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Development and Expert Validation of SciTin AR Learning: Integrating Augmented Reality, Problem-Based Learning, and the Local Tin Mining Context into Junior High School Science

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Abstract: The integration of digital technology and contextual learning has become increasingly important for improving the quality of science education. Although mobile learning, Augmented Reality (AR), and Problem-Based Learning (PBL) have individually demonstrated positive contributions to science learning, few studies have integrated these approaches with local environmental contexts into a single mobile learning platform. To address this gap, this study developed *SciTin AR Learning*, an innovative science mobile learning application that integrates AR, PBL, and the local tin mining context to support meaningful junior high school science learning. This study aimed to develop and conduct expert validation of *SciTin AR Learning*. This research employed a Research and Development approach using the Analysis, Design, and Development phases of the ADDIE model. The product was evaluated by four expert validators consisting of two university experts and two professional science teachers using content and media validation instruments. Prior to product evaluation, the instruments demonstrated high content validity based on Aiken's V coefficients, with mean values of 0.987 for the content validation instrument and 0.979 for the media validation instrument. The results showed that *SciTin AR Learning* achieved a Very Good level of validity, with mean scores of 3.96 for content validity and 3.94 for media validity. Expert feedback led to improvements in application functionality, contextual learning content, literacy integration, and interactive worksheet features. These findings indicate that *SciTin AR Learning* is a valid instructional product and provides a foundation for subsequent studies evaluating its practicality and effectiveness in junior high school science learning.

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Introduction

Recent global education reports, including the UNESCO Global Education Monitoring Report 2023, have highlighted the growing importance of digital technologies in transforming teaching and learning worldwide. UNESCO (2023) emphasizes that technology should be integrated into education in ways that improve learning quality, promote equity, and support meaningful learning rather than simply increasing access to digital devices. The rapid

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advancement of digital technology has significantly transformed educational practices, requiring learning environments to become more interactive, student-centered, and responsive to the demands of twenty-first-century education. In science education, the integration of digital technology is no longer limited to facilitating access to learning resources but has become an essential strategy for promoting meaningful learning experiences that encourage students to actively construct knowledge through inquiry, problem-solving, and scientific reasoning (Ramli & Borhan, 2024; Ubben et al., 2023; Unlu & Dokme, 2020; Wörner et al., 2022). Consequently, teachers are expected to design innovative learning environments that not only enhance students' conceptual understanding but also foster higher-order thinking skills and the ability to apply scientific knowledge in authentic contexts (Nakjah & Adawiah, 2025; Yanti & Thohir, 2024). The increasing availability of smartphones among students has further accelerated the adoption of mobile learning as a promising educational approach, offering flexibility, accessibility, and opportunities for learning beyond conventional classroom boundaries (Mohamed & Al-Hidabi, 2019; Sophonhiranrak, 2021). Nevertheless, the educational benefits of mobile technology depend not merely on its availability but on how effectively it is integrated with appropriate pedagogical approaches and meaningful learning contexts (Khaokhajorn et al., 2020; Martínez et al., 2019; Palalas & Wark, 2020). Among the essential competencies expected from science education in the digital era, scientific literacy has become one of the primary educational goals because it equips students with the ability to understand scientific concepts, evaluate evidence, and make informed decisions in addressing real-world problems (Antonio et al., 2022; Howell & Brossard, 2021; Reddy, 2021; Toole et al., 2020).

Science education plays a strategic role in preparing students to understand natural phenomena, evaluate scientific information critically, and make responsible decisions regarding issues affecting society and the environment. These competencies are closely associated with scientific literacy, which has become one of the primary objectives of contemporary science education (Fortus et al., 2022; Guerrero & Sjöström, 2025; Li & Guo, 2021). Scientific literacy extends beyond mastering scientific concepts; it encompasses the ability to explain scientific phenomena, interpret evidence, evaluate scientific claims, and apply scientific knowledge to solve real-world problems (Ayu et al., 2025). Despite continuous curriculum reforms and technological advancements, numerous studies have reported that students continue to experience difficulties in applying scientific concepts to everyday situations, indicating that science learning frequently emphasizes memorization rather than conceptual understanding and scientific reasoning (Ayu et al., 2025; Kokkonen & Schalk, 2021; Ramlawati et al., 2025; Zhao & Schuchardt, 2021). This situation highlights the necessity of developing learning innovations that encourage students to engage actively with authentic scientific problems and contextual learning experiences.

