presented visually and systematically, thereby supporting a more transparent interpretation of the research landscape.

Research flow

The research procedure followed a systematic workflow, as presented in Figure 1. The first stage involved identifying keywords that reflected the study's main focus. The selected keywords were "Problem Based Learning," "Visual Media OR Visual Learning," and "Physics." These keywords were then entered into the Scopus database to retrieve relevant documents. The search was limited to publications from 2015 to 2025 to capture the most recent decade of research development and ensure alignment with contemporary trends in physics education and digital learning. After applying the inclusion and exclusion criteria, 137 documents were identified as relevant and exported in CSV format. These data were then processed using VOSviewer to visualize keyword relationships, publication distributions, and thematic clusters based on co-occurrence analysis and link strength among terms. The use of co-occurrence analysis is consistent with VOSviewer's function in identifying conceptual relationships among keywords and mapping the structure of scientific knowledge (van Eck & Waltman, 2010; Moral-Muñoz et al., 2020).

Figure 1. Flow chart of the bibliometric research procedure

Source: Adapted from Damarsha et al. (2023), Dawana et al. (2022), *and* Suprapto et al. (2021)

Literature selection process using PRISMA

The literature selection process was guided by the PRISMA framework to ensure that the identification, screening, eligibility assessment, and inclusion of documents were conducted transparently and systematically. The selection of literature was guided by the PRISMA framework to ensure that the process of identifying, screening, assessing eligibility, and including documents was conducted transparently and systematically. PRISMA is widely used in review-based research because it provides a structured reporting framework that helps researchers document how records are selected or excluded at each stage (Haddaway et al., 2022). In bibliometric and systematic review studies, PRISMA is important for reducing selection bias, improving methodological rigor, and providing a clear audit trail that supports replicability (Page et al., 2021; Pham & Le, 2024). Therefore, the application of PRISMA in this study strengthened the credibility of the document selection process and ensured that the final dataset was aligned with the research objectives.

As shown in Figure 2, the PRISMA process consisted of four stages: identification, screening, eligibility, and inclusion. At the identification stage, the search process initially retrieved 49,401 documents. During the screening stage, the records were refined based on keyword relevance, yielding 184 documents, and then further filtered by publication year (2015–2025), resulting in 137 documents. At the eligibility stage, the documents were assessed for alignment with the research focus and citation thresholds, resulting in 117 eligible documents. From these eligible documents, the five most highly cited articles were selected for in-depth qualitative analysis. The selection of highly cited articles was justified because citation counts can indicate the scientific influence and academic impact of publications within a research field (Donthu et al., 2021). Thus, the PRISMA process strengthened the validity of document selection and ensured that the final dataset was relevant to the objectives of this study.

