

Digital Learning Aid Systems for Enhancing Students' Problem-Solving Skills in Physics Education: A Systematic Literature Review

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ABSTRACT

Objective: This study aims to examine how digital learning aid systems support the development of students' problem-solving skills in physics education. The study focuses on identifying how digital tools facilitate conceptual understanding, visualization of abstract physics concepts, inquiry-based learning processes, and student engagement in solving physics problems. **Method:** This research employed a systematic literature review following PRISMA guidelines. Articles were collected from Scopus-indexed journals and Google Scholar using predefined keywords related to digital learning, physics education, and problem solving. A total of 312 articles were identified, 276 remained after duplicate removal, and 20 articles published between 2021 and 2025 met the inclusion criteria, consisting of Scopus Q1–Q3 empirical studies available in full text. Data were analyzed using a structured extraction sheet and thematic synthesis to identify instructional mechanisms and patterns of technology integration. **Results:** A synthesis of 20 studies shows that digital learning aid systems enhance problem-solving through interactive simulations, virtual laboratories, artificial intelligence tools, and immersive visualization technologies. Research trends indicate a shift from simulation-based learning toward AI-supported and adaptive digital environments that provide scaffolding, feedback, and inquiry-based experimentation. These features support conceptual reasoning, analytical thinking, and structured solution strategies. **Novelty:** This review reveals that digital learning aid systems function as integrated problem-solving ecosystems that combine visualization, inquiry scaffolding, and adaptive feedback, extending beyond the single-technology approaches reported in previous studies.

INTRODUCTION

Digital technology has become an integral component of modern physics education, particularly in the context of the 21st-century digital transformation, which emphasizes critical thinking, problem-solving, collaboration, and technological literacy as essential learning competencies. Educational institutions increasingly integrate digital platforms, interactive applications, and online learning environments to support student-centered learning and flexible instructional practices. These technologies allow educators to design learning environments that combine visualization, interaction, and immediate feedback, often difficult to achieve in traditional classroom instruction. Research shows that digital technologies can improve accessibility of learning materials and promote active participation in physics learning activities (Jugembayeva & Murzagaliyeva, 2022). Technology integration also supports innovative instructional strategies that encourage inquiry and exploration of physical phenomena (Kamarudin et al., 2024). Furthermore, digital learning environments enable collaborative learning and facilitate

knowledge construction through interactive engagement among students (Leow & Neo, 2023; Qureshi et al., 2023).

The integration of digital technology is particularly important in physics education because many physics concepts are abstract and mathematically complex. Students often struggle when they try to apply conceptual knowledge to solve physics problems in unfamiliar situations. Several studies report that students tend to rely on memorizing formulas rather than understanding the underlying physical principles needed for problem solving (Gjerde et al., 2022). This tendency often leads to fragmented conceptual understanding and ineffective reasoning strategies during problem-solving (Braun & Graulich, 2024). Research also indicates that limited conceptual understanding can hinder students' ability to analyze and interpret physics problems systematically (Bouchée et al., 2022; Guerra-Reyes et al., 2024). Recent studies also indicate that technology-rich learning environments in 21st-century learning require students to engage in higher-order thinking. However, many learners still demonstrate low performance in analyzing, evaluating, and applying physics concepts during technology-supported learning, highlighting a gap between technology integration and students' problem-solving competence.

Digital learning technologies offer opportunities to address these challenges by providing interactive learning environments that support conceptual exploration and reasoning in physics learning. Simulation-based platforms enable students to visualize abstract physical phenomena and dynamically manipulate variables. For example, interactive simulations enable students to observe processes such as wave motion, electric fields, or particle interactions that are difficult to represent in conventional classrooms (Ogegbo & Ramnarain, 2022). Studies show that simulation-based environments and virtual laboratories can improve conceptual reasoning and inquiry skills in physics learning (Papalazarou et al., 2024). In addition, technology-supported learning environments encourage students to test hypotheses and evaluate outcomes through experimentation, thereby strengthening conceptual understanding (Kranz et al., 2023).

Besides simulations, gamified digital learning platforms have also attracted significant attention in physics education research. Gamification integrates elements such as challenges, rewards, and immediate feedback into learning activities to increase student engagement. Platforms such as Quizizz and Kahoot allow teachers to conduct formative assessments while encouraging students to actively participate in solving physics problems (Zhang & Crawford, 2024; Maraza-Quispe et al., 2024). Research indicates that gamified learning environments can enhance student motivation and classroom participation during physics instruction (Gaurina et al., 2025). In addition, digital assessment platforms provide immediate feedback that helps students identify misconceptions and refine their reasoning strategies during problem-solving activities (Stanja et al., 2023; Gross et al., 2025).

