25 (3), 2024, 1051-1066

Jurnal Pendidikan MIPA

e-ISSN: 2685-5488 | p-ISSN: 1411-2531

http://jurnal.fkip.unila.ac.id/index.php/jpmipa/

Trends and Development in Digital Learning Research for Enhancing Scientific Literacy in Physics Learning: Literature Review and Bibliometric Analysis

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Abstract: In the current era, the ability to face the challenges posed by advances in science and technology is needed. One of the skills needed is science literacy. The development of technology affects the world of education, namely the development of digital learning. This study aims to provide an overview of trends, methods, and research findings related to digital learning in training science literacy in physics learning. The method used in this research is Systematic Literature Review (SLR) with the help of visualization using vosviewer software. Article data for the last 10 years (2014-2023) were collected from the Scopus database, with 10 articles selected using the PRISMA technique and bibliometric analysis. Quantitative and qualitative analysis techniques were used. Research on digital learning to train science literacy skills has increased significantly over the past 10 years with Spain as the country with the most research contributions. Digital learning supports a lot in improving students' science literacy skills in physics learning. The focus of future research can also be directed at developing 21st century skills through digital learning media in various disciplines.

Keywords: digital learning, scientific literacy, physics learning.

▪ INTRODUCTION

Currently, science literacy has become a major concern in the field of education in Indonesia, especially with the aspects of literacy, numeracy, and character (Shofatun et al., 2021). However, the science literacy skills of students in Indonesia are in the low category and have decreased. This is based on the results of the Program for International Student Assessment (PISA) assessment, in 2015 students in Indonesia achieved a score of 403 from the international average score of 493 (OECD, 2015b). Then in 2018, students in Indonesia only reached a score of 396 from the international average score of 489 (OECD, 2019). Whereas in 2022, Indonesian students reached a score of 383 out of an international average score of 485. This means that Indonesia experienced a continuous decline from 2015 to 2022 (OECD, 2023a).

Science literacy involves the ability to use scientific knowledge, analyze questions, draw conclusions based on evidence, and make decisions related to nature and the impact of daily human activities. Science literacy is defined as an individual's ability to understand science and apply it directly in everyday life in society. (OECD, 2015a; Wasis et al., 2020). Individuals who have science literacy skills can understand and explain scientific concepts and phenomena. According to the PISA science literacy framework (OECD, 2023b). According to the PISA science literacy framework (OECD, 2023b), science literacy skills include several indicators of competence, namely explaining phenomena scientifically, constructing and evaluating designs for scientific inquiry and critically interpreting scientific data and evidence and researching, evaluating and using scientific information for decision-making and action. Those who master science tend to

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DOI: http://dx.doi.org/10.23960/jpmipa/v25i3.pp1051-1066
Received: 13 November 2024
Accepted: 24 November 2024
Published: 28 November 2024

follow and adopt technological developments in their daily lives (Magsamen-conrad & Muhleman, 2020; Widodo et al., 2020). One of the problems in current physics learning practices is the lack of technology utilization in the learning process. This causes students to feel bored and less motivated (Ahmad et al., 2020; Puspitasari et al., 2021). The utilization of technology in physics learning can help create a more innovative and interesting classroom atmosphere (Novitra et al., 2021; Rahim et al., 2022).

Along with the rapid development of technology, the demand to integrate technology in learning is getting bigger. The utilization of technology in physics learning not only creates a more innovative atmosphere, but is also in line with the needs of education in the 21st century which presents new challenges and requires a fast and adaptive response. (Sarwi et al., 2019). Technological developments in the field of education can be seen with the emergence of digital learning systems. This learning system makes maximum use of technology and information in the teaching and learning process, such as the use of laptops, mobile devices, cell phones, and various other digital products, both in the form of hardware and software. These products are currently easy to obtain at an affordable cost (Haleem et al., 2022). Digital learning for science literacy is an innovative idea that utilizes technology to improve science understanding among students (Ardianti et al., 2020; Gürsoy, 2020).