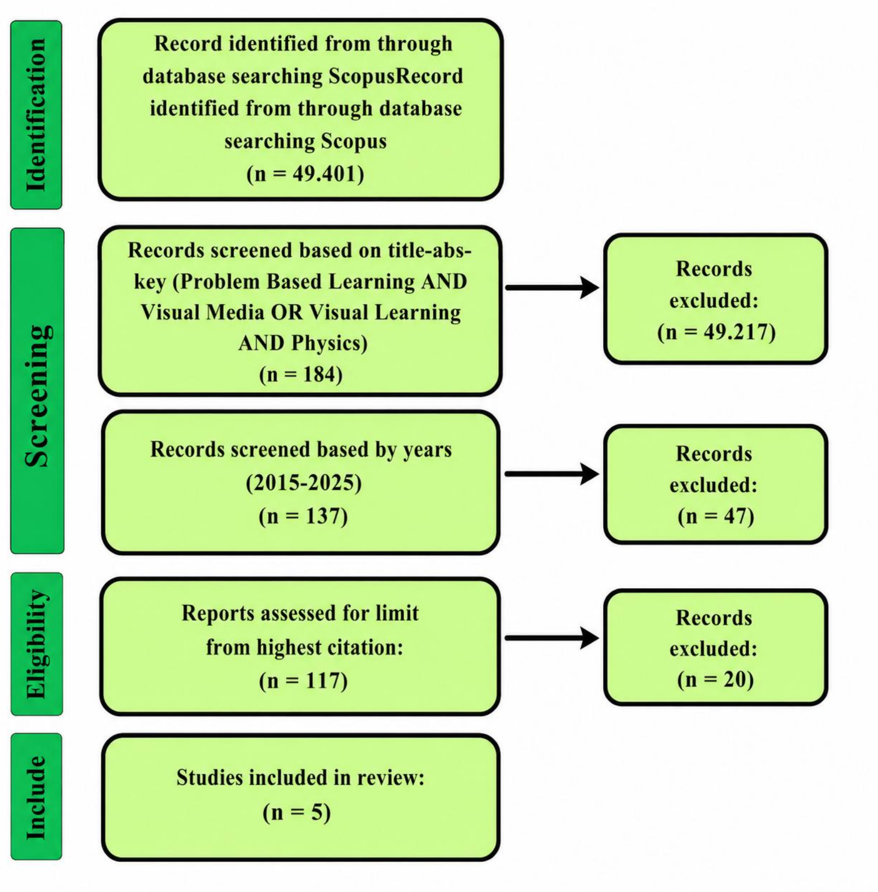


Figure 2. PRISMA flowchart of the document selection process

Data analysis technique

The results of the bibliometric mapping were analyzed using a descriptive–analytical approach to interpret dominant research focuses, thematic developments, collaboration patterns, and potential research gaps in studies on PBL supported by visual media in physics education. A descriptive–analytical approach is well-suited to bibliometric studies because it enables researchers to go beyond numerical publication counts and interpret broader patterns of scientific development (Donthu et al., 2021; Snyder, 2019). The analysis focused on publication trends, contributing countries, document types, relevant authors, keyword clusters, overlay visualization, and highly cited publications. Furthermore, the bibliometric findings were linked to pedagogical implications by examining how dominant keywords and thematic clusters reflect the visual media's role in supporting PBL stages. Keyword co-occurrence and thematic clustering provided insights into how visual media may support problem orientation, exploration, conceptual clarification, and solution evaluation in physics learning. Therefore, this study not only mapped research trends but also provided evidence-based directions for improving the practical implementation of PBL integrated with visual media in physics classrooms.

III. RESULTS

Publication trends over time (2015–2025)

Figure 3 presents the publication trend of studies on PBL supported by visual media in physics education from 2015 to 2025 based on Scopus-indexed documents. Overall, the trend shows a gradual increase in scholarly attention during the last decade. In the early period, particularly from 2015 to 2017, the number of publications remained relatively low and stable, indicating that research integrating PBL, visual media, and physics education was still in its early stages. During this period, the topic had not yet become a dominant area of investigation within physics education research.

A more pronounced increase occurred between 2018 and 2019, suggesting growing academic interest in using visual representations to support problem-based physics learning. Although the number of publications decreased in 2020, the trend increased again from 2021 onward and reached its highest point in 2025. This pattern indicates that the integration of visual media into PBL has become increasingly relevant in physics education research, particularly given the need for more interactive, student-centered, and technology-supported learning environments.

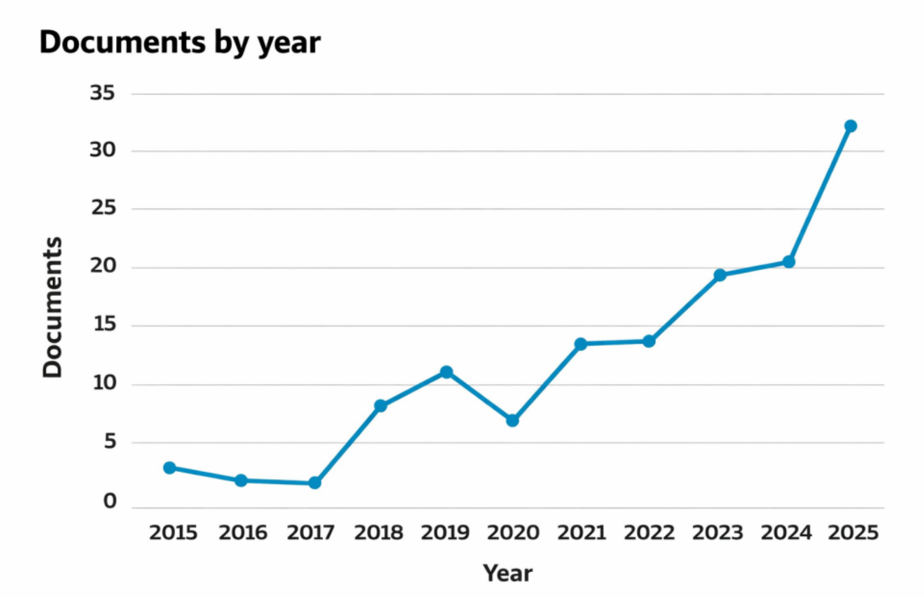


Figure 3. Publications on problem-based learning supported by visual media in physics education research over a ten-year period, based on the Scopus database

Country contributions

Figure 4 shows the distribution of country contributions in publications related to PBL supported by visual media in physics education. The United States appears as the most productive contributor, followed by China and Indonesia. The strong contributions of the United States and

China indicate well-established research ecosystems and sustained attention to educational innovation, particularly in integrating visual and digital technologies into learning processes.

Indonesia's position as the third most productive country is notable because it reflects the growing contribution of developing countries to research on innovative physics learning. This finding suggests that the need for visual and problem-oriented instructional approaches is not limited to technologically advanced countries but is also relevant in educational contexts where students face challenges in understanding abstract physics concepts. Other countries, including Germany, South Korea, Australia, Canada, the United Kingdom, and France, also contribute to the field, although with lower publication outputs. This distribution reflects the global relevance of visual media-assisted PBL in physics education.

