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The Future of Science in The Hand: A Review Literature of Mobile Learning from 2015-2024

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ABSTRACT
This study investigates trends in mobile learning based on data from international publications. Data were collected from the Scopus database covering the period 2015–2024, resulting in a total of 174 selected articles. A systematic literature review (SLR) was employed to synthesize ideas, findings, and knowledge in an academic-oriented framework. The study aimed to analyze annual publication trends, leading contributing countries, targeted skills, educational levels adopting mobile learning, and technologies or applications supporting mobile-based science education. The findings indicate a notable increase in publications in 2020, with the United States contributing the largest share of research. Technologies and applications supporting science learning primarily included virtual reality (VR), augmented reality (AR), and STEM-oriented tools. Mobile learning was found to enhance skills such as conceptual understanding, digital literacy, and science process skills. Among educational levels, mobile learning was most widely implemented in higher education, followed by elementary, middle, and secondary schools. Overall, mobile learning demonstrates potential in fostering essential skills within science and technology education. These findings can inform future strategies and innovations for the effective integration of mobile learning in science curricula.

Keywords: *mobile learning, science learning, educational skills, learning methods, education level.*

INTRODUCTION

Mobile learning has emerged as an innovative approach to enhance accessibility and flexibility in the teaching and learning process. This approach contributes to technological advancement by integrating new forms of interaction and learning (Alam & Mohanty, 2023; Arrasyid, 2020). Additionally, mobile learning facilitates students and teachers in navigating the evolving landscape of distance education (Sobral, 2020; Elfeky & Elbyaly, 2023; Ewais et al., 2021). Beyond its practical applications, mobile learning supports education for sustainable development and promotes sustainable citizenship (Sebastián-López & González, 2020). In this context, modern information technologies have the potential to transform how people think, live, and learn (Nanning et al., 2020; Hwang et al., 2021; Turan & Yaman, 2022; Cahyana et al., 2020; Bolatli & Kizil, 2022).

Mobile learning enables access to educational game-based pedagogy, quizzes, and mobile virtual worlds, thereby expanding the availability and diversity of learning materials (Criollo et al., 2018; Baharum et al., 2020; El-Sofany et al., 2020; Huang et al., 2020; Kousloglou et al., 2023; Salami & State, 2021; Yıldız et al., 2024; Qureshi et al., 2020). Mobile devices provide novel communication and interaction methods and can also be used for field-based data collection and analysis (Whitmeyer et al., 2020; Sirisathitkul & Sirisathitkul, 2023). Importantly, mobile learning ensures near-unlimited access to resources, supporting continuous engagement in the learning process (Yosiana et al., 2021; Gupta et al., 2021).

The implementation of mobile learning has a significant impact on students' outcomes, particularly in science education. It influences variables such as self-directed learning skills and understanding of technological concepts (Mahasneh, 2020). Moreover, it enhances communication and collaboration (Ayu et al., 2021; Dwikoranto et al., 2020; Bayar, 2018), which in turn affects academic achievement (Lestari et al., 2019; Amin et al., 2022). Ethnopedagogy-based mobile learning approaches further support students in comprehending learning content (Rochmah et al., 2021; Nuri et al., 2023). Nevertheless, while mobile learning effectively conveys knowledge and skills, fostering moral and ethical development through these platforms remains a challenge (Isrokatun et al., 2023). Previous studies highlight technology as a connecting medium in educational activities. Online distance mobile learning allows students to engage in practical work and demonstrations, enriching the learning context (Singh-Pillay, 2023; Afikah et al., 2022; Boari et al., 2023; Schaal & Lude, 2015). Furthermore, this method simplifies the learning process through collaboration between teachers and students (Zhai & Jackson, 2021; Hamdu et al., 2021).

The potential of mobile learning in science education is considerable, as it can transform how students understand and interact with scientific concepts. Mobile learning facilitates a more interactive, personalized, and adaptive learning experience, aligning with technological advancements and the accessibility of mobile devices (Vallejo-Correa et al., 2021). It also enables the development of essential skills tailored to different educational levels. However, challenges remain, including technology access disparities, varying digital competencies of teachers and students, and differences in the effectiveness of learning strategies across diverse contexts.

This study provides a comprehensive overview of mobile learning in science education from 2015 to mid-2024. A systematic search of Scopus-indexed journals revealed that only a limited number of studies have specifically examined the trends, developmental trajectories, and analytical directions of mobile learning within science education. Although Scopus is a leading international database indexing high-quality research across disciplines, the findings highlight a significant gap: no study to date has systematically mapped the evolution, thematic focus, and research direction of mobile learning in science over the past decade.