In addition to scientific literacy, environmental literacy has emerged as another essential competency for students living in an era characterized by increasingly complex environmental challenges. Environmental issues such as climate change, biodiversity loss, pollution, and unsustainable exploitation of natural resources require citizens who possess not only scientific knowledge but also environmental awareness, responsible attitudes, and informed decision-making skills (Adamou et al., 2021; Ardoin et al., 2020; Kranz et al., 2022; Saputra, Wilujeng, & Wiyarsi, 2026). Science learning therefore should provide opportunities for students to investigate environmental problems within their own communities and explore scientifically sound solutions (Ariza et al., 2021; Chastenay et al., 2023; Lubis, 2022). Integrating environmental issues into science instruction enables students to connect classroom

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knowledge with real-life experiences, making learning more meaningful while simultaneously fostering environmental responsibility (Kumar et al., 2024; Marfiana et al., 2025). Consequently, learning resources that incorporate local environmental contexts are increasingly recognized as an effective means of strengthening both scientific literacy and environmental literacy among secondary school students.

Previous studies consistently suggest that scientific literacy and environmental literacy are closely interconnected rather than independent educational outcomes. Scientific literacy enables students to understand scientific concepts, interpret evidence, and evaluate scientific claims, whereas environmental literacy extends these competencies by fostering environmental awareness, responsible attitudes, and informed decision-making regarding environmental issues (OECD, 2023). Consequently, strengthening scientific literacy provides the cognitive foundation upon which environmental literacy can be developed, allowing students not only to understand environmental problems scientifically but also to make responsible and sustainable decisions. This relationship highlights the need for science learning environments that simultaneously promote scientific reasoning and environmental responsibility through authentic and contextual learning experiences. Accordingly, learning environments supported by digital technologies have considerable potential to foster both scientific literacy and environmental literacy through contextual, inquiry-based, and student-centered learning experiences.

One promising approach to addressing these educational challenges is the implementation of science mobile learning. The widespread ownership of smartphones among students has created new opportunities for learning that extend beyond traditional classroom settings (Firmansyah et al., 2019; Hartley et al., 2020; Ruiz-martínez et al., 2022). Science mobile learning enables students to access instructional materials, interactive multimedia, and learning activities anytime and anywhere, thereby promoting flexible, self-directed, and continuous learning experiences (Palalas & Wark, 2020; Widowati & Tyas, 2024). Previous studies have demonstrated that mobile learning can enhance students' motivation, engagement, and conceptual understanding in science education (Anselmo et al., 2024; Kalogiannakis et al., 2021; Palalas & Wark, 2020; Siswanto et al., 2025). However, systematic reviews also indicate that many mobile learning applications continue to emphasize content delivery rather than supporting inquiry-based, contextual, and collaborative science learning. Existing applications often provide limited opportunities for students to engage in authentic scientific investigations and meaningful interaction with real-world contexts, highlighting the need for more pedagogically integrated mobile learning environments (Liu et al., 2021). Consequently, there remains a need to develop science mobile learning applications that integrate innovative technologies with effective pedagogical approaches to create more meaningful learning experiences.

Among emerging educational technologies, Augmented Reality (AR) has attracted considerable attention because it enables students to visualize abstract scientific concepts through interactive three-dimensional virtual objects integrated into real-world environments (Tilili et al., 2023). In science education, AR facilitates students' understanding of scientific phenomena that are difficult to observe directly, thereby improving conceptual visualization, learning engagement, and cognitive processing (Saputra, Wilujeng, Wiyarsi, et al., 2026). Previous studies have consistently reported that AR enhances students' visualization and conceptual understanding of scientific concepts. However, recent reviews also indicate that most AR applications in science education are primarily designed to support visualization and content presentation, with limited integration of inquiry-based pedagogies, collaborative

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learning, authentic problem-solving, and local contextual issues. Consequently, AR is often implemented as a stand-alone technological tool rather than as part of a comprehensive instructional framework that promotes meaningful scientific learning (Irwanto et al., 2022; Parga et al., 2023; Rahmat et al., 2023). Therefore, the educational potential of AR can be further optimized when combined with an appropriate instructional model that actively engages students in the learning process.

