

Developing a Multi-Representation-Based Physics Mobile Learning to Enhance Critical Thinking and Creative Problem-Solving Skills: A Storyboard

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Article Info	Abstract
Article history: Received: June 24, 2024 Revised: January 14, 2025 Accepted: January 29, 2025 Keywords: Creative problem-solving Critical thinking Physics mobile learning This article is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License © 2025 Berkala ilmiah Pendidikan Fisika	This investigation aims to develop an M-Learning-based learning design for high school pupils in the context of a soundwave lesson specifically to increase critical thinking (CT) skills and creative problem-solving (CPS) ability. This learning media design is created through the ADDIE process, comprising five stages: analysis, design, development, implementation, and evaluation. In this paper, we will elaborate on the analysis and design phases. The analysis phase involves a preliminary examination of the teaching materials necessary for mobile learning. The design stage also involves selecting the proposed prototype's overarching design and creating storyboards. Three of the five subchapters that have been developed have the potential to employ CPS features, while CT features are feasible to integrate into all chapters. These findings suggest that physics mobile learning can be designed to incorporate CT and CPS specifically in the lesson on soundwave.
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INTRODUCTION

Rapid technological advancements in the twenty-first century have resulted in unforeseen scenarios, underscoring the necessity of individuals possessing innovative problem-solving skills and the ability to think critically ([Thornhill-Miller et al., 2023](#)). Critical thinking is necessary to quickly identify legitimate and accurate information, as is creative problem-solving when facing uncertain and unpredictable obstacles ([Kasidin, 2019](#); [Mar, 2021](#); [OECD, 2014, 2018](#)). Consequently, students must engage in educational activities that enhance their creative problem-solving and critical-thinking skills.

The necessity of fostering students' critical thinking and problem-solving abilities is also acknowledged in the curriculum development in Indonesia. The 2013 Curriculum demonstrates the importance of high-level thinking skills-oriented learning, encompassing critical and creative thinking skills, problem-solving, analytical abilities, and reasoning ([Kemendiknas, 2014](#)). In addition, Kurikulum Merdeka Belajar, implemented in stages starting in 2023, includes the term "Pancasila student profile," which denotes the student's character expected to develop upon completing their education. This character is characterized by faith, devotion to God Almighty, universal variety, cooperation, independence, critical reasoning, and creativity. In addition, the accompanying document on learning outcomes in high school physics learning mandates that students in both segments can employ physics concepts to resolve problems ([Permendikbud Nomor 22 Tahun 2016, 2016](#)).

However, the quality of students' reasoning abilities remains a concern in Indonesian secondary institutions. The national assessment indicates that two out of every three pupils and one out of every two students did not meet the required competency in reading and numeracy, respectively, as noted in the Indonesian education report card issued by the Indonesian Minister of Education, Nadiem Makarim, via the Indonesian Ministry of Education and Culture's YouTube account ([Kemdikbud, 2022](#)). In addition, specific prior investigations implemented questionnaires to evaluate students' capacity for problem-solving. [Tumanggor et al. \(2019\)](#) surveyed 65 high school students in the classroom to address students' problem-solving skills in the optics lesson. [Rachmawati et al. \(2022\)](#) conducted a comparable investigation on 100 students enrolled in the grade 11 science program. The findings indicated that the students' problem-solving abilities were still in the weak group, with a score range of 0-50. The subsequent investigation conducted by [Prahani et al. \(2023\)](#) of 154 high school students in the 11th grade demonstrated that the student's capacity to solve physics problems was still insufficient. As a result, misconceptions were generated. [Zamil et al. \(2021\)](#) distributed questionnaires to 87 class members. In addition, respondents reported that the characteristics of physics studies are perplexing and difficult to understand.

Numerous factors can contribute to a lack of creative problem-solving ability. [Amin et al. \(2020\)](#) demonstrated that the teacher's design of competency achievement indicators in the lesson plan does not incorporate higher-order thinking and problem-solving characteristics. Consequently, students employ plugs and chugs to solve physics problems based on equations they can recall ([Nurhayati et al., 2016](#)). Additionally, the results of open interviews with many physics instructors in South Sumatra indicated that physics learning activities were exclusively employed to disseminate knowledge in the classroom. In addition, many educators have implemented printed physics textbooks that the government has supplied for students to use during the learning process. The hands-on exercises are exclusively employed to introduce concepts and are limited to specific materials, including static fluids and pressure.

