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The Role of Mobile Learning in Facilitating Science Learning to Enhance Higher Order Thinking Skills (HOTS): A Systematic Review

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ABSTRACT

The existence of mobile devices and technological developments have made mobile-based learning a major trend in education, from elementary to secondary schools in Indonesia. This research is a systematic literature review limited to 10 articles published in 2018 to 2023. This research aims to answer questions about the use of mobile technology in learning contexts as well as the types of learning models used in science teaching to improve students' higher-order thinking abilities. The results of this research follow the research objectives, where the mobile technology most often used to achieve learning objectives is smartphones and tablets. The most effective learning models for improving high-level thinking skills in science learning are problem-based learning, project-based learning, Inquiry learning, Collaborative learning, Flipped Classroom, and Blended Learning. This research can become a reference for subsequent research in developing creative learning methods.

Keywords: *Higher Order Thinking Skills; Mobile Learning; Science Learning*

INTRODUCTION

Over the past twenty years, digital technology developments have profoundly transformed the global cultural landscape (I. Y. Maureen et al., 2018). Entering the era of Industry 4.0 and Society 5.0, the world has experienced significant technological transformations. This era has changed the way we work, learn, communicate, and interact with the world around us. The Fourth Industrial Revolution brought profound technological advancements, while the Society 5.0 era emphasized humanity in the use of technology. Therefore, in the era of the Fourth Industrial Revolution, we need to follow the cultural learning developments of students according to their characteristics (Suyatna, 2019). Technology has entered various sectors, including retail, advertising, healthcare, finance, and manufacturing, and the education sector is no exception (Matyushok et al., 2021). Technological advancements require the adjustment of resources ready to compete with the times (Ahmad, 2018). Many believe that 21st-century technological advancements have brought positive changes in human living conditions and quality. Rapid technological growth must be followed by developments in the field of education and the ability to produce a digital culture in Indonesian education (Sari & Marlena, 2022).

Indonesia ranks highest in terms of the number of smartphone and internet users worldwide. According to data revealed by research company Data Reportal, the number of connected mobile devices in Indonesia reached 370.1 million in 2022. Based on a report compiled by We Are Social, in January 2022, there were 204.7 million internet users in Indonesia (Soepriyanto et al., 2021). It can be said that smartphones and the internet are two inseparable things as they enable access to various types of multimedia and mobile applications, whether connected to a network or in offline mode (Nuryantini & Yudhiantara, 2019).

Technological advancements impact the digital culture in school environments, reflected in the high usage of smartphones and gadget devices by students at school. Mobile learning is defined as a learning method that can be conducted through mobile devices, such as smartphones, tablets, or tablet computers (Almaiah et al., 2022). According to a report from Aptika IKP Kominfo Research Center in 2022, smartphone usage by students aged 9-19 years reached 65% of total smartphone users in the same age range (Adisty, 2022). Students utilize smartphones and various other available devices to support learning activities (Sari & Marlena, 2022). The utilization of technology in the learning process can transform the model from teacher-centered to student-centered learning activities (Suyatna, 2019).

Mobile technology offers various benefits to users, including portability, responsiveness of operating systems and applications, smooth connections in various locations and times, and enhanced social interaction. Global recognition of technological advancements and mobile applications in the education sector is a commonly observed trend (Bano et al., 2018). Researchers, especially those in the field of education, are very interested in the potential of mobile technology (Mou & Cohen, 2014). Educational technology allows students to engage in social learning environments and appropriate scenarios, creating conditions that encourage collaborative learning among students.

Learning through mobile technology is a form of electronic learning that involves the use of mobile technology such as computers, laptops, mobile phones, audio players, and electronic books (Hamidi & Chavoshi, 2018). With mobile learning, students can collaborate with fellow students in the learning process, and share ideas, supported by the internet and technological advancements, without space and time constraints (Gikas & Grant, 2013). The presence of constantly connected mobile technology provides students access to course information and opportunities to interact with and explore learning content.

The use of mobile technology in education has the potential to eliminate the boundaries between the learning process and everyday life. Mobile technology has a strong appeal in bringing new elements such as space, time, and efficiency into the classroom environment. Researchers have noted that mobile technology can act as a bridge between formal and informal learning, allowing an understanding of the differences between the two based on context and existing features (Shao & Liu, 2021). Most of the literature discusses the affordability of mobile technology to implement its methods, strategies, and applications, which generally focus on the teacher's role.

However, practical implementation has not achieved significant progress due to various obstacles and challenges. These obstacles include financial resource limitations, slow development of educational policies related to mobile learning, lack of adequate understanding among human resources, especially teachers as facilitators, and a shortage of skilled personnel in effectively implementing pedagogy. Other challenges include changes in pedagogical understanding that teachers must comprehend regarding mobile learning, resource limitations for complex tools such as infrastructure and the internet, parental concerns regarding perceived health and psychological issues that may arise from prolonged use of mobile technology by students, and a shortage of educators trained in mobile learning (Khairunnisa et al., 2022).