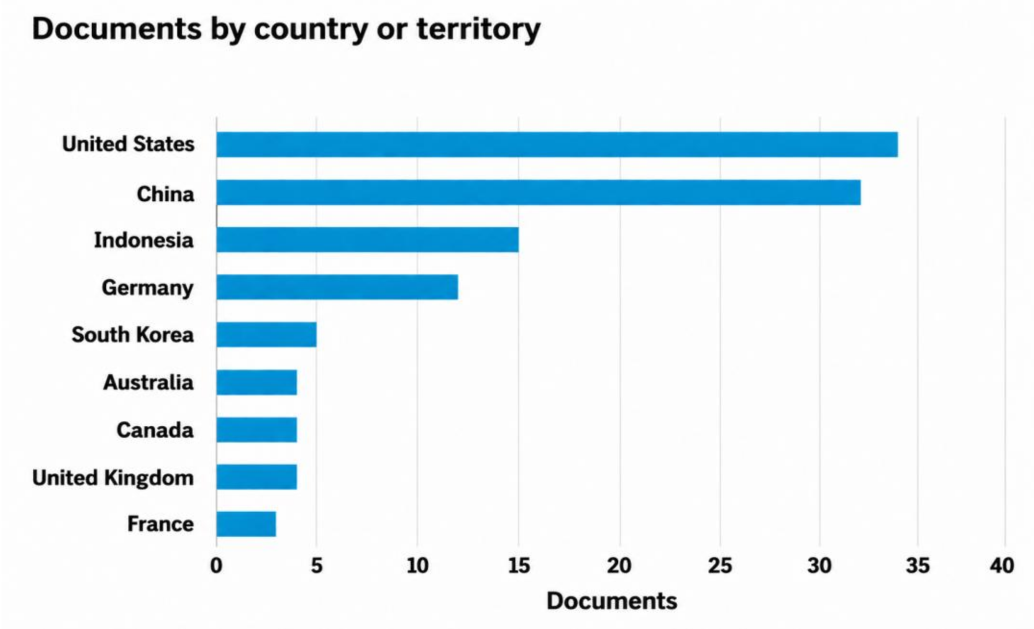


Figure 4. Contributing countries

Document types

Figure 5 illustrates the distribution of document types in the dataset. The majority of publications are journal articles, accounting for 53.3% of the total documents, followed by conference papers at 39.4%. Reviews and book chapters represent a smaller proportion of the dataset. The dominance of journal articles indicates that research on PBL supported by visual media in physics education has been widely disseminated through peer-reviewed academic outlets.

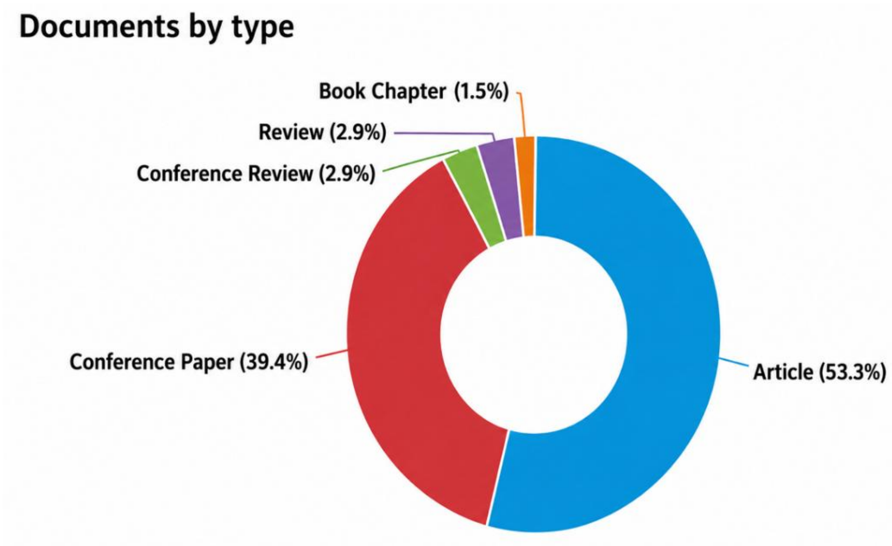


Figure 5. Distribution of document types

The relatively high percentage of conference papers also indicates that this topic remains dynamic and continues to develop through academic forums and scholarly discussions. This distribution shows that the research field is supported by both mature publication outputs and ongoing exploratory studies. The presence of different document types further suggests that the topic is interdisciplinary, connecting physics education, instructional design, educational technology, and digital learning media.

Subject areas

Figure 6 illustrates the distribution of publications by subject area. The results show that research on PBL using visual media in physics education is dominated by Computer Science, which accounts for 27.2% of the total publications. Engineering follows with 19.1%, while Physics and Astronomy contributes 13.2%. This distribution indicates that the development of visual media-assisted PBL is strongly connected to digital technology, computational systems, and technology-based instructional design.

The dominance of Computer Science reflects the increasing role of digital learning tools, interactive platforms, simulations, and computational visualization in physics education. Meanwhile, the contribution of Engineering suggests that research in this field also involves developing learning media, instructional systems, and technology-based learning environments. Contributions from Mathematics, Social Sciences, and other fields indicate that research on visual media-assisted PBL has developed as an interdisciplinary area. This pattern shows that the topic is not limited to physics education alone but also intersects with broader developments in digital learning, educational technology, and multidisciplinary instructional innovation.