Despite these advantages, the integration of digital technology in physics education does not always lead to improvements in higher-level cognitive skills, such as analysis, evaluation, and creation, within the higher-order thinking skills required for structured physics problem-solving. Some digital platforms focus primarily on engagement or content delivery rather than on guiding students through the structured reasoning processes required to solve physics problems. Research suggests that the effectiveness of digital technology depends heavily on its integration into instructional design and pedagogical strategies. Without appropriate learning scaffolds, students may interact with digital tools without developing deeper conceptual understanding or systematic problem-solving strategies (Vo et al., 2025). Therefore, digital learning environments should function not only as instructional media but also as learning aids that guide students through structured reasoning processes during physics learning (Santoso et al., 2022). Previous studies also tend to examine digital tools separately, focus on limited learning outcomes, and rarely synthesize how digital learning aid systems collectively support structured problem-solving processes, creating a gap that requires a comprehensive systematic literature review.

To facilitate a deeper understanding of how digital learning aid systems support the development of students' problem-solving skills in physics education, previous literature reviews have primarily focused on specific technologies such as simulations, virtual laboratories, or gamification without systematically comparing their instructional roles as learning aid systems for problem-solving development. In addition, limited reviews synthesize empirical findings across different digital platforms while examining their pedagogical characteristics and the structured reasoning support they provide. This study conducts a systematic literature review of recent empirical studies on digital learning technologies used in physics learning environments. The objective of this study is to analyze the types of digital learning platforms used in physics education, examine their instructional characteristics, and evaluate their reported impact on students' problem-solving skills. This study is necessary to provide an integrated synthesis of digital learning aid systems, identify inconsistencies in previous findings, and highlight research gaps in structured problem-solving support in physics education. This review also aims to identify current research trends and highlight potential directions for future research on the integration of digital learning aid systems in physics education.

RESEARCH METHOD

This study employs a systematic literature review (SLR) design to systematically collect, evaluate, and synthesize empirical findings from previous studies, using a structured review protocol rather than generating primary experimental data. A systematic literature review is not positioned as purely qualitative research, but rather as a structured review method that integrates qualitative synthesis of findings, supported by transparent selection procedures. A systematic literature review identifies, evaluates,

and synthesizes relevant studies in a structured and transparent manner. This approach was selected because research on digital learning aid systems in physics education is fragmented across various technologies, necessitating the synthesis of empirical findings to identify trends, instructional characteristics, and research gaps related to students' problem-solving skills.

This approach allows researchers to examine research trends and theoretical developments related to a specific topic. According to Lim (2025), qualitative research is conducted to understand phenomena in depth through systematic analysis. Meanwhile, literature reviews focus on collecting research data from scientific publications, such as journal articles, books, and academic databases (Chigbu et al., 2023). To ensure methodological transparency and rigor, this study follows a structured SLR procedure adapted from PRISMA guidelines, which organizes the review process into identification, screening, eligibility, and inclusion stages. The PRISMA framework, adapted from Dwikoranto et al. (2025) and Lintangesukmanjaya et al. (2025), was adopted because it provides a transparent procedure for reporting article identification, screening, eligibility assessment, and inclusion in systematic review studies.

The data sources for this research were obtained from reputable academic databases, including Google Scholar and international journals indexed in Scopus. The initial search identified 312 articles, comprising 214 from Google Scholar and 98 from Scopus-indexed journals. The article search process used several keywords related to the research topic. The keywords applied in the search process include the following terms: digital learning; technology integration in education; educational technology in higher education; digital learning effectiveness; and technology-based learning. The search focused on articles published within the last five years (2021–2025) to ensure the selected studies reflect recent developments in educational research. Boolean operators (AND, OR) were applied to refine the search strings, such as “digital learning AND physics education”, “technology integration AND problem solving”, and “digital learning systems OR educational technology AND physics learning”. The screening process consisted of several stages: duplicate removal, title screening, abstract screening, and full-text eligibility assessment. A structured search protocol was applied to ensure consistency in identifying relevant studies across databases, including the use of Boolean operators (AND, OR) and predefined search strings. After duplicate removal, 276 articles remained. Title screening excluded 142 articles that were not relevant to physics education or digital learning aid systems. Abstract screening further excluded 84 articles that did not examine problem-solving skills. The remaining 50 articles were assessed for full-text eligibility.

The article selection process applied several inclusion criteria. First, the articles must be relevant to the research topic. Second, the articles must be published in international journals indexed in Scopus Quartile 1 (Q1), Quartile 2 (Q2), or Quartile 3 (Q3). These quartile categories were selected to ensure the credibility of the research sources while allowing broader coverage of relevant studies within the limited publication period.

Third, the articles must be written in English and available in full text. In addition, exclusion criteria were applied to remove duplicate articles, non-peer-reviewed publications, and studies that did not explicitly address problem-solving skills or digital learning systems. During the eligibility stage, 30 articles were excluded because they did not meet the quartile requirement, did not provide full-text access, or did not report empirical findings related to problem-solving skills.