In the 21st century, one of the main challenges faced by educators is maintaining student interest and participation to stay engaged and connected through mobile technology in an efficient learning process (Atika et al., 2022). The importance of supporting the growth of digital literacy skills in the 21st century cannot be ignored (I. Maureen, 2014). The significance in developing students' higher-order thinking skills, such as problem-solving and critical thinking skills. Mobile learning can be considered an innovative option in the educational context. In addition to helping students and teachers understand the learning material content, mobile learning also facilitates communication, problem-solving, creative exploration, and reinforcement of students' higher-order thinking skills.

Considering this, appropriate pedagogical and theoretical methods are needed to support teachers in designing mobile technology (Makhrus & Busyairi, 2022). This learning model includes strategies for integrating mobile learning into the classroom context to achieve learning objectives with mobile devices. Additionally, existing strategies should encourage the development of critical inquiry skills in learning while still challenging students to provide solutions.

From a systematic content analysis of empirical research articles in science education, this review seeks to answer the following questions: 1) what mobile technology is used in learning?, 2) what learning models are used in science learning to enhance students' higher-order thinking skills (HOTS)?

METHODS

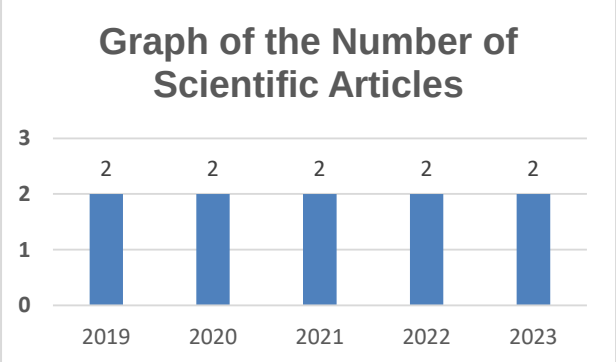
Research Design

This research is a systematic literature review. The systematic literature review model is a highly analytical and transparent method for searching, assessing, selecting, and combining information sources from published empirical data. Its main purpose is to provide answers to the research questions posed.

Sample and Data Collection

The data used in this research is secondary data. Secondary data refers to a documentation method that uses existing data, rather than data obtained from direct observation. The secondary sources of this research are scientific articles in leading journals accessed through the Google Scholar database. The keywords used in the article search on the Google Scholar database are “mobile learning,” “science learning,” and “higher-order thinking skills.” The article search is limited to the years 2018 to 2023 and only includes 10 articles relevant to the research topic. The distribution of the articles is as follows:

Figure 1. Distribution of Articles



Data Analysis

The main focus of this research is to enhance higher-order thinking skills (HOTS) in science learning through the application of mobile learning. Therefore, in conducting a systematic review, it is crucial to perform a thorough search to identify the most relevant primary empirical studies. Additionally, explaining in detail how the review process is conducted is key to maintaining the quality and transparency of the review. Thus, the following briefly outlines the steps for searching, selecting, data collection, and data analysis. The steps are as follows: 1) identifying relevant terms and phrases in the initial literature exploration to be used; 2) selecting various data sources online through Google Scholar; 3) evaluating by reviewing article summaries related to the research subject, the researcher gathers descriptive information such as authors, publication year, topics, research types, and results; 4) organizes information (quotations and summaries) based on the research objectives and problem formulation; 6) creating a review report that aligns with the research variables; 7) referring to the main research questions, the researcher aims to identify three main keywords: Mobile Learning Media, Science Learning, and higher-order thinking skills (HOTS). After analysis, the distribution of research methods used in the 10 articles was obtained. The following is the distribution of research methods used in the 10 articles.

Table 1. Distribution of Research Methods

Research Method	Quantity	Percentage
Quantitative	7	70 %
Research and Development (RnD)	3	30 %
Number	10	100 %

The analysis of the types of quantitative research methods will be presented in the following table:

Table 2. Distribution of Types of Quantitative Research

Types of Quantitative Research	Quantity	Percentage
Quasi-Experimental Design	6	86 %
Structural Equation Modelling	1	14 %
Number	7	100 %

In the utilization of mobile technology to facilitate learning, the following table presents the use of mobile technology as reported in 10 articles.

Table 3. Distribution of Mobile Technology Use in Learning

Mobile Technology	Quantity	Percentage
Smartphone	8	80 %
Tablet	2	20 %
Number	10	100 %

To support the role of mobile learning media in the learning process, it is closely related to the learning models used to facilitate the use of mobile technology in education. The following table shows the distribution of learning models employed to support the utilization of mobile learning media.