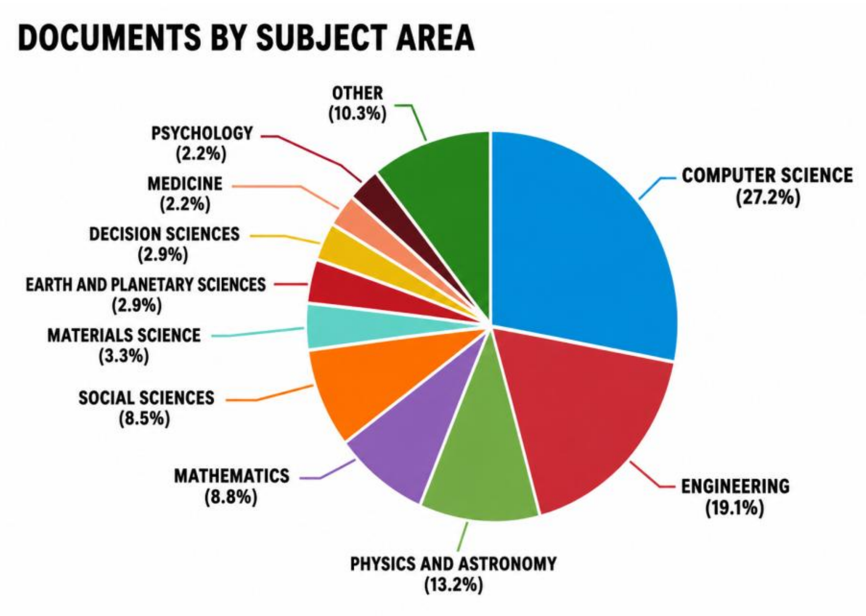


Figure 6. Distribution of subject areas

Network visualization of research themes

Figure 7 presents the keyword co-occurrence network visualization. The network shows the relationships among keywords that represent the main research themes in studies on PBL supported by visual media in physics education. The presence of several interconnected clusters indicates that the field has developed across pedagogical, technological, computational, and learning outcome dimensions. The strong connections among keywords also suggest that visual media-assisted PBL is closely related to recent educational innovations and the use of technology-enhanced learning environments.

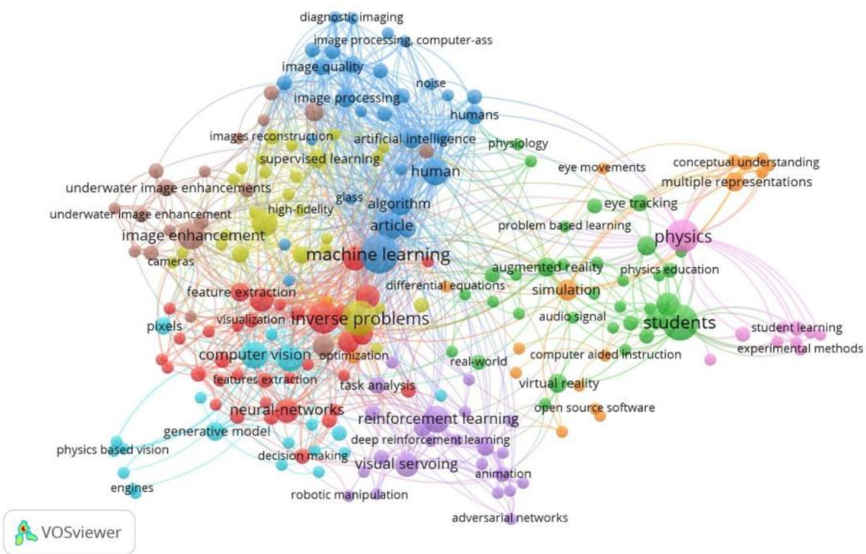
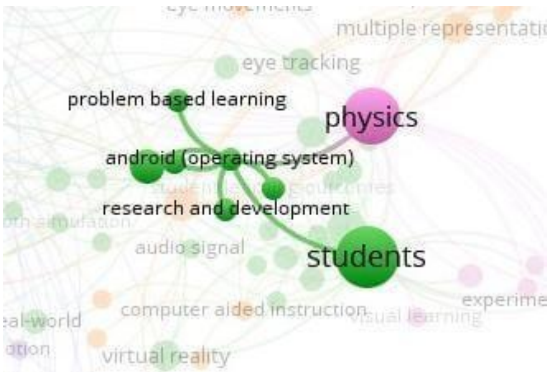


Figure 7. Keyword co-occurrence network visualization

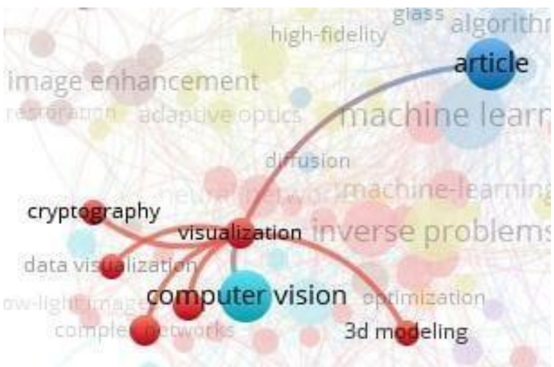
The red cluster includes keywords such as neural networks, feature extraction, visualization, and optimization. This cluster indicates a research focus on computational approaches and intelligent systems in the development of visual learning media. The green cluster encompasses physics education, students, problem-based learning, and augmented reality, highlighting the central relationship among PBL implementation, student learning, and technology-supported physics education. The orange cluster includes simulation, virtual reality, computer-aided instruction, and open-source software. This cluster emphasizes the role of simulations and virtual environments as visual media that support problem-based learning.

The blue cluster comprises image processing, image quality, artificial intelligence, machine learning, and algorithm*s*, indicating the growing integration of artificial intelligence and computational image analysis in visual learning environments. The purple cluster, which includes reinforcement learning, deep learning, and decision making, reflects the development of adaptive learning systems and intelligent educational environments. The yellow and brown clusters emphasize image reconstruction, image enhancement, visual quality, and real-world data representation. Finally, the pink cluster, which includes physics, student learning, experimental methods, and learning outcomes, shows that learning processes and educational outcomes remain central concerns in this research field.