The utilization of technology in a learning environment is believed to enhance the learning capabilities of students ([Alenezi, 2020](#); [Closs et al., 2022](#); [Lacka et al., 2021](#)). The technology-based learning method will provide content through various media, positively impacting student learning achievement ([Aprilia, 2021](#); [Fitriawan, 2022](#); [Rusticus et al., 2023](#)). Student learning outcomes are enhanced through multimedia instruction ([Hadi et al., 2022](#)). The development of mobile learning instructional materials is an example of IT deployment in the learning industry.

The problem of low critical thinking skills and creative problem-solving is caused by not being drilled into students' learning ([Amin et al., 2020](#); [Mohd Abeden & Siew, 2022](#); [Permata et al., 2019](#)). Moreover, previous studies analyzed that printed physics books have shortcomings in training critical thinking and creative problem-solving skills because assignments in printed physics books measure memorization skills and basic conceptual understanding compared to analytical or evaluative tasks and do not integrate inquiry-based learning and conceptual mapping and limitations in representation format ([Jamil et al., 2024](#); [Mohd Abeden & Siew, 2022](#)). Also, there is still a lack of research on mobile learning development that trains creative problem-solving skills as part of critical thinking.

It is imperative to develop m-learning teaching materials, mainly when utilized in education, as they will enhance student engagement and learning outcomes ([Marunevich et al., 2021](#)). Android-based smartphones are a technological advancement that is currently of fascination to a significant number of individuals. The open operating system of smartphones enables users to incorporate a variety of applications due to their ease of use ([Camarata et al., 2022](#); [Chmielarz, 2020](#)). The utilization of mobile learning in the field of physics has been demonstrated to enhance vector representation abilities, high-level

thinking abilities, learning performance, and attitudes ([Darimi, 2017](#); [Dasilva et al., 2019](#); [Husna & Kuswanto, 2018](#); [Saputra & Kuswanto, 2019](#); [Wongwatkit et al., 2017](#)).

Consequently, we must make an effort to create educational materials that are based on Android. This paper presents the initial stages of the development of mobile learning on soundwaves based on Android to enhance students' critical thinking and creative problem-solving abilities.

METHODS

The ADDIE model is employed with Research and Development (RnD) methods. This developmental model aims to generate and assess educational products, including learning materials. The ADDIE model comprises five stages: analyze, design, develop, implement, and evaluate, as provided in Figure 1.

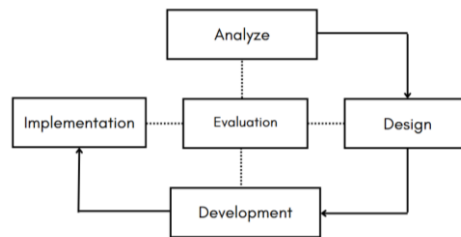


Figure 1 ADDIE flowchart

We develop teaching material content that is in accordance with the design through storyboard development. The development of teaching material drafts refers to the teaching material writing process model, illustrated in Figure 2.