The initial search generated a large number of articles from the selected databases. After screening based on titles, abstracts, and inclusion criteria, 20 articles were selected as the final sample for analysis. The number of 20 articles was considered adequate to represent current research trends while allowing a focused, in-depth analysis of the literature. Figure 1 illustrates the data analysis process used in this study. The research procedure is visualized in Figure 1 using a structured flow diagram adapted from the PRISMA framework, which clearly presents the stages of identification, screening, eligibility assessment, and final inclusion of articles. This visualization enhances the clarity and transparency of the article selection process. According to the PRISMA procedure, the identification stage involved retrieving articles from selected databases. The screening stage included duplicate removal, title screening, and abstract screening. The eligibility stage involved a full-text assessment using predefined inclusion and exclusion criteria. The inclusion stage yielded 20 final articles that met all synthesis requirements. This structured process follows PRISMA reporting standards proposed by Page et al. (2021) to ensure transparency and reproducibility of systematic review studies.

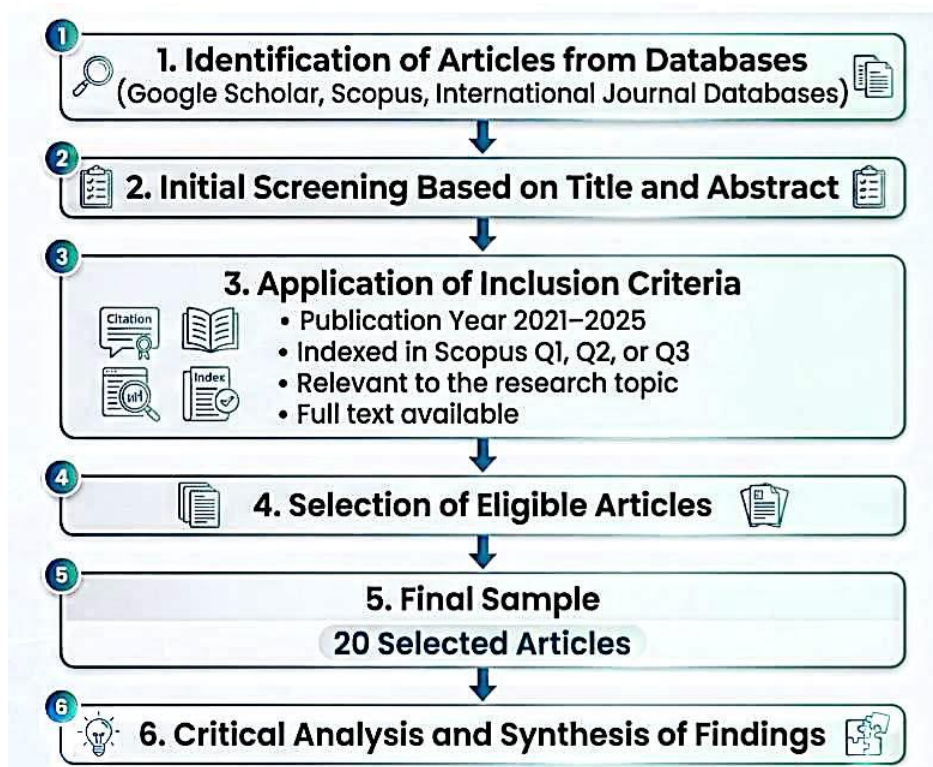


Figure 1. The flow of data analysis.

Research Instruments

This study employed several research instruments to ensure systematic data collection and analysis. First, a search protocol was used as a guideline to identify relevant articles from selected academic databases. Second, inclusion and exclusion criteria were used to filter and select appropriate studies based on relevance, quality, and accessibility. Third, a data extraction sheet was used to systematically record key information from each selected article, including research objectives, methods, types of digital learning tools, instructional features, and findings related to problem-solving skills. Fourth, an analysis framework was developed to categorize and interpret the data into key themes, including conceptual understanding, visualization, inquiry processes, and student engagement. These instruments ensured that the review process was conducted systematically, consistently, and transparently.

After the article selection process was completed, the selected articles were analyzed using critical analysis techniques. Paul & Barari (2022) explain that critical analysis aims to systematically interpret research findings to identify patterns, relationships, and research gaps within the literature. Each selected article was examined across several aspects, including research objectives, research methods, key findings, and implications for the research topic. The results of this analysis were then synthesized to identify similarities, differences, and emerging research trends. The limitations of the screening process included restricting articles to publications between 2021 and 2025, limiting sources to Scopus-indexed Q1 and Q3 journals, including only English-language articles, and excluding studies that did not explicitly report problem-solving outcomes. These limitations were applied to maintain data quality while acknowledging potential exclusion of relevant studies outside the defined criteria. The predefined analysis framework guided the synthesis process to ensure consistent interpretation of findings across studies. This approach strengthens the validity and reliability of the conclusions drawn from the literature.

RESULTS AND DISCUSSION

Results

The integration of digital learning technologies into physics education plays a key role in improving students' problem-solving abilities, particularly in addressing the abstract, mathematically complex nature of physics concepts. Digital tools such as simulations, virtual laboratories, augmented reality, and intelligent learning platforms provide interactive environments that enhance visualization, support conceptual understanding, and guide structured problem-solving processes. Research trends from 2021 to 2025 show a shift from simulation-based approaches toward more advanced systems involving artificial intelligence, gamification, and adaptive learning platforms, indicating the evolution of digital tools into intelligent learning environments. Overall, these technologies not only improve conceptual understanding but also strengthen

analytical thinking, reasoning, and independent learning skills, which are essential for higher-order thinking in physics education.