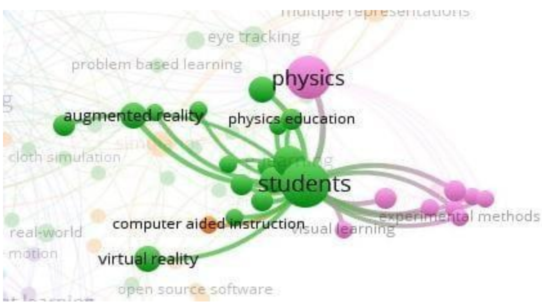
Correlation between problem-based learning, visual media, and physics



(a)



(b)



(c)

Figure 8. Correlation between problem-based Learning, visual media, and physics

Figure 8 presents the correlations among PBL, visual media, and physics using three network visualizations. Figure 8(a) shows that students are positioned as a central keyword with strong connections to physics and PBL. This indicates that research in this field is primarily oriented toward student learning activities and learning outcomes. The connection with the Android operating system reflects the use of digital technology in PBL implementation. The presence of research and development also suggests that many studies focus on the development of instructional media and digital learning tools.

Figure 8(b) shows a cluster centered on computer vision, visualization, cryptography, and 3D modeling. This pattern indicates that visual and computational technologies play an important role in the development of visual media for physics learning. The strong relationship between visualization and other technical nodes suggests that visual representation is increasingly used to support understanding of complex scientific concepts through dynamic, technology-based representations. Meanwhile, Figure 8(c) shows that research on PBL using visual media in physics education is strongly connected with physics, students, computer-aided instruction, virtual reality, and augmented reality. This finding indicates that immersive visual media are increasingly used to help students understand abstract physics concepts through contextual problem-solving activities.

Overlay visualization of research topics

Figure 9 presents the overlay visualization of keyword trends by publication year. The visualization shows the temporal development of research topics in PBL supported by visual media during 2015–2025. Darker colors indicate earlier research periods, while lighter colors indicate more recent developments. In the early period, particularly from 2015 to 2018, research was dominated by keywords such as physics education, students, multiple representations, conceptual understanding, and experimental methods. This pattern indicates that early studies focused primarily on using visual representations to support students' conceptual understanding in physics learning.

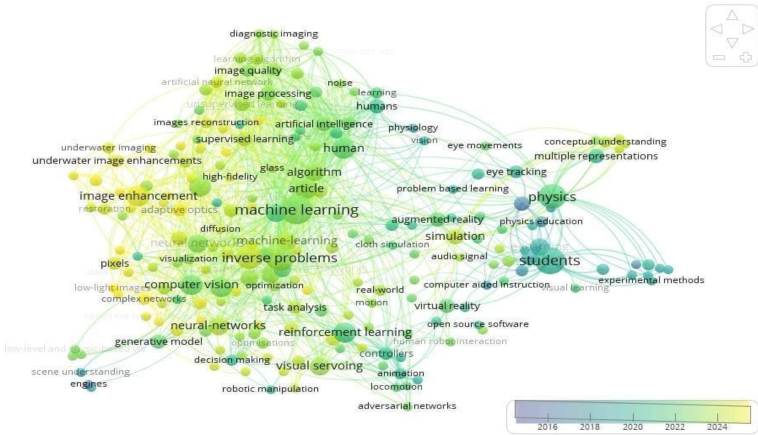


Figure 9. Overlay visualization of keyword trends by publication year.

During the middle period, approximately from 2018 to 2021, keywords such as problem-based learning, simulation, visualization, learning, and augmented reality became more visible. This indicates that digital media and interactive simulations began to be more widely integrated into PBL-based physics instruction. In the most recent period, particularly from 2022 to 2025, research trends shifted toward more advanced technologies, including machine learning, computer vision, image processing, neural networks, and inverse problems. This shift indicates that visual media in PBL research have evolved from basic visual representations into more adaptive, data-driven, and computational forms. Overall, the overlay visualization shows that research on PBL in physics education, supported by visual media, has advanced both pedagogically and technologically.

Review of the five most highly cited articles

Table 2 presents the five most highly cited documents related to PBL, visual media, and physics learning. These publications were selected based on citation counts because highly cited documents often indicate strong academic influence within a research domain. The most cited article is Agrawal et al. (2016), with 322 citations, followed by Wu et al. (2013) with 246 citations, Aurisano et al. (2016) with 197 citations, and Bergamin et al. (2019) with 117 citations.

The selected articles indicate that influential research in this field is strongly associated with visual interaction, simulation, deep learning, differentiable physics models, and data-driven visual systems. Agrawal et al. (2016) emphasize learning through physical interaction to support intuitive understanding from visual data. Wu et al. (2013) show the potential of combining deep learning with physics engines to interpret object properties from visual inputs. Aurisano et al. (2016) show the application of convolutional neural networks in analyzing complex physics data, while Bergamin et al. (2019) emphasize the role of data-driven learning in physics-based simulations.

Table 2. Five most highly cited documents related to PBL, visual media, and physics learning

No.	Author and year	Source	Number of citations	Research findings and recommendations
1	Agarwal et al. (2016)	Advances in Neural Information Processing Systems	322	This study shows that experience-based and simulation-oriented learning approaches can substantially enhance students' comprehension of physics concepts. Therefore, further research is encouraged to incorporate physics simulations into problem-based learning.
2.	Wu et al. (2013)	Advances in Neural Information Processing Systems	246	The study emphasizes that visual perception and simulation play an important role in understanding physical objects. Thus, the use of simulation-based visualization is strongly recommended to support conceptual reasoning in problem-based physics learning.
3.	Aurisano et al. (2016)	Journal of Instrumentation	197	This study proves that convolutional neural network–based visual approaches are effective in classifying complex scientific phenomena. Hence, data-driven visual approaches are suitable for application in inquiry learning and problem-based learning.
4.	Bergamin et al. (2019)	ACM Transactions on Graphics	117	This study highlights the importance of authentic, problem-based, and visual contexts in science and engineering learning. Therefore, the use of data-driven and physics-based visual models is recommended to foster students' higher-order thinking abilities.