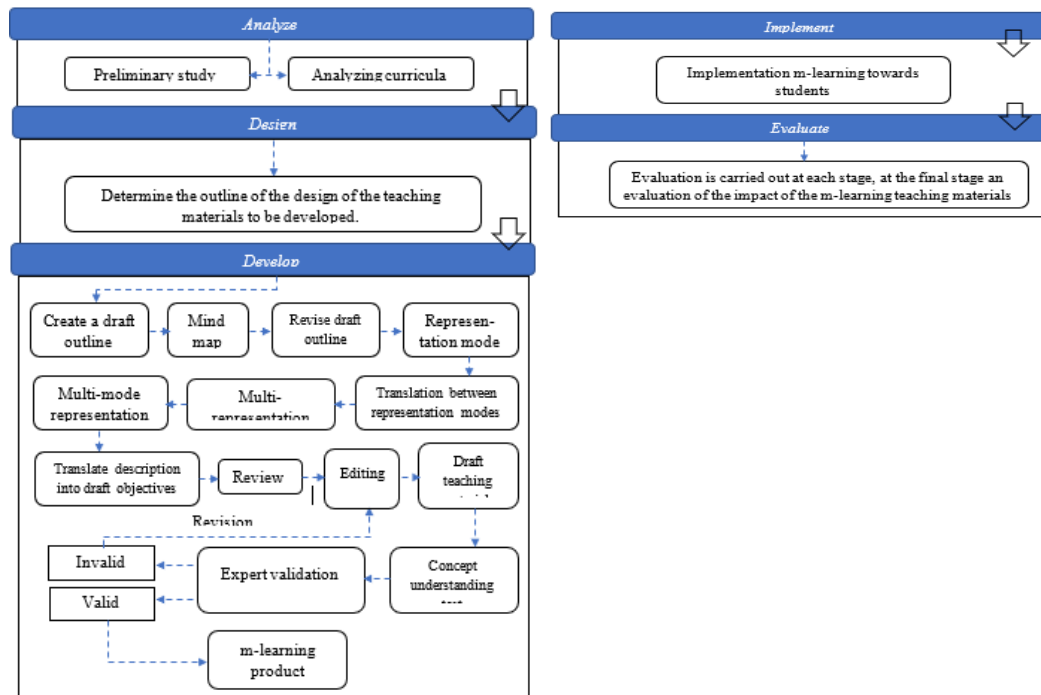


Figure 2 Research procedure

In this article, we elaborate on the results during the analysis and design phase, which comprises the theoretical background and the proposed storyboard.

RESULTS AND DISCUSSION

Critical Thinking Skills

Critical thinking is logical, reflective thinking that determines what to believe or do. It can be applied to other concepts, including metacognition, higher-order thinking, and problem-solving ([Ennis, 1989](#)). According to ([Facione, 2015](#)), critical thinking is an advantageous investigative instrument. To innovate, students must possess critical thinking and creativity to employ various techniques or perspectives to identify and resolve issues ([OECD, 2019](#)). *Critical thinking capacity* can be defined as an individual's capacity to construct an assessment by objectively analyzing and evaluating an issue, information, or experience. Our work following a critical thinking skills framework according to [Facione, \(2015\)](#) which is provided in Table 1.

Table 1 CTs framework

Indicators	Sub-Indicators
Interpretation	Categorize
	Decode significance
	Clarify meaning
Analysis	Examine ideas
	Identify arguments
	Identify reasons and claims
Inference	Query evidence
	Conjecture alternatives
	Draw logically valid or justified conclusions
Evaluation	Assess the credibility of claims
	Assess the quality of arguments that were made using inductive or deductive reasoning
Explanation	State results
	Justify procedures
	Present arguments

Creative Problem-Solving Skills

The capacity to solve problems creatively can be employed to assess an individual's capacity to adapt to changing circumstances and their potential as a reflective and constructive citizen ([OECD, 2014](#)). In this study, the creative problem-solving abilities of the participants will be evaluated using a framework based on the Osborn-Parnes CPS process ([Evans, 1997](#); [Isaksen, 2023](#); [Parnes, 1988](#); [van Hooijdonk et al., 2020](#)) This framework comprises five core components of CPS: fact-finding, problem-finding, idea-gathering, and solution-finding. Due to the complexity of the CPS, the investigation did not concentrate on the acceptance-finding stage. The acceptance-finding stage is a time-consuming and challenging process for students, as they must select a solution that does not cause additional issues and persuade others that the idea used as a solution is worthy of acceptance and implementation.

Mobile Learning

Mobile learning is characterized by the absence of a fixed, predetermined location or the utilization of mobile technology to facilitate learning ([Bano et al., 2018](#); [Grant, 2019](#); [O'Malley et al., 2003](#)). According to [Gawlik-Kobylińska et al. \(2023\)](#), mobile learning addresses student mobility, which entails that students must be able to participate in educational activities without being confined to a strictly defined physical location. Therefore, mobile learning enables students engaged in educational activities to utilize technology as a learning medium by utilizing mobile devices that can access data and communicate with other individuals via wireless technology ([El-Sofany & El-Haggar,](#)

2020). Cell phones, laptops, and personal digital assistants (PDAs) comprise the wireless devices (Sarsar et al., 2019).

