Mobile Learning in Science Education to Improve Higher-Order Thinking Skills (HOTS) and Communication Skills: A Systematic Review

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***Abstract*—Today, the increasing use of technology and mobile applications in education was interesting. This research was a systematic review study with limited 30 articles from 2012 to 2021. It aims to answer research questions about what mobile devices used in learning and what learning approaches are used in science learning to improve higher-order thinking skill and communication skills. The findings of this study were in line with the research objectives: First, the most appropriate mobile devices used to achieve learning objectives are mobile phones, followed by PDAs, tablets, iPad, laptops, e-books, and iPods. Second, the learning approach used in science learning to improve higher-order thinking skills and communication skills are a collaborative learning approach, inquiry learning, project-based learning, problem-based learning, game-based learning, and flipped classroom learning. It was hoped that this research can be an illustration for other researchers to create innovative learning approaches. Some research that can be done next based on this research is how mobile learning in social learning or comparing the two, further research on the most appropriate learning media for mobile learning, and research on the effectiveness of implementing approach strategies in mobile learning.**

***Keywords*—Communication skills; higher-order thinking skills; mobile learning; science education**

I. Introduction

Mobile technology provides many advantages for users, such as ease of carrying, sensitivity in operating systems and applications, connecting between different spaces and times, and facilitating social interaction. The improvement of technology and mobile applications in education is a common phenomenon observed worldwide [1]. Mobile technology has great appeal for researchers, including researchers from education field [2]. Technology in education makes students enter into social learning contexts and appropriate situations with circumstances to encourage students to learn together or collaboratively.

Mobile learning is electronic learning through mobile technologies such as computers, laptops, cell phones, audio players, and electronic books [3]. Mobile learning allows students to learn in collaborative learning with other students to share ideas with the help of the Internet and technological developments that can be done without the boundaries of space and time [4]. Always-connected mobile device allow students to access course information and provide students with opportunities to interact with content and to explore it.

Mobile learning can help remove the barriers between learning and real life. Mobile learning is powerful in its appeal of bringing new space, time, and geography into the classroom. According to some researchers, mobile learning can be a bridge between formal and informal learning to judge the difference between the two based on the context and its features [5]. Most of the literature discusses the affordability of mobile learning to implement its methods, strategies, and applications, which are mostly teacher-centered.

However, the realization of its practical implementation has not been much because its implementation has various obstacles and challenges. There are limited financial resources, inadequate educational policies for mobile learning that have not developed rapidly, human resources that do not have a good understanding, and there is still a lack of skilled personnel for effective implementation of pedagogy. Another challenge is changing the pedagogical understanding that teachers have to understand mobile learning, the lack of resources for complex tools such as infrastructure and bandwidth, parental trust because there are perceptions of health and psychological problems that follow and are associated with prolonged use of mobile devices by students. And then the lack of educators trained with mobile learning [6]–[12].

In addition to the actual implementation problems that arise in learning practices, there are fundamental problems regarding the theoretical and pedagogical foundations in mobile learning applications in the world of education, which are still lacking and not yet on target. Many authors have discussed and have investigated this with a socio-constructivist approach and found that communication features on mobile devices can encourage collaboration and become the basis of mobile learning. However, students can participate and can collaborate in learning with themselves and others, not with the devices or media used [13]. Therefore, every element of education, government, teachers, students, and society, must adapt to mobile learning so that its effectiveness can be felt.

In the 21st century, one of the biggest challenges faced is maintaining students' interest and involvement to keep interacted and connected through mobile devices in effective learning [14]. The importance of developing students' higher-order thinking competencies, such as problem-solving and

critical thinking skills [15]. Mobile learning can be an innovative option for education [5]. Mobile learning not only helps students and teachers understand the content of the material in learning, but also facilitate communication, problem-solving, creativity, and students' higher-order thinking skills.

Based on this, appropriate pedagogical and theoretical methods are needed to assist teachers in designing mobile learning [16]. This method has a strategy to integrate mobile learning into the classroom to achieve learning objectives with mobile devices. In addition, existing strategies must instill critical inquiry skills in learning while still presenting problems for students to provide solutions [17].

This review, derived from a systematic content analysis science education empirical research articles, sought to address the following questions:

- What mobile devices use in learning?
- What learning approaches are used in science learning to improve higher-order thinking and communication skills?

II. Literature Review

A tool containing several solutions to educational problems often describes technology [17]. Education aims to make people knowledgeable, creative, informative, digitally capable, and adaptable [5]. Furthermore, information technology such as the internet and multimedia systems that have been utilized and applied in learning aims to improve the quality of learning by facilitating students' access to adequate resources and services [18].