Several researches conducted by Herlina & Abidin (2024), Istyadji (2023), Yuliati et al., (2020) have studied the development of interactive modules to improve students' science literacy through the literature review method. Research conducted by Simanjutak & Purwaningsih (2024) is a literature review on STEM in science learning. As well as research conducted by Dewi et al., (2021), Deta et al., (2021) and Dewi et al., (2021) who conducted bibliometric analysis on the methods and media used in physics learning. However, until now, there has been no publication that specifically presents a literature review that integrates bibliometric analysis using VOSviewer related to digital learning in improving science literacy, especially in physics science learning. Therefore, this systematic review will identify opportunities for further research and development of digital learning products to improve students' science literacy in physics learning. This study aims to provide an overview of trends, methods and research findings related to digital learning. Future researchers can utilize these results to fill the gaps and strengthen the findings on digital learning to train science literacy in physics learning. This analysis not only improves understanding of the distribution of relevant research topics, but also provides recommendations for future research directions. (Hashim et al., 2018; Merigó & Yang, 2017; Priyan et al., 2023). The research questions posed in this study are as follows:

- How does the representation of the research fit the general characteristics?
- What is the effectiveness of digital learning in practicing science literacy in physics learning in Indonesia?

▪ METHOD

Research Design

This research is a qualitative study using the Systematic Literature Review (SLR) method with the help of visualization using vosviewer software (Ariyani et al., 2022; Nuryana et al., 2023; Pradana et al., 2022; Suprapto et al., 2021). SLR aims to obtain a structured, consistent, and reliable method. SLR is carried out with the main objective of answering specific research questions (Roslina et al., 2022).

Search Strategy

This study uses a systematic review method by following the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines which involve the stages of identification, screening, evaluation of eligibility, and inclusion of relevant articles. This study used the Scopus database (https://www.scopus.com) with a distribution of articles for the last 10 years or 2014-2023 (Admoko et al., 2021; Gupta et al., 2021; Jauhariyah et al., 2021; Mishra et al., 2021). Scopus is used as the main database because it provides access to shigh-quality articles, excellent coverage, extensive bibliometric analysis assistance, and coverage of relevant international journals (Mongeon & Paul-Hus, 2016). The main focus of this study is the development of research on digital learning to train students' science literacy skills. The research began with an online data search in June, 2024. The steps in filtering the article database can be explained through the prism diagram shown below.

