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Developing a Problem-Based Science Mobile App to Enhance Critical Thinking Skills and Digital Literacy

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Abstract: The use of technology in the learning process can support 21st century learning. The purpose of this study is to determine the feasibility of a problem-based science mobile app to improve students' critical thinking skills and digital literacy, to determine students' responses to a problem-based science mobile app to improve students' critical thinking skills and digital literacy. The method used is research and development (R&D). The stages carried out adapt the Borg & Gall model, namely preliminary studies, planning, initial product development, product validation, limited trials, revisions to produce the main product, and product dissemination and implementation. The results of the study showed an average total validation score from media experts, material experts and teachers/practitioners in the learning aspect of 52.17, material aspects 54.17, media display aspects 77.33, and programming aspects of 43.17, all aspects of the very good category. The results of the analysis of student responses to the problem-based science mobile app obtained an average score of 14.39 in the very good category. Based on the results of the study, it can be concluded that the developed problem-based Science Mobile App is suitable for use by teachers as a medium to improve critical thinking skills and digital literacy. Student response to the problem-based science mobile app was very good, so the app can be used well by students.

Keywords: Application; Critical thinking; Pproblem-Based; Digital literacy; Science mobile app

Introduction

Education plays a strategic role in driving the success of the Sustainable Development Goals (SDGs). Education for sustainable development (ESD) is key to realizing SDG 4 on quality education. Within this framework, science education, as a dynamic and applicable discipline, directly contributes to the achievement of sustainable education goals by bridging scientific knowledge with social and environmental contexts (Allen et al., 2021; Asrizal et al., 2018). Thus, science learning plays a role not only in the transfer of scientific concepts but also in fostering awareness and concrete action on sustainability issues (Sauvé et al., 2016). One of the essential competencies supporting the success of the SDGs is critical thinking skills (Straková & Cimermanová, 2018). This competency is crucial for achieving inclusive and quality education (Boluk et al., 2019) as it enables students to analyze, evaluate, and solve various global problems in depth, while simultaneously understanding sustainability issues from a social, economic, and environmental perspective (Shutaleva, 2023). Critical thinking also fosters self-reflection, empathy, and a sense of responsibility for sustainability (Zarzycki, 2025). In science learning, this ability is realized through the practice of assessing evidence, constructing arguments, and communicating findings responsibly (Giri & Paily, 2020). However, various studies show that students' critical thinking skills in science learning are still relatively (Adinda et al.,

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2022), with achievements ranging from 32% to 36.59% in the aspects of interpretation, analysis, evaluation, inference, explanation, and self-regulation. Hidayati & Sinaga (2019), also reported that the average score for students' critical thinking skills was only 45%. This low achievement is influenced by, among other things: a curriculum that does not explicitly formulate indicators and strategies for developing critical thinking the use of monotonous teaching methods that do not stimulate higher-order thinking skills (Yang et al., 2025) and an excessive emphasis on the technical aspects of using digital media without critical reasoning and problem-solving, which are demands of the 21st century.

In addition to critical thinking skills, digital literacy is an equally important competency in education. Digital literacy is the ability to use technology to access information and participate in decision-making processes, this is important in supporting the 2030 Sustainable Development Goals (SDGs) (Putri et al., 2024). Digital literacy is also an important competency to master, as it enables students to understand scientific content more deeply, increases motivation, and strengthens competencies in science learning (Atmojo et al., 2021). However, several previous studies indicate that students' digital literacy levels are low to moderate (Son & Ha, 2025), with significant differences in perceptions between teachers and students. Although most students possess adequate digital literacy skills, technology use is still predominantly for recreational purposes, rather than for learning activities (Dashtestani & Hojatpanah, 2022). Furthermore, the integration of digital literacy into the school curriculum is still suboptimal, compounded by teachers' limited ability to implement digital-based learning effectively (Widiyawati et al., 2021). In fact, strong digital literacy is a crucial prerequisite for developing critical thinking skills, as it enables students to sort scientific information, evaluate data sources, and integrate knowledge from various digital platforms to construct valid arguments. Therefore, enhancing critical thinking skills and digital literacy should be integrated into the science learning process.