These findings indicate that visual and computational approaches provide an important foundation for developing learning media that can support physics education. Although several of the highly cited studies are rooted in computational modeling rather than direct classroom implementation, their concepts remain relevant for designing visual media that allow students to explore, observe, and interpret physical phenomena. In the context of PBL, such tools can support students in analyzing problems, constructing explanations, testing solutions, and refining conceptual understanding through visual evidence.

IV. DISCUSSION

The findings of this bibliometric analysis indicate that research on PBL supported by visual media in physics education has experienced a meaningful development during the 2015–2025 period. The increasing publication trend suggests that this topic has gained growing scholarly attention as physics education responds to the demands of more active, contextual, and technology-enhanced learning environments. This development is consistent with the broader transformation of education in the digital era, in which learning is increasingly expected to move beyond teacher-centered instruction toward models that emphasize student engagement, inquiry, collaboration, and problem-solving (OECD, 2021; Sari et al., 2025). In physics education, this shift is particularly important because students are often required to understand abstract concepts, interpret multiple representations, and apply theoretical principles to real-world phenomena. Therefore, the increasing number of publications can be interpreted not merely as a quantitative growth of research output, but as evidence of a broader pedagogical response to persistent challenges in physics learning.

The findings of this bibliometric study provide a comprehensive overview of how research on PBL supported by visual media in physics education has developed during the 2015–2025 period. The increasing number of publications indicates that this topic has gained sustained attention in response to the growing demand for student-centered, technology-enhanced, and conceptually meaningful physics instruction. This trend is consistent with the broader transformation of education in the digital era, where technology integration has shifted instructional practices from teacher-centered approaches toward learning environments that emphasize student participation, inquiry, collaboration, and problem solving (OECD, 2021; Lintangesukmanjaya et al., 2025b; Sari et al., 2025). In physics education, such transformation is particularly important because students frequently encounter difficulties in understanding abstract concepts, interpreting mathematical representations, and applying theoretical principles to real-world situations (Latifah et al., 2024; Banda & Nzabahimana, 2021). Therefore, the growth of studies on PBL supported by visual media reflects not only an increase in publication output but also a pedagogical response to persistent challenges in physics learning.

The publication trend found in this study also strengthens the argument that PBL has become an increasingly relevant instructional model in physics education. Previous studies have shown that students often experience misconceptions and conceptual difficulties in fundamental physics topics, particularly electricity and magnetism (Pratiwi et al., 2025). These difficulties are also evident in students' inability to identify relevant information, select appropriate formulas, and construct coherent problem-solving strategies (Jannah et al., 2022; Syahril & Jarnawi, 2023).

Furthermore, students' problem-solving difficulties occur across multiple stages, especially in planning solutions and evaluating results (Evendi et al., 2025). In this context, PBL is pedagogically relevant because it places contextual problems at the center of learning activities and encourages students to analyze, investigate, discuss, and reflect on possible solutions (Muslimin & Purwaningsih, 2023). Empirical studies have also demonstrated that PBL can improve learning outcomes, scientific literacy, critical thinking, and problem-solving competencies when supported by appropriate instructional strategies and media (Purwati & Mundilarto, 2021; Karmila et al., 2021; Pujiyanti et al., 2021; Wulansari et al., 2025). Thus, the increasing publication trend identified in this study confirms that PBL is widely recognized as a meaningful approach for addressing conceptual and procedural difficulties in physics learning.

However, the results also indicate that PBL implementation in physics education is increasingly associated with visual media and digital technologies. This finding is important because the effectiveness of PBL in physics is closely tied to the availability of representational tools that help students visualize abstract and complex phenomena. Physics concepts often involve processes that are not directly observable, such as electric fields, microscopic interactions, wave propagation, energy transformation, and dynamic systems. When such concepts are presented only through verbal explanations or mathematical symbols, students may experience difficulty in constructing accurate mental representations. This concern is consistent with previous studies emphasizing that visual representations are essential for supporting conceptual understanding in physics learning (Latifah et al., 2024; Padilla, 2009). Multimedia learning theory also explains that integrating verbal and visual information can support deeper understanding when designed to align with students' cognitive processing capacity (Mayer, 2020). Therefore, the emergence of visual media as a dominant theme in this bibliometric mapping suggests that researchers increasingly recognize the need to combine PBL with media that can concretize abstract physics concepts.

The country contribution analysis shows that the United States, China, and Indonesia are the most productive contributors in this research area. The dominance of the United States and China may be interpreted as a reflection of strong research ecosystems, technological infrastructure, and sustained investment in educational innovation. Indonesia's position as the third most productive country is particularly notable because it shows that research on PBL supported by visual media is also developing strongly in emerging educational contexts. This finding suggests that the need for contextual, visual, and problem-oriented physics learning is not limited to technologically advanced countries but is also highly relevant in developing countries, where students often struggle to understand abstract scientific concepts. The Indonesian contribution may also be connected to the growing emphasis on digital learning innovation, physics learning media development, and problem-solving-oriented instruction in national education research (Lintangesukmanjaya et al., 2025a; Lintangesukmanjaya et al., 2025c). This result extends previous bibliometric work in physics education by highlighting the role of developing countries in shaping research on visual media-assisted PBL.