Problem-Based Learning (PBL) is widely recognized as an instructional model that promotes meaningful learning by engaging students in authentic problems that require investigation, critical thinking, collaboration, and evidence-based decision making. Through PBL, students are encouraged to construct scientific knowledge while simultaneously developing problem-solving skills and scientific reasoning (Funa, 2021; Magaji, 2021; Tawfik et al., 2020). The characteristics of PBL closely align with the objectives of science education, particularly in fostering scientific literacy and environmental literacy through contextual learning experiences (Fadilah et al., 2025; Pertiwi et al., 2019). Integrating PBL into science mobile learning is therefore expected to provide a more structured pedagogical foundation that supports active student participation rather than passive information consumption.

In addition to technological and pedagogical integration, contextual learning represents another important aspect of meaningful science education. One contextual resource with considerable educational potential in Indonesia is local tin mining. Tin mining activities involve various scientific concepts, including geological processes, mineral resources, ecosystem changes, environmental pollution, natural resource management, and sustainable development. Integrating local tin mining potential into science learning enables students to connect scientific theories with environmental issues encountered within their surrounding communities. Such contextualization not only enhances conceptual understanding but also encourages students to develop environmental awareness and responsibility toward sustainable natural resource management.

Although previous studies have reported the positive contributions of mobile learning, Augmented Reality, Problem-Based Learning, and local-context-based instruction to science education, these approaches have largely been investigated as separate instructional innovations. Only limited studies have attempted to integrate these four components within a single science mobile learning platform designed to support both scientific literacy and environmental literacy. As a result, the potential of integrating technological, pedagogical, and contextual dimensions to simultaneously foster scientific literacy and environmental literacy has not yet been fully explored. Furthermore, previous research has primarily emphasized learning effectiveness, whereas comprehensive expert validation of integrated digital learning media prior to classroom implementation remains relatively underexplored. This gap indicates the need for systematic development and validation studies to ensure that innovative learning media possess adequate content quality, instructional appropriateness, media design, language quality, and technical functionality before being implemented in science classrooms.

To address these research gaps, this study developed *SciTin AR Learning*, an innovative science mobile learning application that integrates Augmented Reality, Problem-Based Learning, and local tin mining potential into a single digital learning platform for junior high school science education. Unlike previous learning applications that emphasize only technological innovation or learning effectiveness, *SciTin AR Learning* was designed by integrating technological, pedagogical, and contextual dimensions to support meaningful science learning. Prior to classroom implementation, comprehensive expert validation was conducted to evaluate the quality of the developed application from multiple perspectives,

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including science content, instructional design, media design, language, and technical aspects. Therefore, this study aims to develop and validate *SciTin AR Learning* for junior high school science education through comprehensive expert evaluation. The findings are expected to provide empirical evidence regarding the validity of the developed learning application as a prerequisite for subsequent implementation and effectiveness testing in science learning.

Research Method

Research Design

This study employed a Research and Development (R&D) approach to develop and validate *SciTin AR Learning*, a science mobile learning application integrating Augmented Reality (AR), Problem-Based Learning (PBL), and local tin mining potential for junior high school science learning. The development process adopted the ADDIE instructional design model, consisting of Analysis, Design, Development, Implementation, and Evaluation. However, because the primary objective of this study was to develop the learning application and establish its validity before classroom implementation, only the Analysis, Design, and Development phases were carried out. The Implementation and Evaluation phases, which focus on practicality and effectiveness testing, were beyond the scope of this study and will be reported in subsequent research. This methodological adaptation is consistent with Research and Development studies that emphasize expert validation as an essential prerequisite before conducting field implementation and effectiveness evaluation. The overall development procedure adopted in this study is illustrated in Figure 1.