One of the benefits of a mobile learning system is that students can participate in different learning situations, such as school learning and online distance learning [2]. However, distance learning is not in a room like schools in general, but in a scope that is not traced by using cellular technology beyond the existing distance [19].

Mobile learning aims to provide a different and meaningful student learning experience, but it is not the primary learning method because it must have the right learning approach. Mobile devices can influence and improve student learning outcomes and motivation in learning. However, there are limitations in its application; although teachers and students will become more familiar than usual because of the efficiency and effectiveness of this method in learning, teachers and students must maintain educational ethics [3]. Research also shows that with awareness and adequate support from all aspects of education, mobile learning will answer the 21st-century challenges of learning anywhere and anytime, a centered and innovative learning method.

Higher-order thinking skills are the ability of students to think at a higher level. Students who have these abilities will analyze, evaluate, and create innovations in solving problems. These mobile and science learning skills are necessary because many problems can be solved using higher-order thinking skills [20]. Higher-order thinking skills can improve with various learning approach strategies, learning media, and teaching materials.

Cognitive taxonomy bridges understanding higher-order thinking skills' concepts and characteristics. The most popular cognitive taxonomy is Bloom's taxonomy, revised by [21], consisting of two dimensions: the dimensions of knowledge and cognitive processes. The Knowledge Dimension classifies the types of knowledge students acquire into four types: factual, conceptual, procedural, and metacognitive. While the cognitive process dimension consists of six levels: remembering (C1), understanding (C2), applying (C3), analyzing (C4), evaluating (C5), and creating (C6) [22].

The three categories of HOTS assessment abilities are as follows: first, the ability to transfer concepts to other concepts, higher-order thinking skills as a form of knowledge possessed, the ability to relate to other people in unfamiliar situations. Second, critical thinking skills are the ability to understand logical problems, reflective thinking skills, and the ability to argue that can focus on making decisions or doing something. Third, problem-solving skills (problem-solving), namely the ability to find new ways, unconventional and creative solutions [23].

Communication refers to a person's ability to express ideas using words and language that can be accepted both in written and spoken form, such as articulating, explaining, describing, clarifying, listening, questioning, sharing, which are from a learning process [2]. Communication skills are the main factor to be able to understand learning. Teachers, students, and everyone in the educational environment can support each other's learning goals by communicating. In addition, communication has a significant contribution to student success in school aligns with millennial habits and lifestyles that are identical to communication technology if used wisely by students [24].

One of the learning objectives is to master the concept; students must also have good communication skills to convey their knowledge and find. However, based on the research results, many students still do not have good communication skills [5]. Therefore, a method is needed in the form of an appropriate learning approach to develop students' communication skills, and their understanding of concepts can be appropriately conveyed.

III. Material and Method

A. Research Design

This research is systematic literature review. The systematic review is a critical and transparent method for finding, determining, selecting, and synthesizing sources of information from published empirical evidence so that it can answer research questions to be carried out. The systematic review is a research method that based on evidence that has had high credibility in many research disciplines in recent years, including education.

B. Sample and Data Collection

The data used in this research is secondary data. Secondary data applies the documentation method from existing data, not data obtained from direct observation. This research's

secondary sources are books, proceedings, and scientific articles in reputable journals accessed on databases in Table I. The keywords used in the search for articles in the SCOPUS database were mobile learning, higher-order thinking skills, and communication skills. The article search was limited from 2012 to 2021, with 30 articles.

TABLE I. THE NUMBER OF PAPERS FROM EACH JOURNAL ANALYZED

Publisher	Frequency	Percentage (%)
https://scholar.google.co.id	3	10
https://doaj.org	5	16.67
https://www.elsevier.com	7	23.33
https://www.tandfonline.com	7	23.33
https://onlinelibrary.wiley.com	4	13.33
https://iopscience.iop.org	4	13.33

C. Analyzing of Data

The main focus of the study in this research is learning science with mobile applications/technology to improve higher-order thinking and communication skills. Therefore, a systematic review requires an appropriate search for the most relevant primary empirical studies. In addition, it is essential to provide details on how the review process was carried out so that the review is transparent and adequate. Therefore, in the following sections, the process of searching, selecting, extracting, and analyzing data is briefly discussed.