This gap indicates a lack of integrated analyses that can inform educators, researchers, and policymakers about how mobile learning has been conceptualized, implemented, and evaluated in science education globally. Therefore, this research addresses this gap by conducting a structured literature review of Scopus-indexed articles published between 2015 and mid-2024, aiming to answer the following research questions and provide a clear direction for future scientific inquiry and innovation in mobile learning: (1) What are the annual research trends related to mobile learning in science? (2) Which countries contribute the most to mobile learning research in science? (3) What skills can be developed through mobile learning in science education? (4) Which educational levels implement mobile learning most extensively? (5) What technologies and applications are used to support mobile-based science learning at each educational level?.

METHODOLOGY

Research Design

This study employed a Systematic Literature Review (SLR) approach to rigorously collect, evaluate, and synthesize evidence on the implementation of mobile learning in science education from 2015 to mid-2024. The SLR methodology was chosen due to its ability to ensure transparency, replicability, and methodological rigor through a structured process of identifying, assessing, and synthesizing primary studies (van Dinter et al., 2021). The analysis focused on several key indicators, including annual publication trends, geographical distribution of research, educational levels most frequently adopting mobile learning, competencies or skills targeted, and learning models commonly integrated with mobile learning in science contexts. These indicators were selected to provide a comprehensive mapping of mobile learning as a pedagogical innovation and to identify existing gaps in the literature.

Article Identification and Search Strategy

A comprehensive search was conducted in the Scopus database, a globally recognized index for high-impact, peer-reviewed publications across various disciplines. The search utilized targeted keywords, including "mobile learning for science education" and "mobile learning for science," to ensure precise retrieval of relevant studies. To enhance the accuracy and relevance of the selection process, a manual screening was performed by examining titles, abstracts, keywords, and, when necessary, full-text content. Only studies explicitly situated within the domain of science education were considered. Research focusing on other disciplines or on general digital learning without specific reference to mobile platforms was excluded.

Inclusion Criteria

Inclusion criteria were established based on the study objectives to systematically filter relevant articles (Yanti & Anas Thohir, 2024). Articles eligible for review were required to: (1) be written in English; (2) be published in peer-reviewed journals or reputable conference proceedings between January 2015 and July 2024; (3) focus directly on mobile learning within science education; and (4) provide empirical or conceptual contributions relevant to the research questions. This time frame was selected to capture recent developments in mobile learning, reflecting rapid technological advancements and the widespread adoption of mobile devices in educational contexts.

Data Analysis

The initial search yielded 174 publications that matched the defined keywords through Scopus's advanced search features. Data were systematically extracted from each article, including bibliographic information, research variables, methodologies, and main findings, into a predesigned coding sheet. During the initial screening phase, duplicates and studies outside the scope of science education were filtered using a combination of database tools and manual verification. A multi-stage screening process followed, including examination of titles, abstracts, and full texts, to ensure methodological relevance and thematic alignment. Two independent reviewers performed content analysis to categorize themes and detect emerging patterns, maintaining inter-rater reliability through consensus meetings to resolve any discrepancies. After applying inclusion and exclusion criteria, 148 articles were excluded due to irrelevance, duplication, or insufficient alignment with the research objectives. Ultimately, 26 articles were retained for detailed analysis using descriptive statistics and thematic synthesis.

Relevance Evaluation and Data Synthesis

The 26 selected articles underwent full-text review to extract key data aligned with the study objectives. Extracted information was systematically organized in an Excel database to facilitate categorization and identification of patterns across variables, such as country, educational level, mobile learning strategies, and reported outcomes. In cases where relevance was unclear, independent evaluations were conducted to ensure validity of inclusion. This structured synthesis enabled the identification of prevailing trends, methodological approaches, and thematic gaps in the existing literature, providing robust evidence for the development of mobile learning research in science education. The findings not only highlight progress achieved in the field but also pinpoint critical gaps that warrant further investigation, guiding future research and innovation in mobile-based science learning..