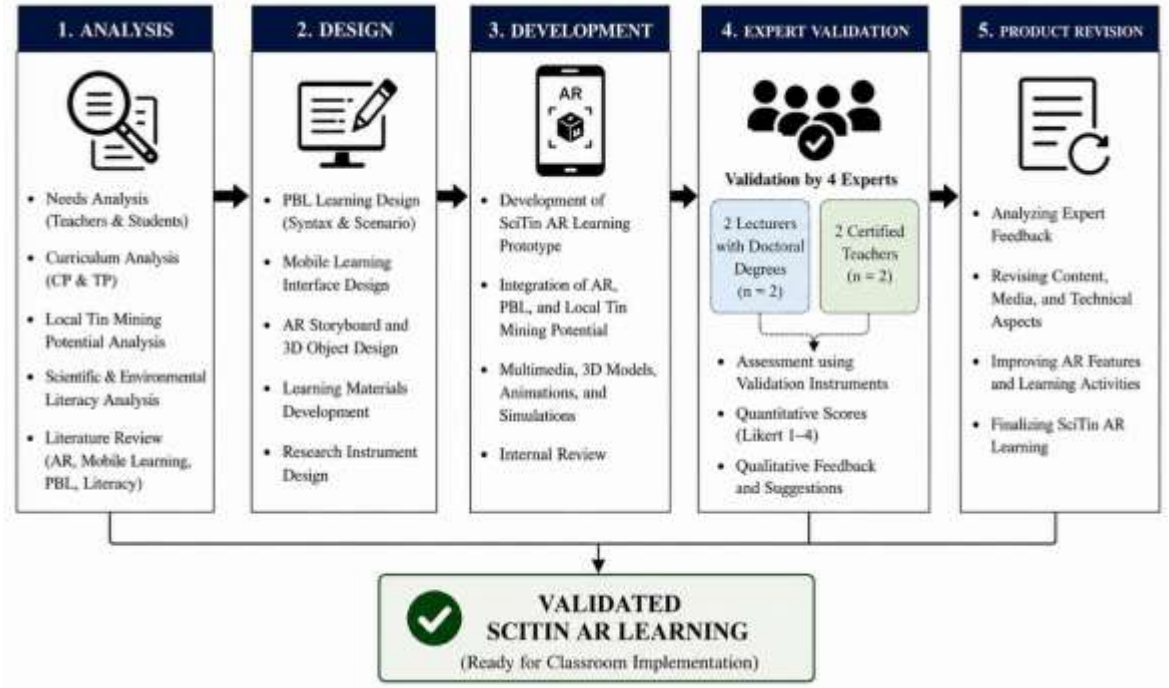


Figure 1. Development Procedure of *SciTin AR Learning*

Development Procedures

The development of *SciTin AR Learning* was conducted through three sequential phases adapted from the ADDIE model.

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Analysis Phase

The analysis phase aimed to identify instructional needs and establish the conceptual foundation for developing *SciTin AR Learning*. Five analyses were conducted: (1) a needs analysis involving science teachers and students to identify challenges in science learning and the need for digital learning media; (2) curriculum analysis to align the application with the learning outcomes and learning objectives of the Indonesian junior high school science curriculum; (3) an analysis of the local potential of tin mining to identify authentic environmental issues relevant to science learning; (4) an analysis of scientific literacy and environmental literacy indicators to ensure alignment with the intended learning competencies; and (5) a literature review on mobile learning, Augmented Reality, Problem-Based Learning, scientific literacy, and environmental literacy to establish the theoretical framework for product development.

Design Phase

Based on the findings from the analysis phase, the design phase focused on preparing the instructional and technical specifications of the application. Learning activities were designed according to the syntax of the Problem-Based Learning model and integrated into a mobile learning environment. A storyboard was developed to determine the learning sequence, user interface, navigation structure, multimedia components, and Augmented Reality interactions. Learning materials, student worksheets, assessment activities, and supporting research instruments were also designed during this phase.

Development Phase

The development phase involved transforming the design into a functional mobile learning application named *SciTin AR Learning*. The application was developed by integrating digital learning materials, interactive multimedia, three-dimensional Augmented Reality objects, animations, simulations, and contextual learning activities related to local tin mining. After the prototype had been completed, expert validation was conducted to evaluate the quality of the developed application. Feedback obtained from the validators was used to revise and improve the application until it met the predetermined validity criteria.