The following section presents a synthesis of previous studies examining the role of digital learning aid systems in supporting students' problem-solving skills in physics learning, as summarized in Table 1. This study included 20 articles that met all predefined inclusion criteria, including publication years between 2021 and 2025, publication in Scopus-indexed Q1-Q3 journals, an empirical research design, and an explicit discussion of digital learning systems related to problem-solving skills. The selection of 20 articles also aligns with systematic literature review practices that emphasize depth of analysis and rigorous screening rather than large sample size. After applying PRISMA-based screening procedures, only 20 articles satisfied all eligibility requirements and were therefore considered sufficient to represent recent research trends while enabling a comprehensive synthesis of findings.

Table 1 was constructed to summarize the selected studies by author, year, journal quartile, research method, and key findings, without including full article titles to reduce redundancy and avoid unnecessary textual overlap. This format follows systematic review reporting practices that emphasize synthesis of findings rather than reproduction of bibliographic details, which are already provided in the reference list.

Table 1. Characteristics of Selected Studies.

No	Author	Year	Article Title	Journal/ Quartile	Method	Key Findings
1	Banda, H. J., & Nzabahimana, J.	2021	Effect of Integrating Physics Education Technology Simulations on Students' Conceptual Understanding in Physics: A Review of Literature	Physical review physics education research/ Q1	Literature Review	The study analyzed 31 quasi-experimental and experimental studies that examined the use of PhET simulations in physics learning. The results indicate that simulation-based digital learning significantly improves students' conceptual understanding of abstract physics concepts such as energy, motion, electricity, and waves. Interactive simulations enable students to manipulate variables and observe dynamic scientific phenomena, which strengthens conceptual visualization and inquiry-based learning. The study also reports that digital simulation

No	Author	Year	Article Title	Journal/ Quartile	Method	Key Findings
						environments increase student engagement and reduce misconceptions in physics learning. These findings demonstrate that simulation technologies represent an effective digital learning tool for supporting deeper conceptual understanding in physics education.
2	Espinel-Rubio, G. A., Hernández-Suarez, C. A., & Paz-Montes, L. S.	2021	Digital Portfolio: A Tool for Learning Physics	Journal of Physics/ Q1	Quantitative (Non-experimental design)	This study examined the use of digital portfolios as a learning and assessment tool in physics education. The findings show that digital portfolios support formative assessment and enable students to monitor their learning progress systematically. Students can document their learning activities, reflect on conceptual understanding, and receive feedback from instructors through digital platforms. The results indicate that digital portfolios improve student reflection, support independent learning, and enhance communication between teachers and students within digital learning environments. The study confirms that digital portfolio systems can strengthen digital learning practices by integrating assessment, reflection, and continuous feedback in physics learning.
3	Katanosaka, T., Khan, M.,	2024	PhyGame: An Interactive	International Journal of	Experimental Study	The study developed and evaluated a gamified digital learning system designed to

No	Author	Year	Article Title	Journal/ Quartile	Method	Key Findings
	& Sakamura, K.		and Gamified Learning Support System for Secondary Physics Education	Advanced Computer Science & Applications/ Q3		support physics education at the secondary level. The results demonstrate that the integration of game elements such as challenges, rewards, and interactive simulations significantly increases students' motivation and engagement in physics learning. The gamified platform also enables students to experience physics concepts through virtual experiments that replicate laboratory activities. Students reported higher enjoyment and persistence in solving physics problems when using the gamified system. These findings suggest that gamification can enhance the effectiveness of digital learning by making physics instruction more interactive and motivating.
4	Georgiou, Y., Tsivitanidou, O., & Ioannou, A.	2021	Learning Experience Design with Immersive Virtual Reality in Physics Education	Educational Technology Research and Development/ Q1	Mixed Method	This study explored the integration of immersive virtual reality simulations in physics learning to support students' understanding of the Special Theory of Relativity. The results show that VR environments provide immersive visualization of complex physical phenomena that cannot easily be demonstrated in traditional classrooms. Students who participated in VR-based learning demonstrated improved conceptual understanding and stronger

No	Author	Year	Article Title	Journal/Quartile	Method	Key Findings
						engagement in learning activities. The study also found that immersive digital environments enhance students' curiosity and interest in physics. These findings highlight the potential of virtual reality technologies to support experiential digital learning in science education.
5	Liang, Y., Zou, D., Xie, H., & Wang, F. L.	2023	Exploring the Potential of Using ChatGPT in Physics Education	Smart Learning Environments/ Q1	Exploratory Study	This research examined the potential role of ChatGPT as an artificial intelligence tool in physics education. The results indicate that ChatGPT can assist students in solving physics problems, generating explanations, and creating practice questions. The system can provide step-by-step explanations that help students understand complex calculations and scientific reasoning processes. The study suggests that AI-based digital tools can function as intelligent tutoring systems that support personalized learning and self-directed study. These findings indicate that artificial intelligence technologies can become an important component of digital learning ecosystems in physics education.
6	Hennig, F., Tóth, K., Förster, M., & Bitzenbauer, P.	2024	A New Teaching-Learning Sequence to Promote Secondary School	Physics Education / Q2	Design-Based Research	The study proposed a digital learning sequence that integrates GeoGebra simulations and interactive digital experiments to teach quantum physics concepts. The findings show that digital