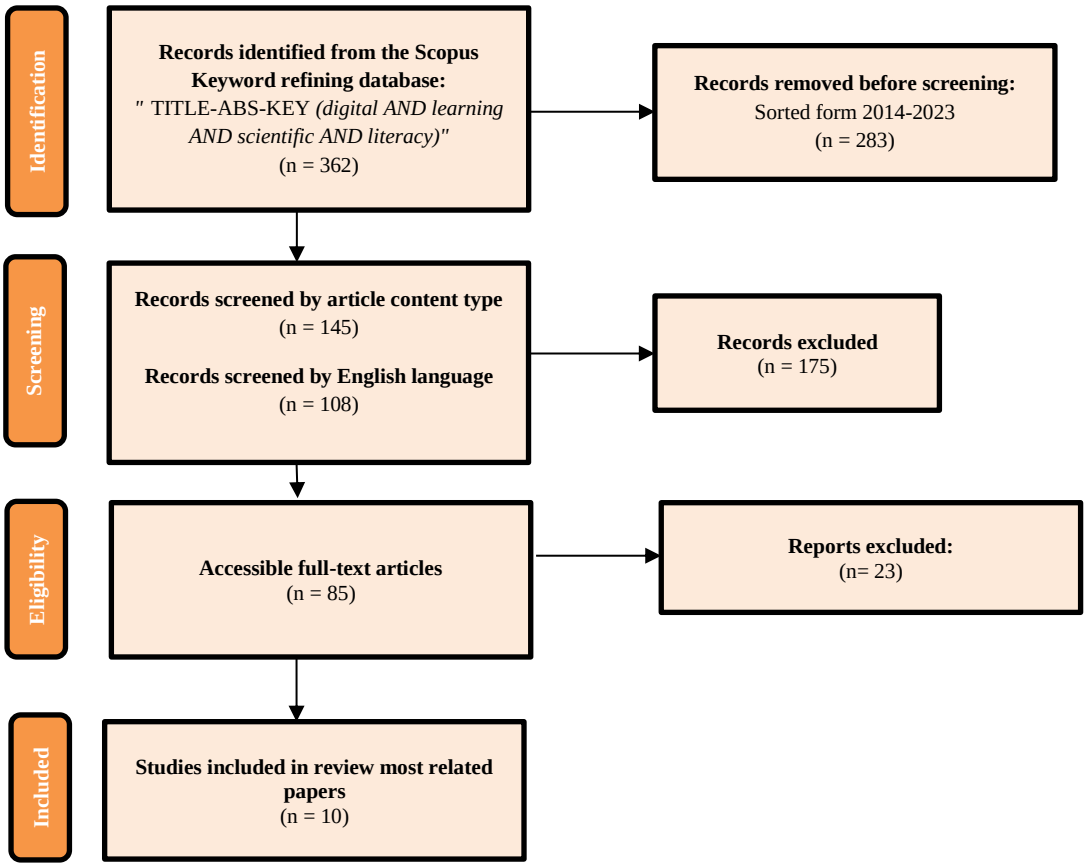


Figure 1. PRISMA flow stages

The PRISMA flowchart includes a four-stage flowchart that includes an identification stage based on the keywords “TITLE-ABS-KEY (digital AND learning AND scientific AND literacy)”, a screening stage based on article form and English articles, a full-access article eligibility assessment stage, and a study inclusion stage within the scope of the review. This diagram emphasizes quantitative aspects, such as the number of accepted and unaccepted studies. The application of the PRISMA method

makes it easier for researchers to select relevant studies according to the research questions posed.

Inclusion and Exclusion Criteria

The studies selected for analysis met the following criteria: (1) the research focused on the application or development of digital learning in training students' science literacy, (2) the research articles were published in the time span of 2014 to 2023, (3) the articles were published in accredited and reputable journals, and (4) the articles were written in English. The exclusion process was carried out by in-depth reading of the summary or abstract of the publication, resulting in n = 10 publications for further analysis.

Data Analysis

Data analysis was conducted using VOSviewer software to visualize the network of relationships between keywords. This method helps researchers understand the interrelationships between concepts while identifying emerging or under-explored areas of research. The review of various studies on digital learning to train science literacy in physics education includes the development of learning media, learning model innovation, and the development of relevant assessment instruments. The analysis of this research results in a comprehensive synthesis of new knowledge related to the topic. This synthesis serves as a strategic foundation to support further relevant research in the application or development of digital learning to improve science literacy in physics education.

▪ RESULT AND DISSCUSSION

Q1: How does the representation of the research fit the general characteristics?

Based on the data obtained, 283 documents from the Scopus database were published related to Digital Learning and Scientific Literacy in the period 2014 to 2023. Analysis of publication trends from this period has increased significantly each year even though the number of documents published is still relatively small. The number of documents entering the number above 30 each year occurred from 2020-2023 (the last 3 years). Since 2019 to date, the number of publications related to this subject has increased, which is probably because during the pandemic period many schools and universities adopted digital learning in a new way (Cisneros-Barahona et al., 2023). This can be seen in Figure 2.