Table 4. Learning Models to Support Mobile Learning Media

Learning Models	Quantity	Percentage
Problem-Based Learning	3	30 %
Project-Based Learning	2	20 %
Inquiry Learning	2	20 %
Collaborative Learning	2	20 %
Flipped Classroom	1	10 %
Number	10	100 %

RESULTS AND DISCUSSION

Mobile Technology in Facilitating Learning

The use of mobile technology in the learning process can gradually help students build statistical thinking skills in their daily lives. Students have internalized self-directed learning concepts that align with their characteristics, resulting in sustained interactions. Currently, the use of mobile technology in the classroom as a model for mobile learning has a more significant impact than learning without the use of mobile technology (Dasilva et al., 2019).

The ability of affordable mobile devices to transcend spatial and temporal boundaries in the learning process can be used to design appropriate learning methods and scenarios. Additionally, the availability of talented resources and interactive experiences that bridge the physical and virtual worlds can address issues that arise from the use of mobile technology in education. In the past five years, advancements in mobile technology have made smartphones, tablets, and computers the most popular new technological devices in the context of learning. The success of technology use, including ICT, is influenced by several factors such as external factors, usability, ease of use, attitudes towards use, effective use, and the systems employed (Arianto et al., 2016).

The variety of mobile devices in the evolving educational context, such as mobile phones and laptops, allows students to use these devices positively to create an interactive knowledge environment focused on them. The role of teachers in supervising the use of mobile technology in the learning process is crucial. Teachers are responsible for ensuring that students optimally utilize mobile devices during the learning process. The use of mobile devices in the learning context helps students access information and enhance higher-order thinking skills. Therefore, integrating mobile technology into education is a vital part of learning innovation.

Previous research conducted by Cahyana & Mukhtar (2019) also emphasizes that mobile phones are the most frequently used learning devices. In many countries, mobile phone ownership exceeds 100%, with nearly every individual having more than one mobile device, indicating that mobile devices in this research are highly accessible. This information also reveals that various devices are used in mobile learning, which does not depend on the type of device used but rather on the availability of access to mobile devices.

Research by Dasilva et al. (2019) also reached similar conclusions, indicating that mobile phones are the most preferred mobile devices for learning purposes. This is because phones offer advantages in multitasking, such as providing a range of features that support the learning process, including photography and video recording capabilities. Additionally, internet access and e-books are easily accessible to students.

Learning Models Used in Science Education to Enhance Higher Order Thinking Skills (HOTS)

Problem-Based Learning

In mobile learning, problem-based learning (PBL) is an applied model in science education (Boari et al., 2023). This model uses phenomena or problems as the main focus to

develop problem-solving and self-regulation skills. The problems commonly used in this model are real-life situations relevant to the subject matter. In problem-based learning, students are expected to investigate knowledge, generate ideas, gather information, and find appropriate solutions to problems (Putranta & Dwandaru, 2021). During the problem-solving process, there is an exchange of knowledge and information among students to reach a solution. The teacher's role in this context is as a facilitator who directs the issues so that student discussions focus on finding appropriate solutions.

The problem-based learning model encourages students to derive meaning from real-world problems involving higher-order thinking skills (Hu & Hwang, 2023). Additionally, this model incorporates problem-solving skills, interdisciplinary learning processes, self-directed learning, and cooperative learning, enhancing all the skills involved (Hu & Hwang, 2023).

Project Based Learning

In mobile learning, project-based learning (PBL) is a utilized model in science education. In this method, students are tasked with investigating complex problems and finding solutions. Project-based learning promotes effective teamwork and coordination among group members, as well as appropriate interactions to enhance student learning outcomes (Cahyana & Mukhtar, 2019). This model allows students to engage in in-depth learning investigations. During this process, students have the opportunity to build understanding from their learning outcomes and conduct evaluations.

Students are expected to learn and have the ability to design projects aimed at solving real-world problems. Additionally, project-based learning can enhance students' higher-order thinking skills because the learning involves comprehensive, follow-up, and communicative activities to discover and integrate concepts (Kim et al., 2020).

Inquiry Learning

One effective science education model in mobile learning is the inquiry-based learning model. This model provides students with opportunities to ask questions, conduct inquiries or searches, and perform experiments independently to acquire the knowledge they need, based on previously established theories.

Inquiry-based mobile learning has been reported to have various research focuses, producing contrasting results, and placing more emphasis on progressive, reliable, authentic, and social characteristics. Inquiry-based learning typically involves stages such as questioning, inquiry, critical thinking, and problem-solving, where evidence is collected, findings are reported, explanations are obtained, and conclusions are agreed upon (Susantini et al., 2022).