No	Author	Year	Article Title	Journal/Quartile	Method	Key Findings
			Students' Learning of Quantum Physics Using Dirac Notation			visualization tools help students understand abstract quantum phenomena that are difficult to observe directly. Students demonstrated improved conceptual reasoning and were able to connect mathematical representations with physical interpretations more effectively. The study also reports a reduction in misconceptions about quantum mechanics after students engaged with interactive simulations. The findings emphasize that digital learning technologies play a crucial role in supporting conceptual understanding in advanced physics topics.
7	Gakime, R. G., Waititu, M. M., & Mwangi, F. G.	2025	Teachers' Perceptions of Digital Game Utilisation in Teaching and Learning Physics Concepts	Journal of Education / Q3	Mixed Method	This study investigated physics teachers' perceptions of digital game-based learning in secondary school classrooms. The findings show that teachers perceive digital games as effective tools for improving visualization of physics concepts and increasing student engagement. Game-based digital learning also encourages active participation and collaborative problem solving during physics instruction. However, the study also identified several barriers to implementation, including limited technological

No	Author	Year	Article Title	Journal/ Quartile	Method	Key Findings
						infrastructure and insufficient teacher training. Despite these challenges, the results indicate that digital game-based learning has strong potential to enhance digital learning practices in physics education.
8	Weiler, D., Burde, J. P., Große-Heilmann, R., Lachner, A., Riese, J., & Schubatzky, T.	2024	Evaluation of a University Seminar on the Use of Digital Media in the Physics Classroom	Journal of Physics/ Q1	Mixed Method	This study evaluated a teacher education seminar designed to improve pre-service teachers' competencies in integrating digital media into physics instruction. The results indicate that participation in the seminar significantly increased teachers' motivation to use digital technologies in classroom teaching. Participants also demonstrated improved awareness of digital pedagogical strategies that support student-centered learning. The findings emphasize that professional development programs play a critical role in preparing teachers to implement digital learning tools effectively. Strengthening teachers' digital competencies is therefore essential for successful integration of digital learning technologies in physics education.
9	Mgeladze, A., & Kapanadze, M.	2025	Integrating TPACK and Collaborative Learning to Enhance Technological	Eurasia Journal of Mathematics, Science and Techno-	Mixed method training program	The study shows that integrating the TPACK framework with collaborative learning activities significantly improves physics teachers' technological proficiency. Teachers who participated in

No	Author	Year	Article Title	Journal/ Quartile	Method	Key Findings
			Proficiency in Physics Education	logy Education / Q2		structured training using mobile applications developed stronger confidence in integrating digital tools into physics instruction. Collaborative projects also created professional learning communities that encouraged knowledge sharing and continuous pedagogical improvement. The findings indicate that combining technological training with collaborative teaching practices helps teachers design more engaging physics learning experiences and improves the effectiveness of technology integration in classrooms.
10	Korur, F., Yerdelen-Damar, S., & Saglam, H.	2021	The Development of an Integrated Scale of Technology Use in Physics (ISTUP)	Research in Learning Technology / Q1	Quantitative instrument development (EFA and CFA)	This study developed and validated a measurement instrument to assess students' frequency of technology use in physics learning. The findings show that students generally use digital tools at a moderate level, but they perceive technology as having a positive influence on their interest and academic achievement in physics. The scale also reveals that students prefer visual and interactive technologies such as simulations and digital applications. The validated instrument provides an important tool for future research examining how technology use relates to student engagement and

No	Author	Year	Article Title	Journal/ Quartile	Method	Key Findings
						learning outcomes in physics education.
11	Banda, H. J., & Nzabahimana, J.	2023	The Impact of Physics Education Technology (PhET) Interactive Simulation-Based Learning on Motivation and Academic Achievement Among Malawian Physics Students	Journal of Science Education and Technology/ Q1	Quasi experimental	The study demonstrates that PhET interactive simulations significantly improve both student motivation and academic achievement in physics topics related to oscillations and waves. Students exposed to simulation-based learning achieved higher post test scores compared with those taught using conventional methods. The intervention also improved several motivational constructs including self-efficacy, active learning strategies, and attitudes toward computer-supported learning. The findings confirm that interactive simulations support conceptual visualization and facilitate deeper understanding of abstract physics phenomena.
12	Cai, S., Liu, C., Wang, T., Liu, E., & Liang, J. C.	2021	Effects of Learning Physics Using Augmented Reality on Students' Self-Efficacy and Conceptions of Learning	British Journal of Educational Technology/ Q1	Quasi experimental	The integration of Augmented Reality technology significantly enhances students' physics learning self-efficacy and promotes higher level conceptions of learning physics. Students using the AR-based application showed stronger conceptual understanding, improved cognitive engagement, and increased willingness to explore complex physics concepts. The study also indicates that AR