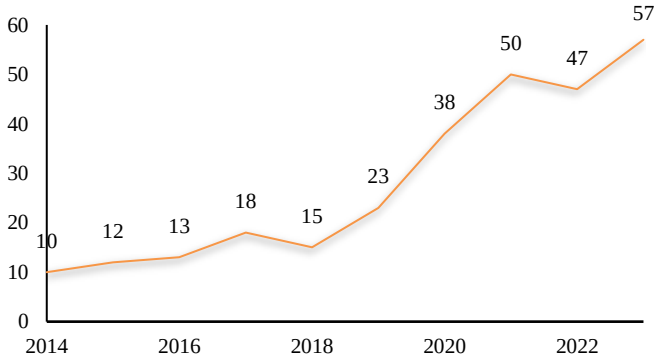
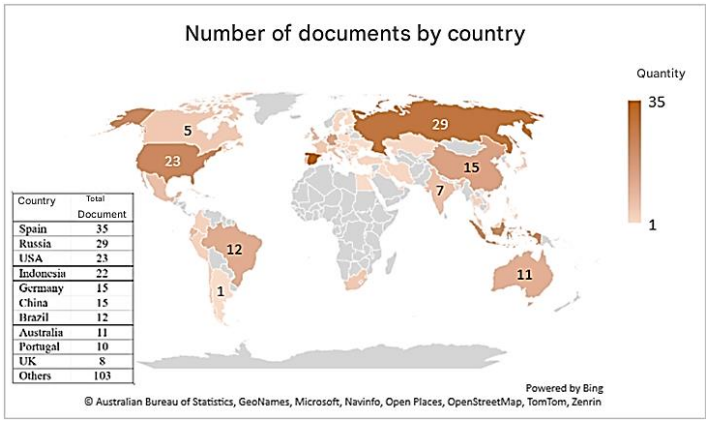


Figure 2. Number of documents from the keywords *digital learning* and *scientific literacy* in the last 10 years (2014-2023)

Furthermore, the number of documents based on countries in the world can be seen in Figure 3. Spain is the country with the most contributions with 35 documents. Then followed by Russia with 29 documents and USA with 23 documents. Indonesia is also a country that contributes to this research in 4th place with 22 documents. Other countries such as Germany, China, Brazil, Australia, Portugal and the UK also contributed under 20 documents. Spain's dominance in research on digital learning for science literacy can be attributed to its progressive educational policies. According to Ministry of Education guidelines, the Childhood Education and Primary Education curricula in Spain explicitly provide professional training for teachers in the use of ICT, which encourages the integration of technology in learning (Mathioudaki & Gkaravelas, 2023). Adequate technological infrastructure and active international collaborations allow researchers in Spain to make significant contributions (Criado et al., 2020). This academic culture that supports innovation is also reflected in the high number of high-quality publications related to technology-based science literacy.



Country	Total Document
Spain	35
Russia	29
USA	23
Indonesia	22
Germany	15
China	15
Brazil	12
Australia	11
Portugal	10
UK	8
Others	103

Figure 3. Number of documents from the keywords *digital learning* and *scientific literacy* by country in the last 10 years (2014-2023)

From 283 documents related to the study in the Scopus database, the researcher visualized the research trends on the topic of digital learning with science literacy using VoSViewer software. This aims to find the novelty of research on this domain. Figure 4 shows the overall keywords in research related to digital learning and science literacy. Based on the visualization of the figure, 4 clusters are obtained which are colored red, green, blue and yellow respectively. Each cluster is associated with other terms indicating progress in the study. This visualization network displays the relationship between various topics in digital literacy research, especially in the realm of science and physics education. It appears that digital literacy, students and learning serve as central themes that connect other clusters, such as curricula, e-learning and teaching. These clusters indicate that much research focuses on utilizing digital technology as an interactive learning medium to support student understanding and the development of science literacy. In addition, there is a close relationship between higher education and digital literacies, reflecting the particular attention to improving digital literacies at the higher education level. This visualization provides insight into the direction of research trends and identifies potential areas for further development, such as the application of augmented reality or machine learning in digital-based science learning. The results of

the bibliometric analysis show one of the relationships of the keyword digital literacy which is connected to e-learning and science education reflects the importance of digital literacy in supporting technology-based learning in science, including physics. Digital literacy allows students to access and utilize learning media such as interactive simulations or LMS to understand abstract concepts more deeply (Sundari, 2024). This relationship also highlights the potential of e-learning in creating active and meaningful learning, although challenges such as technology access gaps still need to be addressed to optimize the application of technology in supporting science literacy (Casfian et al., 2024).