- Define research questions to extract the main search.
- Identify relevant keywords in the primary literature search that will use.
- Select various online databases, journals, and conference proceedings to search.
- Conduct a review by reading the article's abstract about the research topic. The author takes descriptive information such as author, year of publication, topic, type of research, and findings.
- Manage results (citations and abstracts) according to the purpose and formulation of the research problem
- Write the results of the review according to the research topic.

Based on our primary research question, we have four main search terms: Mobile Learning, Science, Higher-order thinking skills, and communication skills. Based on the results obtained in an online database search, 30 articles were synthesized and analyzed to answer research questions.

IV. RESULT

A. Mobile Device use in Learning

Mobile devices that should be used in learning are mobile devices that are easy to carry and have easily accessible on and off buttons. Portable devices, such as cell phones and tablets meet this requirement, with the exception of laptops due to their lack of speed in their ease of use. The results of the study report that in learning mobile phones are the most frequently used mobile devices according to the Table II. However, some studies did not identify the device used [25].

TABLE II. MOBILE DEVICES USED IN LEARNING

Mobile Device	Percentage (%)
Phone	34
PDAs	22
Tablets	16
iPads	11
e-books	2
iPods	1

B. Learning Approach in Science to Improve Higher-Order Thinking Skills and Communication Skills

There are 83% of studies that aim to measure student learning improvements who report achieving their stated goals [1]. Exploratory science learning can be carried out outside formal classroom settings, such as in a natural environment [26]. In the previous research review, of all subjects, natural science was the subject whose mobile learning applications were most frequently used in research [27]. Environmental science is the subject matter in science learning that focuses most of the research, followed by geography and physics [1].

Mobile learning positively impacts students' understanding of learning materials and inferring them. Mobile learning should reflect on every learning encounter with communication and collaboration [28]. Furthermore, mobile devices in learning can expand teacher pedagogy and develop students' critical thinking skills and 21st-century skills [29].

However, cultivating communication and high-level skills takes longer, and measuring these abilities requires the right tools and approaches. Below Table III are the learning approach strategies used in mobile learning to improve higher-order thinking skills and communication skills of students in science.

TABLE III. LEARNING APPROACH STRATEGIES USED IN MOBILE LEARNING

Learning Approach	Percentage (%)
Collaborative Learning	25
Inquiry Learning	25
Project-Based Learning	19
Problem-Based Learning	14
Game-Based Learning	10
Flipped Classroom Learning	7

V. DISCUSSION

A. Mobile Device use in Learning

Using mobile devices in learning can help students gradually develop their statistical thinking in everyday life. Students have the concept of independent learning with their character so that interaction occurs continuously [30]. Currently, mobile devices in the classroom as mobile learning has a more significant effect than learning that does not use mobile devices [5].

The affordability of mobile devices that can cross space and time in learning can be utilized to build appropriate learning methods and scenarios. Furthermore, the availability of talented resources and interactive comfort between the natural world and the virtual world can answer the problems of mobile devices in learning [30]. From the development of mobile devices in the last ten years, smartphones, tablets, and computers are the most popular new technology devices in learning.

The existence of various kinds of mobile devices in the world of education that continues to develop, such as cellphones, laptops, students can use them positively to create an interactive knowledge space that focuses on students. Teachers have an important role in supervising the use of mobile devices in learning. Teachers must make students learn with the maximum use of mobile devices [31]. The use of mobile devices in learning helps students to access information, find communication styles, and hone higher-order thinking skills. Therefore, the existence of mobile devices in learning is an essential part of learning innovation.

Previous research by [32] also found that mobile phones were the most frequently used learning devices. In many countries, mobile phone ownership data is more than 100%, with almost everyone owning more than one mobile device; this shows that mobile devices in this study are very affordable [11]. This data also reveals that many devices are used in mobile learning, not depending on what type of device is used but on the access to have the mobile device.

A study conducted by [3] also got the same result: cell phones are the most popular mobile devices for learning. This is because mobile phones have the advantage of multi-tasking; they have various exciting features to help learn, such as photography and video recording. In addition, other features such as GPS, Bluetooth, SMS, Multimedia Messaging Service (MMS), and all kinds of educational software, including the internet and e-books, can be easily accessed by students.

B. Learning Approach in Science to Improve Higher-Order Thinking Skills and Communication Skills

1) Collaborative learning

One excellent science learning approach to achieve specific mobile learning targets is collaboration. This is because collaborative learning has the right strategies and methods. Students follow the learning process constantly and continuously to understand the material in each learning process [5], [17]. Collaborative learning is a teaching method where students learn together in a group, and students can help each other for learning purposes. This makes collaborative learning that can provide social experiences and self-development [5].