Enhance CTs and CPSs Through Mobile Learning

According to constructivist learning theory, students develop new knowledge by drawing on prior experiences (Suhendi et al., 2021). Consequently, individuals form or construct their new understanding or knowledge through interactions with their beliefs, ideas, events, and activities that are relevant to students (Zajda, 2021). In contrast, Piaget (1964) posits that learning is initiated by external circumstances, psychological experimenters, or teachers. Piaget also underscored educators' need to offer opportunities for students to organize and categorize information to facilitate the integration of new information with their existing knowledge (MacQueeney et al., 2022). The constructivist theory also underscores the necessity of student-centered learning (Simanjuntak et al., 2022).

Cognitive learning theory, which also underpins the cognitive processes that occur in mobile learning and the functioning of the brain, works (Kumar et al., 2018), and constructivist learning theory, which posits that students construct knowledge by interpreting new information based on their prior knowledge, are among the theories that underlie the character of mobile learning. For instance, collaborative learning in mobile learning enables students to engage in social interaction while actively constructing information (Fuad, 2020; Partono et al., 2021). This situation is feasible because mobile learning is student-centered and personalized, whereas constructivist theory mandates that learning be student-centered (Ozdamli, 2012; Saekawati & Nasrudin, 2021; Yakar et al., 2020).

Secondly, the dual coding theory (Paivio, 2014) is another theory that underpins the character of mobile learning. This theory posits that humans have two cognitive sub-systems: the first is responsible for processing non-verbal events or objects such as images. In contrast, the second is for processing verbal language and audio. These two factors substantially impact memory, cognition, and learning, and when combined, they can have even more profound effects. This enables the optimization of learning effectiveness through mobile learning designs that strategically integrate images, spoken language, and printed words (Curum & Khedo, 2021; Noetel et al., 2022).

Additional research conducted by Puspitaningrum et al. (2021) indicated that students who study physics in a multi-representation-based learning environment will experience an impact on their problem-solving abilities. Additionally, the utilization of a variety of representations can assist students in comprehending concepts. This representation is presented in a variety of formats, including tables, graphs, free diagrams, bar charts, and pictures (Bologna et al., 2023; Čančula et al., 2015; Lusiyana et al., 2019; Shete & Khobragade, 2023). Additionally, Ainsworth (1999), Munfaridah et al. (2021), Susac et al. (2023), and Tomkelski et al. (2023) underscored the potential of employing multiple representations to facilitate comprehension of intricate scientific concepts. 1) The complementary function is one of the three primary functions of using multiple representations as Ainsworth (2006, 2008) described. 2) limitations on interpretation; 3) development of a more profound comprehension.

Android-based mobile learning materials are utilized as instructional materials that incorporate multi-mode representation. In Android-based mobile learning, teaching materials incorporate a variety of visual and audio representations, including text, images, tables, graphs, animations, videos, and simulations. Utilizing instructional materials in Android-based mobile learning will offer students valuable experiences in acquiring information. Additionally, using Android-based mobile learning teaching materials will facilitate students' comprehension of educational concepts, enhancing their education's character.

Multiple representations are critical to representation systems and meaningful information transformation in teaching materials ([Leisen et al., 2023](#); [McKendree et al., 2002](#)). Moreover, students' reasoning will be influenced by the variations in representation, which is why it should be incorporated into the learning process to develop a more profound understanding. These representations also foster the development of critical thinking skills in students ([Bronkhorst et al., 2020](#)). [Khotimah et al. \(2017\)](#) demonstrated a linear correlation between the level of response to using multi-representation-based physics teaching materials and the development of critical thinking abilities and student learning outcomes. Additionally, mobile learning can be developed to facilitate creative problem-solving activities ([Bae & Lee, 2017](#)) by incorporating programs that emphasize the stimulation of brain activity or experimental activities that employ graphic processes. By incorporating the most recent news articles, explanations of animated videos, phenomenon videos, images, worksheets, and goal-based learning activities, [Sukmafani et al. \(2021\)](#) have created instructional materials that facilitate creative problem-solving.