The distribution of document types indicates that journal articles and conference papers dominate the dataset. This pattern suggests that research on PBL supported by visual media in physics education has reached a relatively established stage while still remaining dynamic and open to further innovation. The dominance of journal articles reflects peer-reviewed empirical and conceptual contributions, whereas the substantial proportion of conference papers indicates that new ideas, prototypes, and technology-based learning designs are still being introduced through scholarly forums. This is consistent with the nature of educational technology research, where instructional media, simulations, augmented reality tools, and interactive platforms are often first presented in conferences before being developed into more mature journal publications. The distribution of subject areas further confirms the interdisciplinary character of this research field. The dominance of Computer Science, followed by Engineering and Physics and Astronomy, shows that research on visual media-assisted PBL is not only pedagogical but also technological and computational in nature. This finding indicates that future development in this field requires collaboration among physics educators, instructional designers, computer scientists, and technology developers.

The keyword co-occurrence network provides deeper insight into the intellectual structure of the field. The identified clusters indicate that research on PBL supported by visual media centers on several interrelated themes, including physics education, students, augmented reality, simulations, virtual reality, artificial intelligence, image processing, neural networks, reinforcement learning, experimental methods, and learning outcomes. The cluster related to physics education, students, PBL, and augmented reality indicates that student learning remains the central orientation of this research domain. At the same time, the presence of clusters related to artificial intelligence, image processing, machine learning, neural networks, and optimization reveals that visual media in physics education is increasingly influenced by computational technologies. This finding is important because it shows that visual media are no longer limited to static illustrations or simple animations, but have evolved into interactive, adaptive, and data-driven learning tools. The emergence of AI-related and image-processing-related keywords is consistent with recent developments in educational technology, including the use of virtual tutors, intelligent learning systems, and computational visualization tools in physics education (Ding et al., 2023; Valente et al., 2023).

The correlation maps further clarify the relationship among PBL, visual media, and physics. The central position of students in the network indicates that research in this field is primarily directed toward improving student learning processes and outcomes. The strong connection among students, physics, and problem-based learning suggests that PBL is commonly positioned as a framework for engaging students in active learning and contextual problem solving. Meanwhile, the connection with Android operating systems, research and development, computer-aided instruction, virtual reality, and augmented reality shows that many studies focus on designing, developing, and implementing digital learning media. This pattern is consistent with studies reporting the development of Android-based physics learning media, Arduino-based instructional tools, physics e-modules, hybrid PBL e-modules, and electronic live worksheets to support students' critical thinking and higher-order thinking skills (Tania & Jumadi, 2021; Matsun et al., 2021; Nabila, 2023; Rahmawati et al., 2021; Dewi & Nisa', 2025). These findings suggest that the integration of visual media into PBL is increasingly achieved through digital instructional products that enable students to engage more actively with physics concepts.

The overlay visualization reveals a clear temporal shift in research topics. Earlier studies from 2015 to 2018 were primarily associated with physics education, students, multiple representations, conceptual understanding, and experimental methods. This indicates that the field's initial focus was on using visual representations to support conceptual understanding. During the middle period, particularly from 2018 to 2021, keywords such as problem-based learning, simulation, visualization, learning, and augmented reality became more visible. This pattern shows that researchers began to integrate digital and interactive visual media more explicitly into PBL-based physics instruction. In the most recent period, from 2022 to 2025, the emergence of keywords such as machine learning, computer vision, image processing, neural networks, and inverse problems indicates a shift toward more advanced computational and data-driven visual technologies. This development reflects a broader transformation in the role of visual media, from passive instructional aids to adaptive and interactive learning environments that can support exploration, feedback, and decision making in physics learning (Govea et al., 2024; Zhang., 2022).

This thematic evolution has important implications for physics education. The shift from conventional visual representations to immersive and intelligent technologies suggests that visual media are increasingly expected to support deeper learning. Simulations, augmented reality, virtual reality, and computer-aided instruction enable students to manipulate variables, observe dynamic processes, and test predictions in ways that are difficult to achieve through traditional instruction. Previous studies have shown that immersive and interactive technologies can improve engagement, conceptual understanding, and learning experiences when integrated into well-designed instructional environments (Radianti et al., 2020; Hamilton et al., 2021; Makransky & Petersen, 2021; Ibáñez & Delgado-Kloos, 2018). In the context of PBL, these technologies are particularly relevant because they can support students in identifying problems, exploring evidence, constructing explanations, and evaluating solutions. Therefore, the findings of this study indicate that the future of PBL in physics education will likely depend on how effectively digital visual media are integrated into each stage of the problem-solving process.