Strengthening students' critical thinking and digital literacy skills requires a learning ecosystem that is interactive, reflective, and adaptive to technological developments. This requires more than just the introduction of digital media, but also fosters reasoning, collaboration, and in-depth (González-Pérez & Ramírez-Montoya, 2022). The learning process needs to be designed to be interactive, high-quality, and contextual (Tawfik et al., 2021). Therefore, a learning model that integrates real-world problem-solving activities with the support of digital technology in a structured and meaningful manner is needed. Problem-Based Learning (PBL) is a relevant learning model to support student-centered learning and emphasizes complex, authentic problem-solving. Through group work, students are guided to analyze real-world problems, identify learning needs, and apply the acquired knowledge to find appropriate solutions. The problem-based learning process not only fosters critical and collaborative thinking skills but also develops reflection skills, which are essential for continuous learning (Carpenter et al., 2021), which aligns with ESD principles.

The integration of PBL with digital media such as the Science Mobile App enables more interactive, flexible, and contextual implementation of problem-based learning. This app can facilitate simulations, exploration of scientific concepts, collaborative discussions, and assessments of critical thinking and digital literacy directly on students' devices. The use of diverse digital media can facilitate independent, interactive, and reflective learning (Peña-Ayala, 2021). Technology integration enables more participatory learning, enabling students to become not only recipients of information but also creators of knowledge through various media- and computer-based activities (Gretter & Yadav, 2016). With this approach, the Science Mobile App functions not only as an aid but also as a digital learning environment that encourages knowledge construction, scientific exploration, and problem-based collaboration. Interviews with science teachers at SMP Negeri 16 Semarang, SMP Teuku Umar, and SMP Karangturi Semarang revealed several challenges in learning. Teachers experienced difficulties in time management during practical work due to limited facilities and face-to-face time.

The use of technology-based learning media is still limited to presentations and videos from the internet, not interactive applications that engage students in problem-solving. Furthermore, teachers have never developed or used science applications that specifically support practical activities and problem-based learning. Several teachers also stated that students are still passive in presenting arguments or analyzing practical results, and are unable to utilize digital devices to explore science concepts. This indicates the need to develop a problem-based science mobile app that can train students' critical thinking and digital literacy skills. These findings highlight the gap between the demands of 21st-century learning and practical learning, making the development of a problem-based science mobile app a relevant solution for improving students' critical thinking and digital literacy skills.

The purpose of this study was to determine the feasibility of a problem-based science mobile app for improving students' critical thinking and digital literacy skills and to assess students' responses to the problem-

based science mobile app for improving their critical thinking and digital literacy skills. Conceptually, this research is expected to contribute to the development of innovative digital technology-based science learning that aligns with the principles of Education for Sustainable Development.

Method

This research is a research and development (R&D) study. The stages adopted the Borg & Gall research and development model: preliminary study, planning, initial product development, product validation, limited trials, revisions to produce the main product, and product dissemination and implementation. The first stage, the preliminary study, is divided into a field study and a literature review. The field study involved interviews with junior high school science teachers to obtain information on science learning conditions, teachers' use of digital media, students' critical thinking skills, and digital literacy. Furthermore, it also identified teachers' needs for applications or multimedia to support the learning process. The literature review involved gathering relevant literature and reviewing information on learning outcomes (CP) dimension D contained in the independent science curriculum for grade VII junior high school/Islamic junior high school (SMP/MTs), indicators of critical thinking and digital literacy, multimedia, and the problem-based learning model.

The second stage, planning, was conducted to determine the competencies students must master according to the curriculum. This was intended to define the competencies or abilities to be developed through the Science Mobile App. The steps taken include determining learning objectives (TP) and the Learning Objective Flow (ATP) based on the Learning Outcomes (CP) of Dimension D of the Independent Curriculum for science; developing learning indicators that students must master for the topic of matter and its changes; planning a problem-based learning syntax; outlining the topic and planning contextual problems appropriate to the topic of matter and its changes, which will be presented in learning videos, animations, or Student Worksheets (LKPD); designing learning activities (process and content) to be incorporated into the application; designing the format of the Science Mobile App; and designing the learning tools and assessment instruments to be used. The third stage is product development. The initial Science Mobile App is designed based on the design created in the planning stage. The problem-based Science Mobile App is used to present everyday life problems related to the topic of matter and its changes. The Science Mobile App also provides assignments and questions that can be discussed by students in groups.