No	Author	Year	Article Title	Journal/ Quartile	Method	Key Findings
						environments support interactive learning processes by enabling students to manipulate virtual objects and visualize abstract phenomena, which strengthens motivation and conceptual comprehension.
13	Addido, J., Borowczak, A. C., & Walwema, G. B.	2023	Teaching Newtonian Physics with LEGO EV3 Robots: An Integrated STEM Approach	Eurasia Journal of Mathematics, Science and Technology Education /Q2	Quantitative experimental	The study finds that using LEGO EV3 robotics significantly improves students' conceptual understanding of Newton's second law of motion. Students participating in robotics-based STEM learning activities demonstrated higher interest in physics and stronger motivation to pursue STEM careers. The learning activities also enhanced students' computational thinking skills and problem solving abilities. The results suggest that robotics-based learning environments can effectively connect physics concepts with real-world applications and hands-on experimentation.
14	Kandaga, T., Dahlan, T., Gardenia, N., Darta, & Saputra, J.	2021	A Lesson Study to Foster Prospective Teachers' Disposition in STEM Education	Journal of Physics/ Q1	Qualitative lesson study	This research highlights the importance of integrating digital tools in teacher training to foster positive learning dispositions among prospective teachers. Technology-supported lesson study cycles helped student teachers develop greater interest, contextual awareness, and appreciation of STEM topics. The collaborative

No	Author	Year	Article Title	Journal/ Quartile	Method	Key Findings
						reflection process allowed participants to evaluate how technology can support meaningful learning while maintaining critical thinking processes. The study suggests that carefully designed technology integration can strengthen both pedagogical practice and learner engagement.
15	Holly, M., Pirker, J., Resch, S., Brettschuh, S., & Gütl, C.	2021	Designing VR Experiences : Expectations for Teaching and Learning in Virtual Reality	Education al Technology & Society/ Q1	Mixed method user study	The study examines how virtual reality environments can support physics learning through immersive visualization and interactive simulations. VR allows students to explore complex scientific phenomena that are difficult to observe in traditional classrooms. Participants reported higher engagement and stronger conceptual understanding when interacting with virtual environments. However, the study also identifies design challenges related to usability, pedagogical alignment, and cognitive load, emphasizing the need for well designed VR learning experiences in science education.
16	El Kharki, K., Berrada, K., & Burgos, D.	2021	Design and Implementation of a Virtual Laboratory for Physics Subjects in Moroccan Universities	Sustainability/ Q1	Design-based research with evaluation	The development of a virtual physics laboratory integrated into a Moodle learning environment enabled students to conduct practical experiments through computer simulations. The results indicate that virtual laboratories effectively

No	Author	Year	Article Title	Journal/Quartile	Method	Key Findings
						support conceptual understanding and laboratory skills when physical laboratory access is limited. The environment provides interactive simulation activities that allow learners to observe scientific phenomena and practice experimental procedures.
17	Uden, L., Sulaiman, F., Ching, G. S., & Rosales Jr, J. J.	2023	Integrated Science, Technology, Engineering, and Mathematics Project-Based Learning for Physics Learning from Neuroscience Perspectives	Frontiers in psychology/ Q1	Experimental design	The integrated STEM project-based learning model significantly improved students' beliefs about physics and their attitudes toward learning physics. Students in the experimental group demonstrated more positive learning beliefs compared with those experiencing traditional instruction. The integration of technology and engineering design activities enabled students to apply physics concepts to real-world problems. The findings suggest that technology-supported STEM learning environments strengthen conceptual understanding and support active learning processes.
18	Hung, H. C., & Young, S. S. C.	2021	Unbundling Teaching and Learning in a Flipped Thermal Physics Classroom in Higher	Australasian Journal of Educational Technology/ Q1	Quasi-experimental mixed methods	The study shows that integrating open online learning systems with flipped classroom approaches transforms traditional physics instruction. Students used multiple learning modes including face-to-face, blended learning, online learning, and

No	Author	Year	Article Title	Journal/ Quartile	Method	Key Findings
			Education Powered by Emerging Innovative Technology			flipped learning. The results indicate that technology-supported learning environments allow instructors to adapt teaching strategies to students' diverse learning preferences. Students also demonstrated improved engagement and flexibility in accessing learning materials through digital platforms.
19	Klein, P., Ivanjek, L., Dahlkemper, M. N., Jeličić, K., Geyer, M. A., Kuchemann, S., & Susac, A.	2021	Studying Physics During the COVID-19 Pandemic: Student Assessments of Learning Achievement and Online Laboratories	Physical review physics education research/ Q1	Survey study	The transition to online physics learning during the pandemic revealed that digital platforms can support learning achievement when accompanied by strong communication and self-regulated learning strategies. The study found significant correlations between self-organization skills, communication abilities, and perceived learning achievement in online physics courses. Online recitations and virtual laboratory activities enabled students to continue learning physics concepts despite the absence of physical classroom interaction.
20	Essel, H. B., Vlachopoulos, D., Tachimenson, A., Johnson, E. E., & Baah, P. K.	2022	The Impact of a Virtual Teaching Assistant (Chatbot) on Students' Learning in Higher Education	International Journal of Educational Technology in Higher Education /Q1	Experimental design	The integration of an AI-based virtual teaching assistant improved students' academic performance and learning interaction. Students who used the chatbot performed better in achievement tests compared with those who interacted only with instructors. The chatbot provided instant responses to