The review of the five most highly cited articles also provides insight into the scientific foundations underlying this research area. Although several highly cited studies originate from computational modeling, artificial intelligence, and simulation-based research rather than direct classroom-based physics education, their relevance lies in their contributions to visual reasoning and the representation of physical systems. Agrawal et al. (2016) demonstrate how physical interaction can support intuitive understanding from visual data, while Wu et al. (2015) show how deep learning combined with physics engines can support the interpretation of object properties. Belbute-Peres et al. (2018) highlight the value of differentiable physics models for learning physical parameters, whereas Aurisano et al. (2016) and Bergamin et al. (2019) demonstrate the role of convolutional neural networks and data-driven simulations in analyzing complex physical systems. These studies suggest that advances in computational visualization and simulation can provide useful foundations for the development of visual media in physics education. Within PBL environments, such technologies can help students observe patterns, test hypotheses, analyze evidence, and refine their conceptual understanding through interactive experiences.

From a theoretical perspective, the findings of this study support the integration of constructivist learning principles, multimedia learning theory, and problem-solving-oriented instruction in physics education. Constructivist learning emphasizes that students construct knowledge through active engagement with meaningful contexts, while PBL operationalizes this principle by placing contextual problems at the center of learning activities (Muslimin & Purwaningsih, 2023; Sailer et al., 2021). Multimedia learning theory complements this view by explaining how visual and verbal representations can support cognitive processing and conceptual understanding when they are meaningfully integrated (Mayer, 2020). The results of this bibliometric analysis indicate that integrating visual media into PBL aligns with both theoretical perspectives. Visual media provide representational support for abstract physics concepts, while PBL provides a pedagogical structure that encourages students to use these representations in inquiry, reasoning, and problem solving. Therefore, visual media-assisted PBL can be understood as a pedagogically coherent approach that combines contextual learning, visual representation, and active knowledge construction.

The findings also provide practical implications for teachers, curriculum developers, and instructional designers. Teachers should not use visual media merely as presentation tools but should integrate them strategically into the stages of PBL. For example, visual media can be used to introduce contextual problems, support data exploration, clarify abstract concepts, facilitate hypothesis testing, and guide reflection on solutions. Curriculum developers can use the findings of this study to identify priority areas for integrating digital visual media into physics learning materials, particularly in topics that are conceptually abstract or difficult to observe directly. Instructional designers should also consider the accessibility, usability, and pedagogical alignment of visual media, especially when developing simulations, augmented reality applications, virtual laboratories, or AI-supported learning tools. The success of visual media-assisted PBL depends not only on technological sophistication but also on how well the media align with learning objectives, students' prior knowledge, and the problem-solving activities embedded in the learning process.

In addition, this study highlights opportunities for future research that are important for strengthening the field. Although the bibliometric findings show increasing attention to simulations, augmented reality, virtual reality, artificial intelligence, and image processing, further empirical research is needed to examine how these technologies affect students' conceptual understanding, problem-solving skills, critical thinking, scientific reasoning, and long-term retention. Many existing studies focus on short-term learning outcomes, while fewer investigate sustained conceptual change or knowledge transfer across contexts. Future studies should also compare the effectiveness of different types of visual media across physics topics, educational levels, and learning environments. Moreover, the growing contribution of Indonesia and other developing countries indicates the need for research that considers local contexts, cultural relevance, infrastructure limitations, and teacher readiness. Integrating local wisdom and culturally responsive problem contexts into visual media-assisted PBL may provide a meaningful direction for future physics education research, particularly in regions where contextual learning is strongly connected to students' daily experiences (Suprapto et al., 2021).

Nevertheless, several limitations should be considered when interpreting the findings of this study. First, the analysis was limited to Scopus-indexed publications, so relevant studies published in other databases or regional journals may not have been included. Second, bibliometric analysis primarily relies on publication metadata, keyword patterns, citation counts, and co-occurrence networks; therefore, it cannot fully capture the methodological quality, instructional effectiveness, or classroom-level impact of each study. Third, although the overlay visualization shows a shift toward advanced digital technologies, the actual implementation of these technologies in real classroom settings may vary depending on infrastructure, teacher competence, student access, and institutional support. These limitations indicate that bibliometric mapping should be complemented by systematic reviews, meta-analyses, classroom-based experiments, and design-based research to provide a more complete understanding of the effectiveness and feasibility of visual media-assisted PBL in physics education.

V. CONCLUSION AND SUGGESTION

This study concludes that research on PBL supported by visual media in physics education has shown a consistent development during the 2015–2025 period, indicating growing scholarly attention to student-centered and technology-enhanced physics learning. The bibliometric findings reveal that the research field is dominated by studies related to digital visual media, simulations, augmented reality, virtual reality, artificial intelligence, and computer-aided instruction. The United States, China, and Indonesia emerged as the most productive contributing countries, while the keyword network and overlay visualization show a thematic shift from conventional visual media toward more interactive, immersive, and computational visual technologies. Overall, the findings indicate that visual media play an important role in strengthening PBL implementation by supporting students' conceptual understanding, problem-solving processes, and engagement with abstract physics concepts.

This study has several limitations. First, the analysis was limited to Scopus-indexed publications, so relevant studies from other databases, such as Web of Science, ERIC, Google Scholar, or regional journal platforms, may not have been included. Second, this study used a bibliometric approach; therefore, the findings describe publication trends, research patterns, and thematic evolution rather than directly measuring the effectiveness of PBL supported by visual media in classroom practice. Future research should conduct empirical, experimental, longitudinal, or design-based studies to examine how different types of visual media influence students' conceptual understanding, critical thinking, problem-solving skills, and long-term knowledge retention in physics learning. Despite these limitations, this study contributes to physics education by providing a structured map of research development, identifying dominant and emerging themes, and offering evidence-based directions for integrating visual media more strategically into PBL-oriented physics instruction.

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