At each stage of the inquiry-based learning model, students are required to use critical and analytical thinking to solve problems. This model is related to phenomena based on students' prior knowledge, which helps them build new knowledge. It aligns with students' characteristics, emphasizing learning through direct experience, particularly through their activities. Therefore, the teacher's role is crucial as a facilitator who provides the material and problems to be investigated and guides students in solving these problems to understand the concepts involved.

The use of mobile devices in inquiry-based learning has proven to be more efficient than relying on lecture methods, independent learning, and collaborative learning (Dasilva et al., 2019).

Collaborative Learning

One effective method for achieving mobile learning goals in science education is collaboration. This is because collaborative learning offers suitable strategies and models. In this model, students are continuously engaged in the learning process to understand the

material at each stage. Collaborative learning is a teaching model where students learn together in groups and can help each other achieve learning goals. Thus, collaborative learning provides social experiences and supports students' personal development.

Collaborative learning is a model designed to encourage and facilitate interactions among students, teachers, classmates, and the community, both inside and outside the classroom. The collaborative learning model that takes place outside the classroom can become a primary model. Unstructured learning assignments, learner-oriented teaching methods, and mobile learning devices contribute to enhanced social interaction among students (Kwangmuang et al., 2021). Additionally, mobile-based collaborative learning models give significant attention to student communication during classroom activities.

The use of mobile technology in collaborative learning is the most suitable model to stimulate, facilitate, and enhance interaction and cooperation among learners. This collaborative learning model improves students' ability to work together in groups, share goals, understand, and discuss to achieve common objectives.

The collaborative learning model in mobile learning is based on students' ability to engage in productive learning through information within the learning group, allowing them to become researchers and knowledge discoverers. In many studies, students typically participate in multiple learning activities. For example, a student uses a mobile device to find new information and shares that knowledge with other students. This builds students' constructive abilities in collaborative learning. This model prepares students for learning and the digital age (Kwangmuang et al., 2021).

When students participate in a collaborative learning environment, they have the opportunity to discuss and share information to find solutions to everyday problems. Students gain understanding from real-life facts and comprehend current issues related to the learning material. Thus, students can engage in various types of social interactions, including interpersonal, group, inter-group, and human-environment interactions, whether actual or historical, and self-reflection.

In collaborative learning, students in groups achieve learning targets and work on tasks with full responsibility. Teachers encourage students to be more active in learning activities (Dasilva et al., 2019). When the collaborative learning model is correctly implemented, discussions among students in groups become smoother and more insightful, allowing students to understand various aspects of specific knowledge and theories more deeply. Consequently, students' higher-order thinking skills and communication abilities can develop.

The process of knowledge development and higher-order thinking skills needs to involve students in an open learning environment. Students can undergo the learning process flexibly and interact with various options available to build knowledge collaboratively in learning groups and inquiry groups.

Flipped Classroom

The model of learning applied in mobile learning for science education is the flipped classroom model (Handoyono, 2020). In a flipped classroom, learning occurs through two distinct methods: face-to-face classroom meetings and virtual or online interactions that combine synchronous learning with time-unrestricted independent learning. Synchronous learning happens in a physical classroom environment, while independent learning means students study independently. The teaching and learning process in the flipped classroom model also follows a different pattern where students review materials provided by the teacher through their mobile devices at home before attending face-to-face classes.

In classroom situations, students are required to complete tasks related to the material previously covered by the teacher and have the opportunity to discuss with peers and the teacher when they encounter challenging concepts. Through assignments at school,

students can seek help from peers or the teacher to solve problems when they face difficulties. The flipped classroom is a teaching strategy that reduces direct instruction but still emphasizes interaction both in and outside the classroom. This model optimizes the use of mobile technology (Hariadi et al., 2022).

Thus, the problem-based learning model is the most commonly used method to enhance higher-order thinking skills in science education, with the highest percentage. This study has some limitations that restrict the ability to generalize the research findings: First, the study examines the most frequently used mobile learning devices in science education without considering students' economic backgrounds. Second, and more importantly, there are various factors beyond mobile devices and learning models that can enhance higher-order thinking skills.

CONCLUSION

This research has the potential to expand the foundation of scientific research and serve as a valuable reference for future researchers by providing a current review of mobile learning in science education. It was found that the most suitable mobile devices for achieving learning objectives are smartphones and tablets. Additionally, this research is expected to inspire other researchers to develop innovative learning models. Various innovative models that can be applied in science education to enhance higher-order thinking skills include collaborative, inquiry-based, project-based, problem-based, and flipped classroom models. Moreover, mobile learning offers a range of contexts where various methods are available to achieve educational goals, including self-directed learning, learning across different locations and times, interest-based learning, and learning that considers the unique characteristics of each student.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest in any form or with any party regarding the writing of this research. This study was conducted and written genuinely for its intended purpose.

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