No	Author	Year	Article Title	Journal/ Quartile	Method	Key Findings
						questions and supported continuous learning outside classroom hours. The results highlight the potential of artificial intelligence technologies to support personalized learning and improve student engagement in technology-enhanced education environments.

Discussion

The findings of this systematic literature review indicate that digital learning aid systems play a significant role in supporting students' problem-solving skills in physics education. The reviewed studies consistently demonstrate that digital tools are not only used as supplementary learning resources but also function as structured learning environments that facilitate conceptual understanding, visualization, inquiry processes, and student engagement. These findings are consistent with previous studies reporting that digital learning environments improve conceptual reasoning and structured problem-solving when learners interact with simulations, virtual laboratories, and AI-supported platforms (Banda & Nzabahimana, 2023; Cai et al., 2021; Liang et al., 2023). These elements collectively contribute to the development of effective problem-solving abilities in physics learning contexts.

One of the main contributions of digital learning aids is their ability to enhance students' conceptual understanding. Physics concepts often involve abstract principles that are difficult for students to grasp through conventional instruction alone. Digital learning systems provide structured explanations, guided tasks, and interactive content that help students connect theoretical concepts with real phenomena. When students understand the underlying principles of physics problems, they can identify variables, interpret relationships, and formulate appropriate solution strategies. This conceptual clarity serves as the foundation for effective problem-solving. Previous research also confirms that simulation-based learning and virtual laboratory environments significantly improve conceptual understanding and reduce misconceptions in abstract physics topics (Banda & Nzabahimana, 2021; El Kharki et al., 2021). These findings support the argument that conceptual understanding, mediated by digital tools, directly contributes to improved problem-solving performance.

In addition to conceptual understanding, visualization features embedded in digital learning systems significantly support students in interpreting complex physical phenomena. Many physics concepts involve motion, force interactions, energy transfer,

or field representations that cannot be directly observed. Interactive visualizations, animations, and graphical representations enable students to observe dynamic processes that illustrate how physical systems behave. These visual representations reduce cognitive load and allow students to build accurate mental models. As a result, students can analyze problems more effectively and determine solution steps with greater confidence. This result aligns with studies showing that augmented reality, immersive virtual reality, and interactive simulations improve students' mental model construction and analytical reasoning in physics learning (Georgiou et al., 2021; Cai et al., 2021; Holly et al., 2021). Visualization-supported environments, therefore, function as cognitive scaffolds that assist students in translating abstract physics concepts into structured problem-solving strategies.

Another important aspect identified in the reviewed literature is support for inquiry-based learning processes. Digital learning aid systems often integrate structured inquiry activities that guide students through stages of problem identification, hypothesis development, experimentation, and conclusion drawing. Interactive simulations allow students to manipulate variables and observe the consequences of their actions in real time. This process encourages students to test ideas, analyze outcomes, and revise their reasoning. Such inquiry-based experimentation aligns closely with scientific problem-solving processes and helps students develop analytical thinking skills required in physics learning. Previous studies also demonstrate that technology-supported inquiry learning significantly improves students' analytical thinking, experimental skills, and scientific reasoning during physics problem-solving (Uden et al., 2023; Addido et al., 2023). These findings reinforce the role of digital learning systems in facilitating structured inquiry processes that support the development of problem-solving skills.

Furthermore, digital learning systems promote higher levels of student engagement. Interactive environments, immediate feedback mechanisms, and adaptive learning pathways increase students' motivation and participation during learning activities. Engagement is an important factor in problem-solving development because students must actively interact with problems, test different approaches, and reflect on their results. Feedback systems embedded in digital platforms provide instant responses to student inputs, allowing learners to recognize mistakes and adjust their strategies. This iterative process strengthens students' ability to approach complex problems systematically. Research on AI-based tutoring systems and gamified learning platforms also indicates that immediate feedback and adaptive learning significantly improve persistence, engagement, and iterative problem-solving behaviors (Katanosaka et al., 2024; Essel et al., 2022). These findings support the argument that engagement mediated by digital feedback systems improves problem-solving competence.