Design and Storyboard

Skills Matrix

Our goal in developing this application is to offer a learning tool for students in class XI that concentrates on sound waves. The mobile learning design that we have developed incorporates CT (critical thinking) skills and CPS (creative problem-solving) abilities. The CT framework refers to [Facione \(2015\)](#), while the CPS refers to the Osborn-Parness framework ([Evans, 1997](#); [Isaksen, 2023](#); [Parnes, 1988](#); [van Hooijdonk et al., 2020](#)). The material description is summarized in Table 2.

Five subchapters comprise the soundwave material. Regarding the subtopic "What is sound?" It encompasses fundamental concepts, including the definition of sound and the mechanisms by which individuals can perceive it. The critical thinking component of interpretation can be trained on various occurrences, such as the vibration of cricket wings when they produce a cricket sound, to address this issue. Students must offer an interpretation of the behavior and sound of crickets after the phenomenon. The discussions in this sub-chapter are unsuitable for applying CPS, as they are related to fundamental principles, and the issues are more closely related to the advanced topics in the subsequent sub-discussion.

Table 2 Skills component matrix

Sub Topic	CTs	CPSs
What is sound?	✓	×
Properties of soundwaves	✓	✓
Variables in soundwaves	✓	✓
Sounds in daily life	✓	✓
Noise pollution	✓	×

The sub-topic "properties of soundwaves" addresses interference, echoes and reverberations, refraction, and diffraction. In sound reflection, which involves echo and reverberation, we employ critical thinking skills, particularly inference. A virtual simulation of sound reflection is incorporated to enable students to gather data and draw conclusions. Following the discussion of sound diffraction, we incorporated the CPS component, previously addressed in terms of sound interference, reflection, and refraction. During an incident, the mosque's speakers could not communicate the announcement to hilly region residents. Based on this incident, we instruct students to investigate the issues and their underlying causes to design potential solutions.

The third sub-discussion is titled "Variables in soundwaves." It concerns the applications of the Doppler effect, frequency, amplitude, sound intensity, and sound intensity levels in technology. This sub-discussion encompasses an aspect of critical thinking: examining which events include a single frequency and a series of frequencies of two distinct events. In addition, we incorporated the peddler phenomenon after the Doppler effect discussion to address the CPS aspect.

Subsequently, we address the connection between musical instruments and notes in the fourth subtopic, "Sounds in daily life." Our initial conversation focused on basic tones, resonance, and the factors influencing them. Following this discussion, we will incorporate CT skills (evaluation) into evaluating a resonance event. Next, we employ the resonance impacts in apartments to hone our CPS skills.

In the final subtopic, "noise pollution," we provide information on the methods established countries use to address noise pollution and the impact of sound on the lives of humans and animals. The "explanation" aspect of the CT in this subtopic is the phenomenon of two events with varying frequency levels. It elucidates why one set of frequencies is perceived as less comfortable. In the meantime, we discovered that sound pollution has already been addressed in previous subchapters for CPS skills.

Storyboard

Figure 3 illustrates a schematic design that is a blueprint for developing an Android-based mobile learning application prototype.