In addition, a summary of the material, learning videos, assessments, and games will be provided that can be used in learning or as a supplement to deepen the material. The initial step is to compile a flowchart and storyboard. A flowchart is a diagram of the presentation of a media program from the opening, media content to the program exit. Meanwhile, a storyboard is a reference for media display design that contains a description of the visual and audio components of each flow in the flowchart. The next step is to collect materials relevant to the learning objectives to be achieved. The collected materials can be sourced from reference books, journals, websites or personal collections. The collected materials include materials in the form of text, images and videos. The materials to be included in the Science Mobile App are identification of changes in the state of matter, identification of changes in the properties of matter, analysis of types of changes in matter; as well as supporting materials, namely the water cycle, and the concepts of floating, floating, sinking. The Science Mobile App is compiled using the Adobe Flash Professional CS 5 program application supported by other programs, namely Camtasia 2023 for compiling videos, and Plotagon Story for creating animations. Media creation is based on the flowchart and storyboard that have been designed.

Furthermore, the Science Mobile App product is packaged in .apk format and can be used on smartphones offline. The next stage was to develop a science teaching module for the independent curriculum using a problem-based learning model and a teaching-at-the-right-level approach for the topic of matter and its changes to enhance critical thinking skills and digital literacy. The components of the teaching module included general information, core components, and appendices. A validation questionnaire was also developed based on multimedia quality indicators, referring to theories and expert opinions from relevant fields. The questionnaire was structured on a Likert scale with four answer choices. The scores obtained were then converted into a four-point scale. All learning tools and assessment instruments that had been developed were then consulted with colleagues, and then revised based on the criticism and suggestions provided. The fourth stage of product validation included the following steps: Validating the problem-based Science Mobile App product with subject matter and media expert lecturers; Analyzing and revising the product based on criticism and suggestions from subject matter and media experts; Evaluating the resulting product by teachers, namely junior high school science teachers; Analyzing and revising the product based on criticism and suggestions

from teachers; and piloting the revised product based on criticism and suggestions from peer reviewers. The quality of the problem-based Science Mobile App product is assessed based on learning aspects, materials, media presentation, and programming. The scores obtained for each aspect are then converted into a grade. The score conversion is shown in Table 1.

Table 1. Score Conversion for the Problem-Based Science Mobile App Quality Assessment

Aspect	Score interval	Category
Learning aspects	$48.75 \leq \overline{M} \leq 60$	Very good
	$37.50 \leq \overline{M} < 48.75$	Good
	$26.25 \leq \overline{M} < 37.50$	Fair
	$15 \leq \overline{M} < 26.25$	Poor
Material aspects	$48.75 \leq \overline{M} \leq 60$	Very good
	$37.50 \leq \overline{M} < 48.75$	Good
	$26.25 \leq \overline{M} < 37.50$	Fair
	$15 \leq \overline{M} < 26.25$	Poor
Media display aspects	$74.75 \leq \overline{M} \leq 92$	Very good
	$57.50 \leq \overline{M} < 74.75$	Good
	$40.25 \leq \overline{M} < 57.50$	Fair

The fifth stage of the limited trial of the problem-based Science Mobile App was carried out on 15 junior high school students. The students were from class VIII at Kaliwungu State Junior High School who were selected randomly but with attention to their ability levels, namely students with low, medium, and high abilities. Students were asked to provide feedback on the developed media product through a questionnaire. The data from the limited trial results were used as input for media improvements. The sixth stage, product revisions were carried out based on suggestions and input from limited trial students. The seventh stage was product dissemination. The revised problem-based Science Mobile App was then disseminated on a wider scale. This media is expected to be an alternative learning media to explore and develop students' understanding and abilities.

Result and Discussion

At the junior high school level, instruction is directed toward student-centered learning (Afni et al., 2021). The Development of Integrated Science Instructional Materials to Improve Students' Digital Literacy in Scientific Approach (Jumadi et al., 2018) and the development of 21st-century skills (Mabsutsah et al., 2023; Rasmitadila et al., 2020). In this context, students are required to master critical thinking, creativity, collaboration, communication, and digital literacy skills to address real-world (Rahmah et al., 2024; Rahmaniar, 2022; Yuliana et al., 2024). This preliminary study aims to identify the challenges teachers face in implementing science learning within the Independent Curriculum and the need for learning media. The study was conducted through three methods, namely interviews, questionnaires, and Focus Group Discussions (FGD), involving 7th grade science teachers from various schools in Central Java, including SMP Negeri 1 Kaliwungu Kudus, SMP Teuku Umar Semarang, SMP Karangturi Semarang, SMP Kartiyoso Semarang, SMP Plus Daarul Ahgaff Pabelan Semarang Regency, MTs Negeri 1 Demak, SMP Bhinneka Karya Klego Boyolali, and SMP Negeri 16 Semarang. Based on the results of the preliminary study, it was found that teachers face various obstacles in implementing differentiated science learning.