The integration of conceptual explanations, visualization tools, inquiry-based experimentation, and feedback systems demonstrates that digital learning aids function as comprehensive learning ecosystems rather than simple instructional media. These systems support students throughout the entire problem-solving cycle, including

understanding the problem, exploring possible solutions, testing strategies, and evaluating outcomes. This comprehensive role reflects the shift toward digital transformation in physics education, where digital platforms function as intelligent learning environments that integrate visualization, inquiry, feedback, and adaptive guidance within a single ecosystem (Liang et al., 2023; Mgeladze & Kapanadze, 2025). Therefore, digital learning aid systems represent an effective pedagogical approach for improving physics problem-solving skills in modern educational environments.

However, several challenges remain. Some studies highlight that the effectiveness of digital learning systems depends heavily on instructional design and teacher facilitation. Without clear learning guidance, students may focus more on technological features than on conceptual reasoning. In addition, differences in technological access and digital literacy may influence the implementation of digital learning tools in various educational contexts. To address these limitations, this study proposes shifting the digital learning paradigm in physics from a technology-centered approach to a problem-solving-oriented digital ecosystem. This paradigm emphasizes structured scaffolding, adaptive feedback, guided inquiry, and collaborative digital experimentation as core components of physics learning environments. Such transformation aligns with recent research recommending the integration of AI-assisted tutoring, immersive visualization, and inquiry-based simulations to support higher-order thinking and scientific reasoning (Weiler et al., 2024; Klein et al., 2021).

Future research should therefore explore the design of digital learning environments that more explicitly integrate problem-solving scaffolds, adaptive feedback systems, and collaborative inquiry features. Empirical studies are also needed to examine how specific digital learning components influence different dimensions of problem-solving skills, such as conceptual reasoning, strategy formulation, and solution evaluation. Investigating these aspects will help educators design more effective digital learning systems that support physics education in the twenty-first century. Future digital transformation in physics education is expected to move toward intelligent, adaptive, and personalized digital learning environments that integrate artificial intelligence, immersive simulations, and real-time analytics to support continuous problem-solving development. Previous studies indicate that AI-based assistants, virtual laboratories, and immersive learning platforms can create flexible learning pathways and provide personalized feedback, thereby strengthening students' independent problem-solving skills (Essel et al., 2022; Liang et al., 2023). Therefore, future digitalization development should focus on designing integrated digital learning ecosystems that support conceptual understanding, inquiry processes, and adaptive guidance in problem-solving in physics education.

CONCLUSION

Fundamental Finding : This systematic literature review shows that digital learning aid systems strengthen students' problem-solving skills in physics learning. The reviewed

studies indicate that digital tools improve conceptual understanding, support visualization of abstract phenomena, facilitate inquiry processes, and increase student engagement. These features help students analyze problems, explore variables, test solution strategies, and interpret results more systematically. **Implication:** The findings highlight the importance of integrating digital learning systems into physics instruction. Well-designed simulations, feedback systems, and interactive environments can support active learning and improve students' analytical and problem-solving abilities. This review indicates that the effectiveness of digital learning in physics emerges when conceptual scaffolding, visualization, inquiry activities, and adaptive feedback are integrated within a single digital learning environment. This integrated structure provides a practical framework for designing digital physics instruction that directly supports structured problem-solving processes rather than relying solely on digital tools for content delivery. **Limitation:** This review analyzed studies with different research designs, digital platforms, and learning contexts. **Future Research:** Further empirical studies should examine specific digital features that most effectively support physics problem solving skills.

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AUTHOR CONTRIBUTIONS

Each author contributed to this study in accordance with the Contributor Roles Taxonomy (CRediT). **Qurrota A'yun** contributed to the conceptualization of the study, research design, literature review supervision, and overall manuscript validation. **Dwikoranto** was responsible for methodology development, data analysis, interpretation of findings, and critical revision of the manuscript. **Rahmatta Thoriq Lintangesukmanjaya** contributed to data collection, reference management, literature screening, and manuscript drafting. **Imam Sya'roni** contributed to data validation, quality assessment of selected articles, methodological refinement, and enhancement of the analytical framework. All authors reviewed, revised, and approved the final version of the manuscript prior to submission.

CONFLICT OF INTEREST STATEMENT

The authors declare that there are no conflicts of interest, either financial or personal, that could have influenced the research process, analysis, or interpretation of the findings presented in this study.

ETHICAL COMPLIANCE STATEMENT

This manuscript adheres to established research and publication ethics. The authors confirm that the work is original, conducted with academic integrity, and free from any form of unethical practice, including plagiarism, data fabrication, or data manipulation.

STATEMENT ON THE USE OF AI OR DIGITAL TOOLS IN WRITING

The authors acknowledge the limited use of digital tools, including AI-based technologies, as minor assistance during the writing and language refinement stages of this manuscript. Specifically, AI tools such as ChatGPT (OpenAI) and Grammarly were used to support language editing, grammar correction, and sentence clarity improvement. AI tools were used only to support language editing and sentence clarity. All ideas, research design, data interpretation, and academic arguments were developed entirely by the authors. Every AI-assisted output was carefully reviewed, edited, and verified to ensure accuracy, originality, and compliance with academic and ethical standards. Full responsibility for the final content of this manuscript rests solely with the authors.

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