Collaborative learning is a learning approach to encourage and facilitate students, teachers, classmates, and the community, to be able to interact both inside and outside the classroom. Collaborative learning that occurs outside the classroom can be the primary learning approach. The provision of unstructured learning assignments, learner-centered teaching methods, and mobile learning tools help increase social interaction among peers [30]. In addition, the mobile collaborative learning approach pays excellent attention to student communication in every class activity.

Collaborative learning with mobile technology was the most relevant learning to promote, facilitate, and enhance interaction and collaboration between learners [2]. The collaborative learning approach improves the ability of students to work together in groups, share goals, understand, and discuss to achieve agreed goals [33].

The collaborative learning approach in mobile learning is based on students' ability to engage in productive learning from the information held in study groups that enable students to become researchers and discoverers of knowledge [5]. In many studies, students usually participate in more than one learning activity. For example, a student uses a mobile device to search for new information from his knowledge and share that knowledge with other students. In that case, this builds the learner's constructivist abilities in collaborative learning [3], [25]. This approach will make students ready for digital era learning and generation.

When students study in a collaborative learning environment, students can discuss and exchange information to find answers to problems in their daily lives. Learners will learn from real-life facts and understand current issues regarding the subject matter in learning. Thus students can be involved in various social interactions such as interpersonal, intra-group, intergroup interactions, between humans and the actual and historical environment, and self-reflection [2].

In collaborative learning, students in groups achieve learning goals and learn according to the division of tasks given with full responsibility. The teacher motivates students to be more active in learning activities [1]. When the collaborative learning approach is applied correctly, discussions between students in groups will be smoother and wiser so that students can understand various aspects of specific knowledge and theories in depth. Therefore, students' higher-order thinking skills and communication skills can develop.

Developing knowledge, higher-order thinking, and communication skills should engage students in an open learning environment. Students can learn flexibly and interactively with various alternatives for building knowledge socially in shared learning and investigation groups [30].

2) Inquiry learning

One of the excellent science learning approaches in mobile learning is the inquiry learning approach [5]. Inquiry learning facilitates students to ask questions, conduct investigations or searches, and do experiments to research independently to get the knowledge they need, supported by the theories above [34].

Mobile learning with an inquiry approach is reported to have a diverse focus of study, produces contrasting results, and places greater emphasis on progressive, trustworthy, genuine, and social characteristics [1]. Inquiry learning generally has stages, namely, questioning, inquiry, critical thinking, and problem-solving in which evidence is gathered, findings are reported, explanations are obtained, and conclusions are agreed [35].

Each stage of the inquiry learning approach requires students to think critically and analytically in solving problems. Inquiry-based learning is associated with phenomena by the knowledge that students have previously to help students build new knowledge [36]. It follows the characteristics of students, namely learning through direct experience, primarily through their activities [37]. Therefore, the teacher plays an essential role as a facilitator who provides material and problems to be investigated and guides students in solving problems to understand the existing concepts.

The use of mobile devices in inquiry learning is more effective than learning with lecture methods, independent learning, and cooperative learning [5]. Moreover, integrating mobile devices with inquiry learning can expand students' learning opportunities, the depth of the material understanding and improve students' higher-order thinking skills in completing investigations on scientific problems by synchronizing the results obtained with the explanations given by the teacher [17].

3) Project-based learning

The following science learning approach applied in mobile learning is project-based learning [5]. Project-based learning makes students investigate complex problems and solve them [38].

Project-based learning requires good cooperation and coordination between appropriate group members and appropriate interactions to improve student learning outcomes [39]. Project-based learning is a learning strategy that allows students to benefit from completing learning investigations in the form of thoroughness and accuracy, students have the opportunity to create from their understanding, students can learn and assess learning.

Students are expected to learn and have the ability to design projects in order to solve real-life problems. In addition, project-based learning can improve students' higher-order thinking and communication skills because learning consists of comprehensive, follow-up, and communicative activities to find and combine concepts [5].

4) Problem-based learning

The following science learning approach applied in mobile learning is problem-based learning [5]. Problem-based learning is a learning model that uses a phenomenon or a problem as the primary focus to develop problem-solving and self-organization skills. Problems often used in this learning model are problems in everyday life connected to the subject matter. Problem-based learning requires students to explore knowledge, create ideas, gather information, and solve and answer problems with appropriate solutions [40]. In problem-solving, there is an exchange of knowledge possessed and information collected between each student to solve the problem. The teacher acts as a facilitator to direct the problem so that student discussions focus on solutions.