RESULT AND DISCUSSION

Annual Research Trends Related to Mobile Learning From 2015 to Mid-2024

This study collected data by identifying and evaluating publications related to science learning through mobile learning from 2015 to mid-2024. The analysis was conducted in alignment with the research objectives. Mobile learning represents a key component of 21st-century educational approaches, as mobile devices have become integral to daily life (Maxmudovna, 2023). Consequently, the number of mobile users continues to rise, highlighting the need for teachers to effectively integrate these technologies into their instructional practices (Bunterm et al., 2018; Elfeky & Elbyaly, 2023; Suhardi, 2022). This framework underscores the critical importance of combining mobile learning with pedagogical strategies and content knowledge to enhance both teaching effectiveness and the overall learning experience.

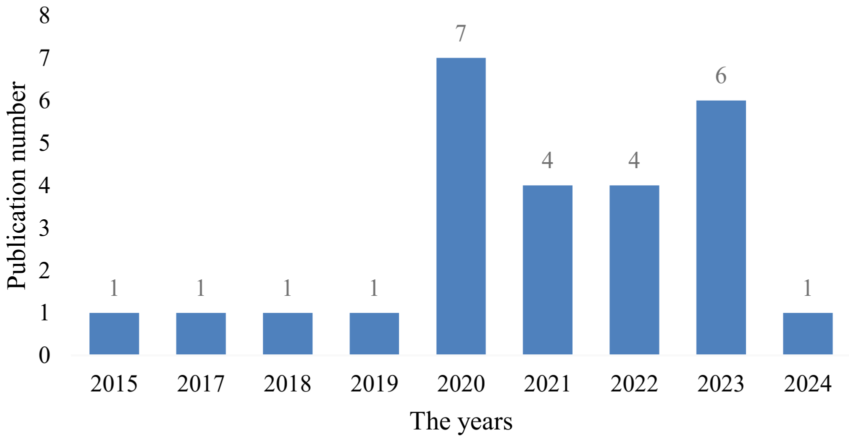

Figure 1: Publications Number Related to Mobile Learning in Science Learning

Mobile learning has experienced rapid development and is increasingly gaining attention in science education research. Figure 1 illustrates the number of publications on mobile learning in science from 2015 to mid-2024. Although research in the early years was limited, a marked increase occurred in 2020, largely driven by the widespread adoption of digital technologies during the COVID-19 pandemic. The pandemic accelerated the integration of technology into daily life and posed challenges for educators in implementing effective distance learning (Turan & Yaman, 2022). Adapting science education to virtual formats using technological tools has been shown to enhance learning effectiveness (Kolokouri et al., 2021; Fathurohman et al., 2023), demonstrating the resilience of mobile learning in overcoming the constraints of traditional classroom delivery. Following the peak in 2020, publication numbers stabilized with a slight decline in subsequent years, before increasing again in 2023.

This publication trend underscores the growing significance of mobile learning in science education. Mobile technologies offer flexible access to learning resources, enhance interactivity, and support richer learning experiences through educational applications, virtual simulations, and other digital tools. Such methods facilitate student engagement and communication, contributing to improved learning outcomes and overall quality of life (Talan, 2020; Traxler, 2021; Galkina et al., 2020). The increasing volume of research reflects a rising interest in exploring and optimizing mobile learning to maximize its potential for student achievement. With ongoing technological advancements and greater accessibility to mobile devices, mobile learning is expected to remain a prominent focus in science education research and practice.

The Country that Contributes the Most Publications Related to Mobile Learning

The search results show that 26 articles were published related to mobile learning for science. Table 1 presents a comparison of the number of publications in each country over the past 10 years.

Table 1: The Country that Contributes the Most Publications from 2015 to Mid-2024

No	The Country	Papers (N)	Percentages (%)
1	America	5	19.23
2	Indonesia	4	15.38
3	Germany	3	11.53
4	China	1	3.84
5	Swiss	1	3.84
6	Yunani	1	3.84
7	South Africa	1	3.84
8	Ecuador	1	3.84
9	Thailand	1	3.84
10	Spain	1	3.84
11	Italy	1	3.84
12	Portugal	1	3.84
13	Estonia	1	3.84
14	Poland	1	3.84
15	Hungary	1	3.84
16	Taiwan	1	3.84
17	Spain	1	3.84
	Total	**26**	**100**

Mobile learning has emerged as a prominent research topic across multiple countries, as evidenced by publication data. Table 1 shows that the United States leads with the highest proportion of publications (19.23%), followed by Indonesia (15.38%) and Germany (11.53%). Other contributing countries, including China, Switzerland, Greece, South Africa, Ecuador, Thailand, Spain, Italy, Portugal, Estonia, Poland, Hungary, and Taiwan, collectively accounted for 3.84% of the total publications. This distribution highlights the global recognition of mobile learning's potential to enhance science education. The United States and Indonesia, which have the largest number of publications, demonstrate a strong commitment to educational innovation by leveraging mobile learning to expand access, increase interactivity, and improve student learning outcomes.