Participants

The validation process involved four validators selected using purposive sampling based on their professional expertise. The validation panel consisted of two expert validators, including one science education expert and one educational technology and instructional media expert, as well as two professional junior high school science teachers who served as practitioner validators. The expert validators held doctoral qualifications and had extensive experience in science education research and instructional media development. The practitioner validators had a minimum of five years of teaching experience and were actively involved in implementing science learning in junior high schools. The combination of expert and practitioner validators was intended to ensure that the developed application was evaluated from both academic and practical perspectives.

Validation Instruments

The validity of *SciTin AR Learning* was assessed using two expert validation questionnaires specifically developed for this study, namely a media validation instrument and a content validation instrument. Both instruments employed a four-point Likert scale ranging from 1 (strongly disagree) to 4 (strongly agree). Before being used in the product validation process, both validation instruments underwent content validity assessment through expert

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judgment conducted by the two expert validators to evaluate the relevance, clarity, and representativeness of each assessment item. Revisions to the wording and organization of several items were made based on the experts' recommendations to improve the clarity and suitability of the instruments prior to their administration.

The media validation instrument evaluated six aspects: software engineering, mobile learning design, Augmented Reality functionality, software usability, interactivity, and overall usefulness. Meanwhile, the content validation instrument assessed content appropriateness, scientific accuracy, integration of local tin mining potential, implementation of Problem-Based Learning, language quality, and instructional presentation. A summary of the validation aspects is presented in Table 1.

Table 1. Validation Aspects of *SciTin AR Learning*

Instrument	Validation Aspect	Number of Items
Media Validation	Software Engineering	3
	Mobile Learning Design	5
	Augmented Reality	4
	Software Usability	2
	Interactivity	2
	Usefulness	4
Content Validation	Content Appropriateness	7
	Scientific Accuracy	5
	Local Tin Mining Integration	5
	Problem-Based Learning	5
	Language	5
	Presentation	5

Data Analysis

The validity validity data obtained from expert evaluations were analyzed using Aiken's V coefficient and descriptive statistics in the form of mean scores. Aiken's V coefficient was employed to determine the content validity of each validation item based on the level of agreement among the expert validators, whereas the mean score was used to determine the overall validity level of the developed product.

The Aiken's V coefficient was calculated using Equation (1).

$$V = \frac{\sum s}{n(c-1)}$$

where:

V = Aiken's V coefficient
s = $r - l_o$
r = score assigned by each validator
l_o = lowest possible score
c = highest possible score
n = number of expert validators.

The interpretation of Aiken's V values is presented in Table 2.

Table 2. Interpretation of Aiken's V Coefficient

Aiken's V Value	Interpretation
0.80 - 1.00	High validity
0.60 - < 0.80	Moderate validity

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< 0.60	Low validity

The overall validity score of *SciTin AR Learning* was subsequently calculated using the mean score as presented in Equation (2).

$$\bar{x} = \frac{\sum x}{n}$$

where:
$\bar{x}$ = mean score;
$\sum x$ = total score obtained from all validators;
n = number of assessment items.

The resulting mean scores were interpreted using the ideal score conversion criteria proposed. Since all validation instruments employed a four-point Likert scale, the validity of *SciTin AR Learning* was classified into five categories, as presented in Table 3.

Table 3. Interpretation of Product Validity

Mean Score	Category
> 3.40	Very Good
2.80–3.40	Good
2.20–2.80	Fair
1.60–2.20	Poor
≤ 1.60	Very Poor

The product was considered valid and suitable for implementation when the overall mean score was classified in the Good or Very Good category. In addition to quantitative scores, qualitative comments and suggestions provided by the expert validators were analyzed descriptively and used as the basis for revising and refining the application before producing the final validated version.

Result and Discussion

Development of SciTin AR Learning

This study produced *SciTin AR Learning*, a science mobile learning application integrating Augmented Reality (AR), Problem-Based Learning (PBL), and the local potential of tin mining to support junior high school science learning. The application was developed on the topic of environmental pollution and designed to strengthen students' scientific literacy and environmental literacy through contextual and technology-enhanced learning experiences.