Teachers have difficulty in identifying the needs, interests, and learning styles of individual students. This process requires time, assessment instruments, and special skills that have not been fully mastered.As a result, differentiated learning becomes less relevant to the diversity of students, particularly in terms of cognitive abilities. Furthermore, teachers face challenges in managing time and class time to ensure all students receive equal attention, resulting in a lack of active student engagement in learning. Current teaching tends to focus on explaining basic concepts without encouraging students to develop higher-order thinking skills (HOTS), which are essential elements of 21st-century skills. Another challenge is the limited availability of diverse learning resources that support differentiated learning. Teachers commonly use PowerPoint in the learning process, but this method remains passive (Lohr et al., 2021). Students only receive information in the form of text or images without in-depth interaction, thus limiting their active engagement and suboptimal competency development.

The limited time for science learning, which is only 160 minutes per week, is also a constraint. This duration is often only sufficient to explain basic concepts without allowing for contextual deepening of the material. Therefore, learning media are needed that are not only varied and support differentiation but also accessible offline. These media are expected to streamline the learning process while encouraging the development of students' higher-order thinking skills. One potential solution is the development of a problem-based science mobile app. This app can be a learning support tool outside of class hours, designed to meet students' individual learning needs. With interactive features such as simulations and real-world problem-based videos, this app can increase student engagement and foster critical, analytical, and creative thinking skills. The increasing accessibility of technology among students, particularly smartphones, presents a significant opportunity to integrate problem-based learning.

Furthermore, the app can be designed for offline access, allowing for flexible use without relying on an internet connection.

With features that support personalized learning, a variety of learning resources, and the development of critical thinking skills, this app aligns with the demands of the 21st-century curriculum. Developing a problem-based science mobile app can not only address challenges faced in science learning but also support the holistic development of student competencies in line with the needs of modern education. The next step is a literature review. This literature review is conducted by collecting and studying information regarding audiovisual media, problem-based learning, differentiated learning in the Independent Curriculum, and 21st-century skills. The literature review activity provides information related to the competencies contained in the Phase D Science Learning Outcomes for grade VII of junior high school/Islamic junior high school. Based on the analysis results, Based, on the learning outcomes in the Independent Curriculum for phase D (grade VII of junior high school), the material on substances and their changes is very potential to train students' critical thinking skills.

This achievement emphasizes understanding the process of identifying the properties and characteristics of substances, physical and chemical changes, and the separation of simple mixtures. This material is closely related to everyday phenomena that students often experience, such as melting ice, boiling water, or burning paper. Through this topic, students can be trained to identify, analyze, and evaluate information based on real situations. Planning is carried out to determine the competencies that students must master according to the curriculum. This is intended to define the competencies or abilities that will be developed through the Science Mobile App product. The next step is to outline the topics to be included in the media, create a design for the learning tools and assessment instruments used. The material used in this study is substances and their changes. The learning objectives to be achieved in this material are to classify matter based on its state of matter; analyze the differences in the properties of solids, liquids, and gases; find examples of matter in the form of solids, liquids, and gases in everyday life; explain the meaning of mixtures and single substances (elements and compounds); classify matter based on its composition (mixtures and single substances); find examples of matter included in mixtures and single substances; explain the principles of separating mixtures; explain the methods of separating mixtures; explain the meaning of physical and chemical properties; explain the meaning of changes in matter (physical and chemical changes); analyze the characteristics of physical and chemical changes; classify the types of changes in matter that occur; and find examples of physical and chemical changes that occur in everyday life.

The material topics to be included in the Science Mobile App are states of matter and particle models, changes in state of matter, physical and chemical changes, and density of matter. The development of the Science Mobile App begins with the creation of a flowchart and storyboard. A flowchart is a diagram of the presentation of a media program, from the introduction and content to the conclusion. A storyboard is a design reference for the media display, containing descriptions of the visual and audio components of each flowchart. The next step is to gather materials relevant to the Learning Outcomes and learning objectives. The collected materials come from reference books, journals, websites, and personal collections. The collected materials include text, images, and videos. The problem-based development of the Science Mobile App uses the Articulate Storyline program, supported by other programs: Camtasia 2019 for video composition, Adobe Illustrator for asset creation, https://elevenlabs.io/app/speech-synthesis/text-to-speech for voiceover narration, and Adobe Animate for animation. Media creation is based on the designed flowchart and storyboard. The developed Science Mobile App is then packaged as an APK file and can be used offline on smartphones. The initial page display of the problem-based Science Mobile App developed is presented in Figure 1.