European countries such as Germany, Switzerland, and Italy, along with Asian nations including China and Taiwan, illustrate that research on mobile learning is not confined to a single region, reflecting a collaborative international effort to explore and implement mobile learning strategies. Technological advancements further support these initiatives by enabling the assessment of collaborative problem-solving and interactive learning using mobile devices (Becker et al., 2021). Methodologically, this body of research is predominantly characterized by quasi-experimental designs targeting high school students, emphasizing the evaluation of mobile learning interventions in structured educational settings (Nugroho et al., 2023).

Skills Achieved Through Mobile Learning for Science Education

Mobile learning becomes the main focus and shows various aspects of skills in the context of science learning. Figure 2 shows the skills achieved through mobile learning in science.

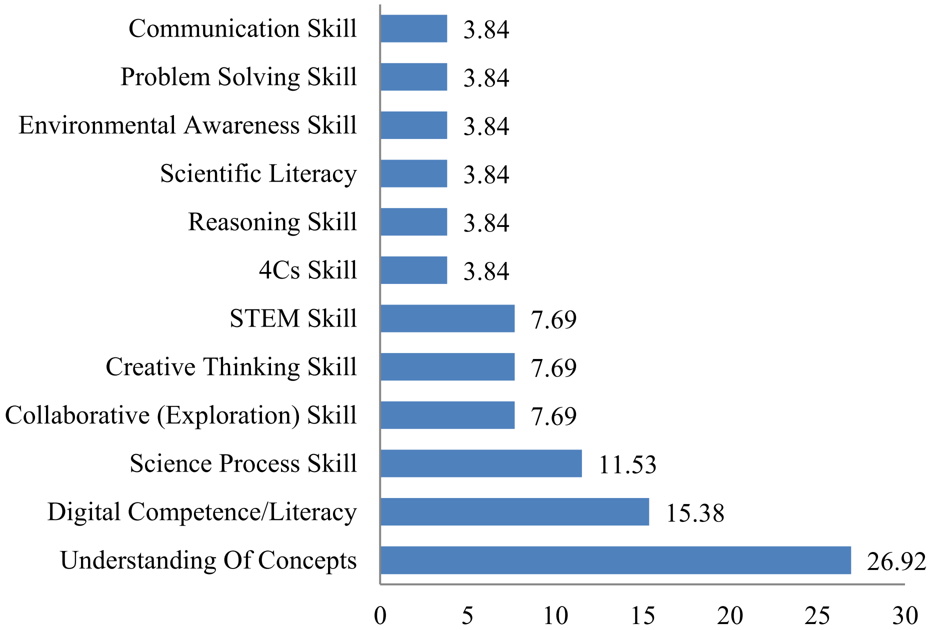

Figure 2: Skills Achieved Through Mobile Learning

Skills developed through mobile learning are diverse, with concept mastery emerging as the most frequently addressed, accounting for 26.92% of the reviewed studies. This highlights the significant emphasis placed on using mobile learning to support students in effectively mastering scientific concepts. Burke (2021) notes that integrating mobile learning positively influences students' learning experiences, with authentic experiences fostering active engagement in the learning process. Similarly, teacher facilitation through blended face-to-face and online interactions has been shown to enhance students' comprehension of complex scientific concepts (Oppong et al., 2022). Moreover, Android-assisted mobile learning offers innovative, creative, and effective instructional approaches that promote higher-order thinking skills in science education, particularly during the new normal era (Laelasari et al., 2025).

The second most prominent skill is digital competence and literacy, representing 15.38% of the studies, underscoring the importance of digital literacy in the effective use of mobile technologies for science learning. Science process skills, including observation, experimentation, and data analysis, accounted for 11.53%, demonstrating that mobile learning can facilitate practical and analytical scientific competencies. Collaborative skills, creative thinking, and STEM-related skills collectively represented 7.69%, indicating the use of mobile learning to foster teamwork, innovation, and integrated problem-solving in modern science education. Additional competencies, including conceptual understanding, problem-solving, and the 4Cs (critical thinking, creativity, collaboration, and communication), contributed 3.84% of the research focus.