In the process, the problem-based learning model has beneficial aspects regarding improving students' communication skills. First, students are involved in solving problems. Students' verbal communication skills will develop when they investigate problems, debate theories related to problems, identify problems, propose solutions to problems, analyze and evaluate the problem-solving process, and share experiences related to the process. Second, at each stage of problem-based learning, students' motivation and confidence in communicating can increase. Third, the knowledge obtained by students at the end of the learning process is their original, from the knowledge construction and exploration process they do in problem-based learning. [2].

Problem-based learning encourages students to make meaning from real-life problems that involve higher-order thinking and communication skills. In addition, it involves problem-solving skills, interdisciplinary learning processes, independent learning, and cooperative learning so that all skills involved can be increased [41].

5) Game-based learning

A game-based learning approach can be applied in mobile learning [1]. Games today are developed as entertainment, but some are also developed for learning purposes. Games that are specially designed with technology in education will stimulate the curiosity level of students to learn the existing material [42]. This game-based learning approach can be a choice for teachers to develop interactive learning media. The games aim to support the learning process and increase knowledge in carrying out the learning process compared to the general concept of learning, namely reading.

Game-based learning is a form of learning packaged with games based on specific plans, programs, tools, and equipment prepared by the teacher, and then students are trained in playing the game to achieve the learning objectives set. The game-based learning process is the right tool to represent, visualize, manipulate, and interact with learning content through technology integration [43]. Game-based learning that is packaged excitingly, according to learning objectives, explores and builds concepts, makes students motivated to develop higher-order thinking skills, especially in analysis. In addition, students' communication and collaboration skills are needed in-game activities, especially in groups.

6) Flipped classroom learning

The following science learning approach applied in mobile learning is the flipped classroom [44]. The reverse class is mixed learning, namely learning in two ways; through face-to-face and through virtual or online interactions that combine synchronous learning and asynchronous self-learning. Synchronous learning occurs directly in the classroom, while asynchronous learning is independent learning. The teaching and learning process in the flipped classroom is different; namely, students learn the subject matter that has been given by the teacher via mobile devices at home before the face-to-face class starts.

In learning activities in class, students are asked to do assignments according to the subject matter that has been given by the teacher before, and students discuss subject matter that is not understood with friends and the teacher. By doing assignments at school, when students experience difficulties, they can be directly consulted with their friends or the teacher to solve the problem immediately. A flipped classroom is a learning approach strategy that can minimize the amount of direct instruction in teaching practice but still maximize the

interaction process both inside and outside the classroom. This approach strategy makes maximum use of cellular technology [44].

As long as students learn outside the classroom in independent learning, students use mobile devices, such as cellphones, laptops, and computers. This mobile device is beneficial for students in following the learning and is very dependent on it. The flipped classroom approach in its application sharpens students' communication skills [5]. Every teacher and student meets online with the intermediary of a mobile device so that learning runs optimally, two-way communication continues.

The highest percentage of learning approach that used to improve students' higher-order thinking skills and communication skills in science learning are collaborative learning and inquiry learning.

This study has several limitations that reduce the generalizability of the findings: First, this study examines what mobile learning devices are most often used in science learning regardless of the students' economic background. Second, and most importantly, various factors other than mobile devices and learning approaches can improve students' higher-order thinking and communication skills

VI. Conclusion

This research can add to the basis of scientific research and be useful for future researchers because it provides an up-to-date review of mobile learning in science. The most appropriate mobile device used to achieve the learning objectives is a mobile phone, followed by PDAs, tablets, iPad, laptops, e-books, and iPod. Furthermore, it is hoped that this research can be an illustration for other researchers to create innovative learning approaches. The innovative learning approach used in science learning to improve higher-order thinking skills and communication skills is collaborative, inquiry, project-based, problem-based, game-based, and flipped classroom learning. In addition, mobile learning has provided a context in which there are many ways to achieve educational goals, such as independent learning, learning anywhere and anytime, learning to interests, and learning to recognize the characteristics of the student.

VII. Recommendation

Based on the learning approach and theory, the problem faced as a teacher and developer of a learning environment is to ensure that learning will occur adequately and comfortably so that students feel interested in learning. Therefore, one of the essential requirements to fulfill such mobile learning is the learning approach and theory.

Some research that can be done next: First, research on how mobile learning in social learning or comparing the two. Secondly, further research on the most appropriate learning media for mobile learning. And thirdly, research on the effectiveness of implementing approach strategies in mobile learning.

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