Figure 1. Home Page View

The Science Mobile App has nine main menus. The main menu page of the Science Mobile App is shown in Figure 2.

The menus in the Science Mobile App include: Objectives, which contain learning outcomes, elements

of science understanding, process skills, and learning objectives; Initial Assessment, which contains 20 multiple-choice questions that can be used as an initial assessment to measure students' cognitive abilities; Teaching Module, which contains the Independent Curriculum teaching module that teachers can use as a learning guide for the topic of substances and their changes; Material, which contains a summary of the topic of substances and their changes; and Simulation, which contains simulations: floating, floating, sinking experiments, and experiments on comparing the densities of substances. Additionally, Student Worksheets (LKPD) are provided as a guide for conducting the experiment simulations independently. A display of the floating, floating, and sinking experiment simulation is shown in Figure 3.

Figure 2. Menu Page Display

Figure 3. Simulation display of floating, hovering, and sinking experiments

The sixth menu is Practice Questions, which presents 25 questions. These questions are used to determine students' level of understanding and critical thinking skills after participating in learning with the Science Mobile App. Discussion, which contains case videos of "making coffee," "cooking eggs," and "making bread." Based on the videos presented, students are asked to discuss problem-solving through activities in the Student Worksheet (LKPD) presented in the media. Glossary, which contains explanations of terms related to matter and its changes; References, which contains a list of references that can serve as learning resources for students. The problem-based Science Mobile App begins with problem orientation through videos or animations depicting everyday phenomena, such as making iced coffee, cooking eggs, and baking bread. The Android application format allows students greater flexibility in learning. According to Chizary & Farhangi (2017), this type of application can provide challenges that increase students' motivation and guide them to develop higher-order thinking skills. The results of the problem-based Science Mobile App validation from material experts, media experts, and teachers are shown in Figure 4.

According to Figure 4, the average total score from the validators for the learning aspect was 52.17, which is in the very good category. For the material aspect, the average total score was 54.17, which is in the very good category. For the media display aspect, the average total score was 77.33, which is in the very good category. For the programming aspect, the average total score was 43.17, also in the very good category. The validation results from subject matter expert lecturers, media experts, and teachers indicate that the developed problem-based Science Mobile App is suitable for use by teachers as a medium to improve critical thinking skills and digital literacy.A limited trial was conducted at SMP Negeri 1 Kaliwungu Kudus with 36 grade VIII A students. Students were asked to provide feedback on the developed product through a questionnaire. The data obtained from the questionnaire consisted of student assessments and responses to the material and media display aspects. The questionnaire contained 15 statements with answer options of yes (1) and no (0). The questionnaire included an assessment of media quality in terms of both material and display. The average score of students' responses in the limited trial regarding the quality of the problem-based Science Mobile App was 14.39 out of a maximum score of 15. The score obtained was categorized as very good. The revised problem-based Science Mobile App was then disseminated to science teachers at SMP Negeri 1 Kaliwungu Kudus.

The development of a problem-based science mobile app is a strategic innovation in science learning aimed at improving students' critical thinking skills and digital literacy in the digital age. Integrating a problem-based learning approach into mobile apps has proven effective in fostering critical thinking skills through a student-centered learning process based on real-world

problem-solving. Various studies have shown that the use of problem-based learning apps significantly improves students' critical thinking scores because the learning process encourages analysis, evaluation, and reflection on the scientific phenomena encountered (Cong & Ironsi, 2025; Ismail et al., 2018; Susanto et al., 2022). Through digitally packaged problem-based learning, students can develop reflective thinking habits oriented toward solving real-world problems in their environment. The integration of digital technology into learning encourages students to become more skilled at using digital devices as a medium for scientific exploration and collaboration. Research shows that the use of mobile applications with a PBL approach significantly improves digital literacy, particularly in the skills of searching for, evaluating, and using scientific information critically and ethically.