Overall, the primary emphasis remains on concept mastery and digital literacy, as mobile learning demonstrates substantial potential to enhance a wide range of skills relevant to science education. Other skills identified in the literature include reasoning, scientific literacy, environmental awareness, problem-solving, and communication, each contributing 3.84% of the focus (Sundari & Sarkity, 2021; Väljataga & Mettis, 2022). Mobile learning has also been shown to support successful implementation of STEM education (Mutambara et al., 2015). Furthermore, computer-based collaborative learning using mobile devices has been proposed for pre-service teachers to strengthen social interaction, networking, and emotional intelligence, highlighting the broader potential of mobile technologies in academic settings (Wetcho & Na-Songkhla, 2022). These findings collectively demonstrate that mobile learning can enhance both cognitive and socioemotional aspects of students' development, contributing to more holistic science education outcomes.

Educational Levels that Use Mobile Learning for Science Education

The utilization of mobile applications has become an increasingly important component of higher education. Younger prospective teachers tend to show a greater preference for mobile learning compared to professionals already active in the workforce (Ateş & Garzón, 2022). Mobile learning has thus emerged as a critical element in tertiary education (Al-Rahmi et al., 2021), largely due to universities' superior facilities and infrastructure, which provide enhanced opportunities for integrating mobile technologies into instructional practices (Nuhu et al., 2022).

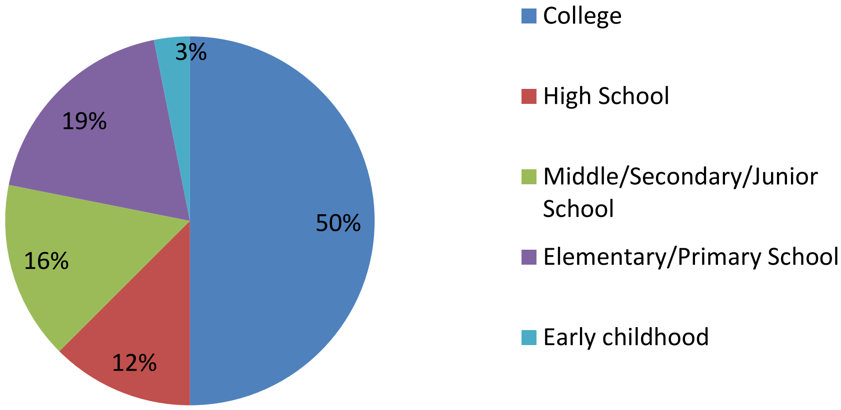

Figure 3: Educational Levels that Use Mobile Learning

Figure 3 illustrates the distribution of mobile learning usage in science education across different educational levels. The most prominent adoption is observed at the tertiary level, accounting for 50% as represented by the largest segment of the pie chart. This indicates that higher education students more frequently utilize mobile technologies to support science learning. At this level, mobile learning significantly enhances engagement with educational content and learning outcomes. For instance, the development of interactive multimedia-based instructional materials demonstrates the effective integration of technology in science education (Affriyenni et al., 2021).

Mobile learning is also notably implemented at the elementary school level, where it serves as a recognized and engaging tool for younger students. In this context, tablets and interactive applications are often employed to facilitate understanding and make learning more enjoyable. Conversely, the adoption at junior high and high school levels is comparatively smaller, as mobile learning is generally in the introductory or adaptation stages. Students at these levels typically begin using mobile devices for more complex science projects, simulations, and collaborative learning activities. In early childhood education, the use of mobile learning is minimal due to constraints in age-appropriate content and technological readiness. Nevertheless, augmented reality (AR) applications can offer interactive and stimulating learning experiences even for younger learners.

Although mobile learning demonstrates substantial potential for supporting science education across all levels, its adoption varies considerably. Stronger implementation is evident in higher education, where access to technological resources and infrastructure is more readily available. This pattern highlights both the opportunities and challenges in integrating mobile learning across diverse educational contexts, emphasizing the need for tailored strategies to maximize its benefits for students at each level of education.

Technologies and Applications that Support Mobile-Based Science Learning at Every Level of Education

The use of mobile learning in the science education process varies depending on the level of education. The types used according to the level of education are shown in Table 2.