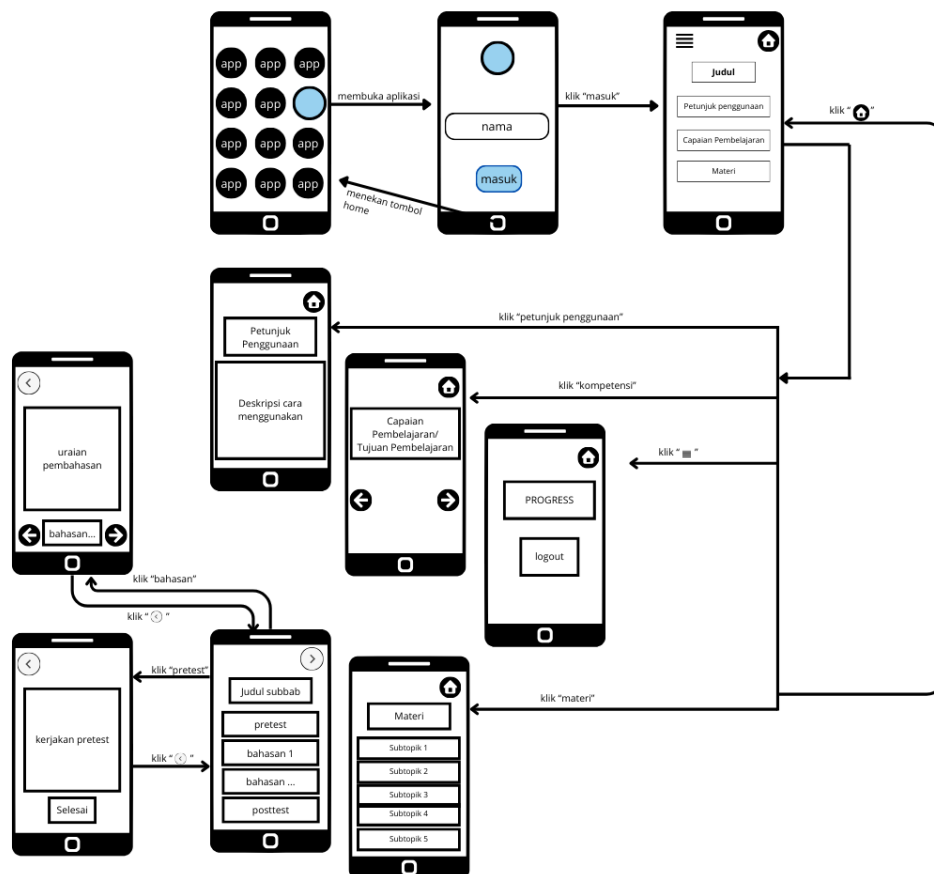


Figure 3 Proposed M-learning storyboard for enhancing critical thinking skills and creative problem-solving abilities

A logon portal will be displayed on the initial screen, where students must input their names. The user will be directed to the dashboard page after successfully logging in. This page contains three tabs: materials, competency achievements, and how to use it. Users can monitor their learning progress by utilizing a droplist feature on the dashboard page, which consists of four vertical black line assets. This feature also includes a logout icon, which will completely erase the work from the system if students log out.

Additionally, students will be directed to the material tab, which encompasses five subtopics. In other words, advanced subchapters cannot be accessed if the prior subchapters have not been completed. Users are required to open subchapters systematically and sequentially on this page. Users must comprehend the fundamental concepts of the material before acquiring advanced concepts, which is why this feature is indispensable.

Pre- and post-tests are administered at the commencement and conclusion of each subchapter. We employ Google Forms for the evaluation, as the inquiries are open-ended.

CONCLUSION

This investigation delineates the theoretical underpinnings and design of mobile learning in physics, which cultivates problem-solving and critical thinking abilities. This system incorporates students into activities that prioritize contextual issues and phenomena, utilizing constructivist learning theory, multiple representation theories, and cognitive-related theory. The content analysis results, which can be associated with aspects of CT and CPS skills training, indicated that CPS could not be implemented in all sub-chapters due to the material's complexity and its correlation with student issues in daily life.

This research offers a concept for developing physics mobile learning, which could improve creative problem-solving and critical thinking abilities. In addition, we guide how to present materials that incorporate elements of CT and CPS, as well as numerous examples of environmental phenomena that can be applied to the physics topic (sound waves). Nevertheless, this investigation has yet to implement a trial to evaluate the efficacy of mobile learning, which has been designed to enhance students' CT and CPS capabilities. For this reason, additional research is required to assess the effectiveness of the mobile physics learning system that has been developed.

CONFLICTS OF INTEREST

The authors declare that there is no conflict of interest.

AUTHOR CONTRIBUTIONS STATEMENT

Conceptualizing research, I.R.S., D.R., S.Z.; designing, I.R.S. and S.Z.; writing—original draft preparation, S.Z. writing—review and editing, I.R.S., D.R., S.Z.

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