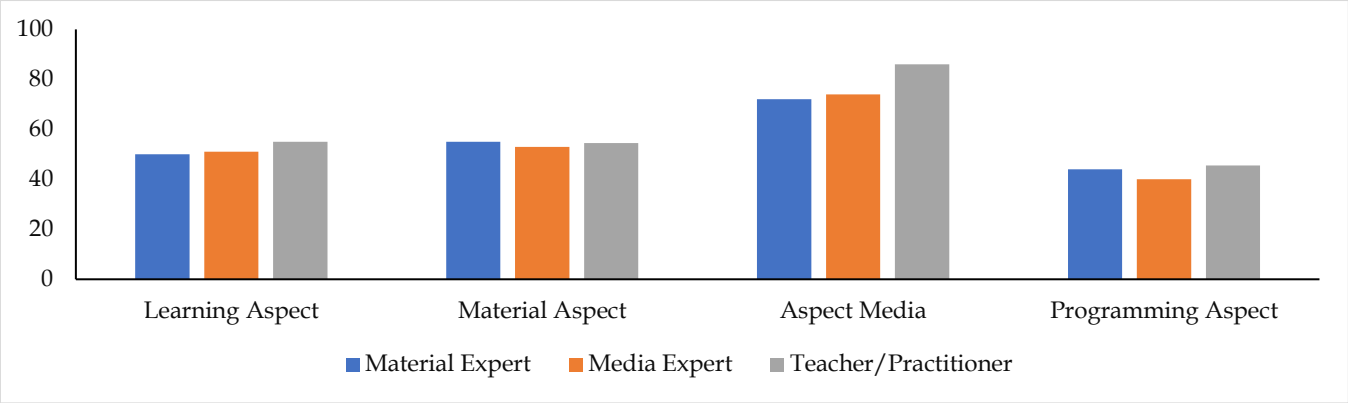

Figure 4. Assessment Results of the Problem-Based Science Mobile App

This technology-based learning allows students to interact with science content through various digital formats such as interactive videos, simulations, and reflective quizzes, all of which strengthen their digital competencies. PBL-based mobile applications are generally equipped with several key features designed to support 21st-century skills. These features include contextual learning narratives, videos of scientific experiments, reflection-based practice questions, and online discussion spaces that encourage collaboration between students. This combination of features not only supports the development of critical thinking and digital literacy but also creates a flexible, engaging learning environment that is accessible anytime and anywhere. Thus, these applications help overcome the limitations of space and time in traditional science learning and provide more adaptive and personalized learning opportunities. Problem-based Science Mobile App is expected to facilitate students with various cognitive levels so that it can improve students' critical thinking skills and digital literacy. The use of audio-visual media has been proven effective in increasing student learning motivation and stimulate students to take an active role in the learning process (Sari & Sugiyarto, 2015). This media is able to accommodate all levels of student cognitive abilities, increase learning concentration and make students more focused on the material given.

Technology-based learning media has an important role in improving students' digital literacy (Lestari et al., 2024). Learning that utilizes audio-visual media becomes more interesting and interactive, allowing students to explore more deeply about the material being taught and improve their understanding. This media can also be used as a supplementary material to make the learning process more effective. The problem-based learning (PBL) approach applied in the Science Mobile App engages students in problem-solving that requires analysis and evaluation. Research by Asyari et al. (2016), shows that PBL is effective in improving critical thinking skills. Santos-Meneses et al. (2023) also added that problem-based questions help students connect knowledge to real-life situations, deepen their understanding, and improve critical thinking skills (Hanzlová & Kudrnáč, 2024). The problem-based Science Mobile App is expected to be an alternative learning medium to facilitate students with various levels of cognitive ability and explore and develop critical thinking skills and digital literacy (Haleem et al., 2022; Wardani & Widodo, 2024).

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Conclusion

Based on the analysis, the average scores for the learning, material, media display, and programming aspects were all in the very good category. Therefore, it can be concluded that the developed problem-based Science Mobile App is suitable for use by teachers as a medium to improve critical thinking skills and digital literacy. The analysis of student responses to the problem-based Science Mobile App yielded an average

score of 14.39, in the very good category. Therefore, the developed problem-based Science Mobile App can be used effectively by students.

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Author Contributions
I.N, D.S.S, and Y.W. developed the research design. Y.W. provided input on the research design. I.N. and D.S.S. developed the content for the problem-based science mobile app and validated the product with experts. I.N., D.S.S., and Y.W. interpreted and analyzed the product validation results. I.N., D.S.S., and Y.W. revised the developed problem-based science mobile app. All authors contributed to the preparation of the research article.

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