Table 2: Technologies and Applications Supporting Mobile Device-Based Science Learning

No	Level of Education	Technology and Applications
1	College	Virtual Reality (VR), Augmented Reality (AR), FieldMove, Evernote, Notability, Joint Visual Attention (JVA), Geographic Information System (GIS), Smartphones in STEM, Application using the Nature of Science, M-Learning, Quizzes, Web-Based Learning, Blended Mobility, Robot Platform—named PlatypOUs, Digital Game-Based Learning (DGBL).
2	High School	Geoarchaeology, Mobile Lab Coalition (MLC), Mobile electronic devices (MED) with integrated GPS.
3	Middle/Secondary/ Junior School	Mobile electronic devices (MED), Collaborative Inquiry-Based Mobile Outdoor, inquiry-based learning (IBL) that supports active learning through mobile technology (mIBL)
4	Elementary/ Primary School	STEMpedia's mobile, Mobile Microscope, Tablet Computers, Mobile Augmented Reality (MAR), Mobile Lab Coalition (MLC).
5	Early childhood	Mobile Augmented Reality (MAR).

At the tertiary level, mobile learning (m-learning) incorporates advanced technologies such as virtual reality (VR) and augmented reality (AR), alongside specialized applications including FieldMove, Evernote, and Notability. Additional methods include Joint Visual Attention (JVA), Geographic Information Systems (GIS), and the use of smartphones for STEM learning. Science-focused applications and web platforms, such as quizzes and web-based learning environments, are also widely employed. Furthermore, blended mobility initiatives, robotic platforms such as PlatypOUs, and digital game-based learning (DGBL) are implemented to enrich the learning experience. PlatypOUs, in particular, provides a specialized platform for STEM education, equipped with navigation and mobility tools, facilitating the preparation of prospective science teachers for future mobile learning applications (Rácz et al., 2022).

At the high school level, mobile learning is supported by applications such as Geoarchaeology, Mobile Lab Coalition (MLC), and Mobile Electronic Devices (MED) integrated with GPS functionalities (Kilty & Burrows, 2020; Bakri et al., 2023). In junior high schools, the use of electronic mobile devices remains predominant, supporting collaborative inquiry-based outdoor learning and inquiry-based learning (IBL) strategies that promote active student engagement. For elementary school students, mobile learning is facilitated through STEMpedia's mobile applications, mobile microscopes, tablets, Mobile Augmented Reality (MAR), and MLC. Future-oriented science learning initiatives suggest the use of mobile microscopes to encourage hands-on exploration of science in outdoor environments (Chou & Wang, 2021). Mobile game-based learning also represents an ideal medium for this age group, as such applications closely align with students' daily experiences, demonstrating the potential to enhance scientific understanding and engagement while addressing gaps in current educational innovation research (Brown et al., 2018). In early childhood education, Mobile Augmented Reality (MAR) is currently the primary technology employed. MAR provides interactive experiences with engaging visual content suitable for young learners, supporting early cognitive and material comprehension (Lo et al., 2021).

Overall, mobile learning exhibits broad and innovative adaptations across educational levels, with each level integrating technology that is developmentally appropriate to enhance engagement and learning in science (Jones & Stapleton, 2017). Nevertheless, further research is necessary to optimize adaptive mobile learning models for long-term knowledge retention, transferability across contexts, and equitable access for diverse student populations. Future studies could examine differences in learning outcomes across educational stages, evaluate the effectiveness of mobile-based differentiated instruction, and identify pedagogical design principles that promote sustained and deeper understanding of scientific concepts.

CONCLUSION

This review of 26 articles published between 2015 and mid-2024 on mobile learning in science education reveals a clear upward trend in research interest. The peak in publications occurred in 2020, reflecting heightened attention to digital technologies in education during the COVID-19 pandemic. This trend underscores the growing recognition of mobile learning as a viable tool to support science instruction. Among the countries contributing to this body of research, the United States emerged as the leading contributor, highlighting its active engagement in advancing mobile learning initiatives. The findings indicate that mobile learning significantly enhances a range of essential skills in science education, including concept mastery, digital literacy, and science process skills. Tertiary education demonstrates the highest adoption of mobile learning, incorporating advanced technologies and applications such as virtual reality (VR) and augmented reality (AR) to improve scientific visualization and conceptual understanding. The empirical evidence from multiple studies supports the effectiveness of these tools in fostering deeper learning and engagement among students. Overall, the synthesis of the reviewed literature confirms that mobile learning adoption has steadily increased over the past decade, yielding measurable benefits for both learners and educators. These benefits include enhanced student engagement, improved learning outcomes, and innovative instructional practices. The patterns identified across the 26 Scopus-indexed studies provide robust evidence of the positive impact and progressive development of mobile learning in science education, establishing a solid foundation for future research and practical implementation.

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