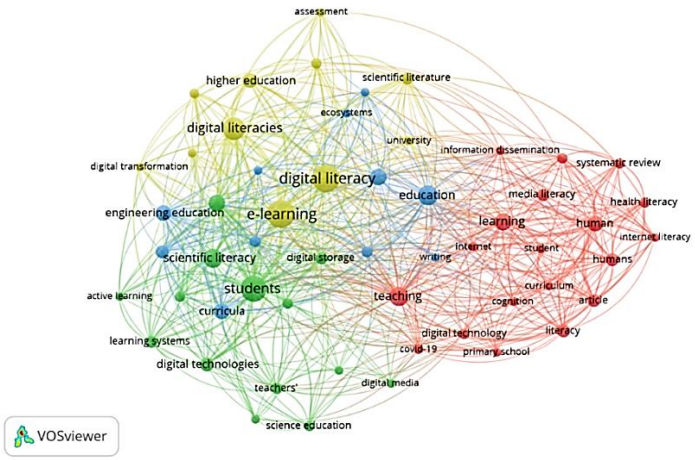


Figure 4. *Network* visualization of *digital learning* and *scientific literacy* keywords in the last 10 years (2014-2023)

In the visualization overlay view display in Figure 5, words that are bolded in bright colors indicate new usage. In the context of 2022, terms such as covid-19, active learning, and digital transformation stand out in yellow, indicating new usage in the literature. Therefore, these terms are the latest research recommendations for the topic of digital learning to improve students' science literacy. The COVID-19 pandemic has accelerated changes in the education system along with the advancement of the digital era, especially in physics learning that focuses on students' science literacy (Alismaiel et al., 2022). Restrictions on face-to-face activities during the pandemic encourage the implementation of distance learning as the main alternative. This condition also accelerates digital transformation in education through the utilization of technology in learning media, which supports the implementation of active learning (Rof et al., 2022; Tuhuteru et al., 2023). Digital media such as interactive simulations and online learning platforms provide opportunities for students to more actively participate in the learning process, explore concepts, and apply their knowledge independently or in group collaboration (Haleem et al., 2022). Therefore, all the recommended keywords can provide good benefits for further research related to digital learning to improve science literacy in physics learning.

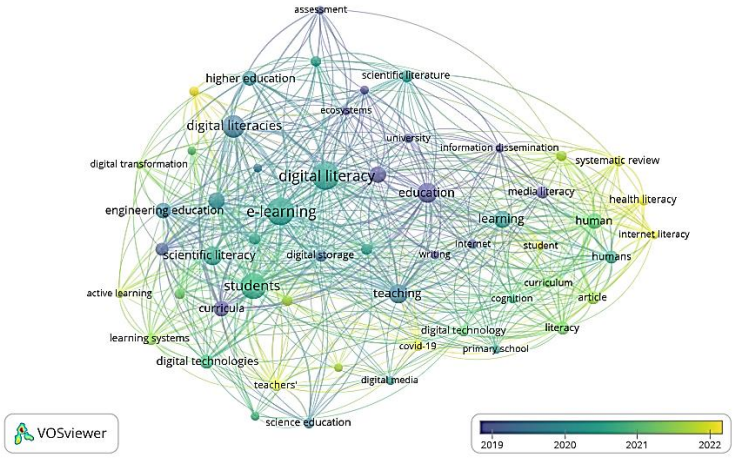


Figure 5. *Overlay* visualization of *digital learning* and *scientific literacy* keywords in the last 10 years (2014-2023)

Q2: How effective is digital learning in practicing science literacy in physics learning in Indonesia?

To answer the effectiveness of digital learning in training science literacy in physics learning, a literature review was used to compare various studies that measured science literacy outcomes after using digital learning. Table 1 contains some of the most relevant articles to this research study. This research findings from the 10 most relevant articles:

1. Research from Shofatun et al., 2021, analyzed students' science literacy competencies using Moodle-based e-learning during the COVID-19 pandemic. Their findings indicated that male and female students displayed similar competencies across OECD indicators. The study highlighted the positive effects of Moodle in helping students identify patterns from scientific data visualizations, make evidence-based decisions, and communicate effectively.
2. Research from Marsuki et al., 2020, developed Android-based digital learning media utilizing a joyful inquiry model to enhance junior high school students' literacy skills in the subject of vibration. Their research concluded that this media was highly feasible and effective, outperforming the guided inquiry model in improving students' science literacy.
3. Research from Narumsari & Wilujeng, 2022, created e-learning worksheets in natural science to optimize students' curiosity and literacy during the COVID-19 pandemic. Their study categorized these worksheets as highly feasible and emphasized the importance of integrating societal and technological issues to improve science literacy.
4. Research from Rodrigues et al., 2021, explored game-based learning's role in developing digital and scientific literacy. Their research demonstrated positive responses from both students and teachers, showing that game-based digital learning effectively enhanced students' literacy skills.
5. Research from Fausan et al., 2021, examined the scientific literacy performance of gifted students in the digital age. They found that students' literacy skills were

generally low and recommended that schools provide better digital facilities to support these skills.

6. Research from Gareis et al., 2022, investigated the use of Wikipedia assignments in STEM courses to teach critical thinking and scientific writing. The study showed improvements in critical thinking, ethical literacy, and science communication, suggesting the inclusion of Wikipedia assignments in post-secondary STEM education.
7. Research from Rosnelli & Ristiana, 2023, analyzed learning management in the independent curriculum to improve students' literacy and numeracy skills. They recommended training educators to effectively integrate ICT into teaching, enhancing students' knowledge, attitudes, and skills.
8. Research from Oktasari et al., 2019, used a 3D page-flipped worksheet on impulse and momentum as a digital learning tool to develop scientific communication skills. The results indicated that this approach successfully enhanced students' oral and written scientific communication abilities.
9. Research from Angraini et al., 2023, implemented TPACK-based active learning methods, including PBL (Problem-Based Learning) and RQA (Reading, Questioning, and Answering), to promote digital and scientific literacy in genetics. Their findings showed significant improvements in both digital and science literacy among students.
10. Research from Fitria et al., 2023, evaluated digital comic teaching materials for the topic of organism characteristics. The study found that digital comics effectively improved students' literacy by presenting science content contextually and encouraging critical thinking through narrative-driven questions.

The results show that based on bibliometric analysis, previous studies tend to focus more on the technical aspects of digital media development, such as the design and implementation of learning software, rather than evaluating the effectiveness of these media in improving students' science literacy. Research assessing the impact of digital media on students' critical thinking, problem-solving skills and conceptual understanding is still relatively limited. Future research topics could focus on developing technology-based learning media to improve students' science literacy in physics learning. One proposal is the use of augmented reality (AR) to help students visualize abstract concepts, such as electric fields or parabolic motion, so that they can connect theories with real contexts interactively. In addition, the integration of machine learning can create an adaptive learning system that strengthens critical thinking and problem-solving skills, which are part of science literacy. With this technology, students not only understand physics concepts more deeply, but are also trained in 21st century skills, such as digital literacy and analytical ability.

In addition, the results show that digital learning can be an effective alternative to train students' science literacy, especially in physics subjects. Physics subjects that are complex and full of concepts require the support of interactive digital media so that learning objectives are achieved optimally (Kurniawan et al., 2024). Several studies have shown that the use of interactive digital learning media, such as PhET simulations, has a positive impact on student understanding. This kind of media not only helps students understand concepts more deeply, but also encourages learning independence, scientific process skills, and critical thinking skills (Ardiyati et al., 2019; Eveline et al., 2019; Ferty

et al., 2019; Utami et al., 2019). Digital media such as simulation experiments are very effective in helping students understand abstract concepts in physics because they support constructivist learning theory. In the constructivist approach, students build their understanding through hands-on experience. Simulated experiments allow students to interactively explore physics concepts, such as Newton's laws or electric fields, in a safe and flexible virtual environment (Agyei, 2021; Banda & Nzabahimana, 2021; Saudelli et al., 2021). This helps students connect simulated experiences with theoretical concepts. Several case studies show the successful implementation of digital learning in improving science literacy skills. Research from Harianto in 2023, which examined the use of Digital Physics Module (DPM) media for physics learning. This study found that digital modules can develop students' science literacy skills on the topic of light and optics with an N-gain score of 0.71 in the high category. In addition, research from Nuriyah et al., 2023, the development of Digital Storytelling of Physics (DiSPhy) which produces digital learning media products to improve students' science literacy on the topic of magnetic fields with a percentage score of 87.84% is very feasible. Several digital learning media that have been developed to support physics learning and improve science literacy, such as Android-based mobile applications, computer-based learning, augmented reality (AR), and Learning Management System (LMS) platforms such as Schoology and Google Classroom (Isnaeni & Sadiyah, 2024; Harianto, 2023; Kastina, 2024; Khasanah et al., 2022; Muzijah et al., 2020). Technology integration through digital learning media offers a promising solution to improve students' science literacy. The rapid development of educational technology allows digital media to be an interactive and contextual learning tool, thus helping students understand abstract physics concepts more easily (Melati et al., 2023; Puspitasari, 2019). In Indonesia, the use of digital media such as PhET, Moodle, and other learning applications has started to be implemented, especially in big cities. However, implementation is still limited in remote areas due to limited internet access and technological devices. Although some projects such as the use of Android apps for virtual experiments have been successful, the spread of these technologies is still constrained by the lack of teacher training and equitable access to technology. Further efforts are needed to ensure this technology can be fully utilized throughout Indonesia. Figure 6 is the type of digital media most frequently used in the study depicted in diagram form.

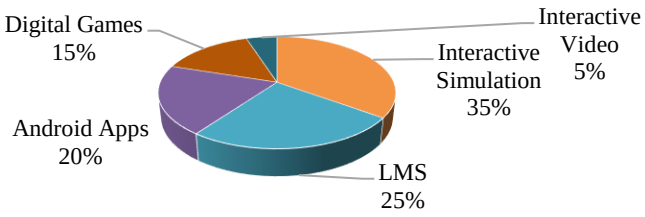


Figure 6. The type of digital media most often used in research

Although digital media has many advantages, the constraints of technology accessibility in remote areas are a big challenge, especially in the Indonesian context. The main obstacle in implementing digital learning in remote areas is limited access to technology, such as poor internet connection and lack of technology devices in schools (Firdaus & Ritonga, 2024; Pahrijal & Novitasari, 2023). In addition, the lack of training

for teachers in using technology also hinders the effectiveness of digital learning. Potential solutions include the development of offline learning media, equitable distribution of technology devices, and intensive training for teachers, so that digital learning can be accessed more widely and equitably.

Overall, this study shows that digital learning media play an important role in improving students' science literacy skills, especially in physics learning. However, to maximize the benefits of digital learning, it is important to ensure equitable access to technology, effective teacher training and content design that suits students' needs. Further research is needed to explore new innovations in digital learning and improve its effectiveness in physics education.

▪ CONCLUSION

Based on the results and discussions conducted to analyze the effectiveness of digital learning in training students' science literacy in science learning, especially physics, through a systematic literature review (SLR), it is concluded that digital learning has become one of the main trends in recent years in the application of physics learning in schools. This research has limitations, in that the field observed is only limited to science education, specifically physics education. Nevertheless, this study plays an important role in mapping the trends and gaps in digital learning research that focuses on developing physics science literacy, so that it can serve as a basis for future research. The analysis in this study only includes articles available in the Scopus database and focuses on research with a local context in Indonesia. Therefore, for future research, it is recommended to integrate data from other databases such as Web of Science, Google Scholar, or even local institutional repositories to broaden the scope and provide a more comprehensive picture of the use of digital media in training students' science literacy in various countries. Physics teachers can utilize digital simulations, such as PhET, to explain abstract concepts that are difficult to understand in person in certain materials. These simulations allow students to observe virtual experiments, reinforcing their understanding of the topic. To measure their impact on students' science literacy, teachers can use pre-tests and post-tests to assess improved understanding, observe student engagement during simulations, as well as provide problem-based assignments that test the application of concepts. Class discussions and reflections also help identify areas for improvement. In this way, digital learning can effectively improve students' physics understanding and science literacy. The results of this study also offer practical insights for digital learning media developers and provide recommendations to educators and policy makers to optimize the use of technology in improving science literacy. Therefore, this finding can be a recommendation for physics teachers to implement engaging digital learning at various levels of education.

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