The development process was conducted through the Analysis, Design, and Development phases of the ADDIE model. During the analysis phase, information was collected regarding students' learning needs, curriculum requirements, local environmental issues related to tin mining, and indicators of scientific and environmental literacy. The design phase focused on constructing the instructional flow according to the syntax of Problem-Based Learning while integrating Augmented Reality into a mobile learning environment. Subsequently, the development phase resulted in a functional learning application containing interactive learning materials, three-dimensional Augmented Reality visualizations, contextual environmental problems, learning activities, and interactive assessments.

SciTin AR Learning consists of several integrated learning features, including the home page, learning objectives, contextual environmental problems, learning materials, Augmented Reality visualization, student worksheets, quizzes, and learning evaluation. These features were designed to facilitate inquiry-based learning while enabling students to connect scientific

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concepts with authentic environmental issues related to local tin mining. Figure 2 presents the main menu interface of *SciTin AR Learning*, including the home page and learning objectives that serve as the initial navigation components of the application.



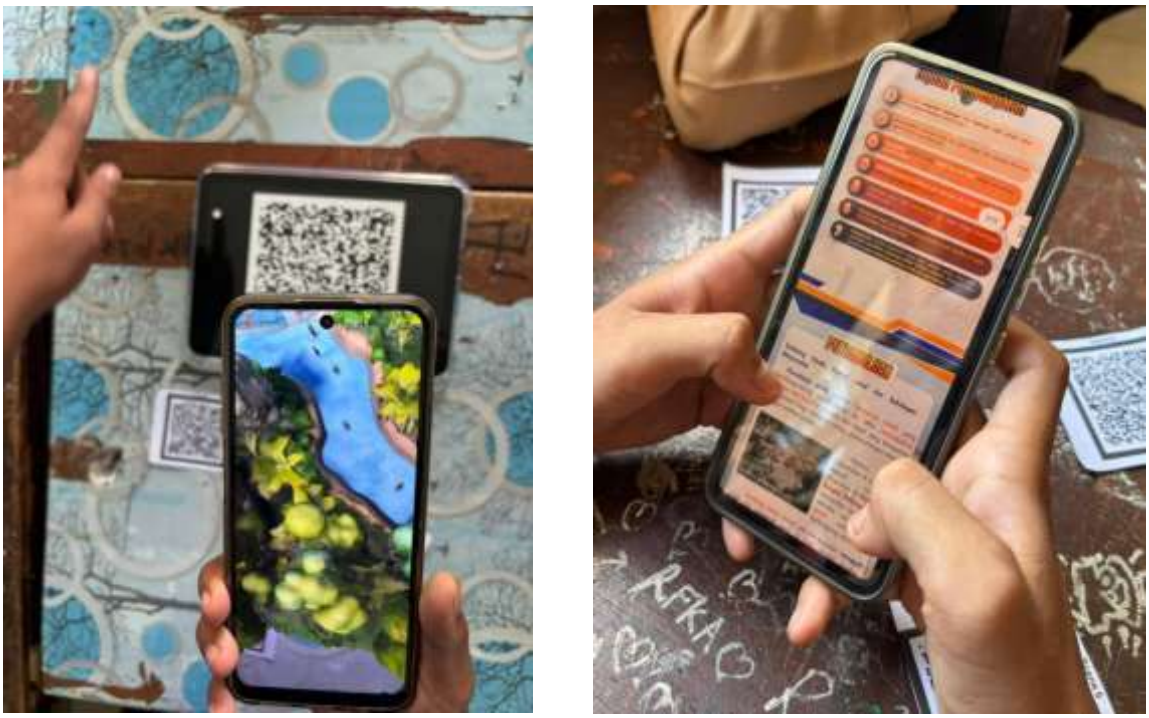
(a) (b)

Figure 2. Main Menu Interface of the *SciTin AR Learning* Application: (a) home page and (b) learning objectives

The home page serves as the entry point to the application, providing users with access to all learning features through an intuitive navigation interface. Meanwhile, the learning objectives page presents the expected learning outcomes, ensuring that students understand the competencies to be achieved before engaging in the learning activities. Figure 3 illustrates the core instructional features of *SciTin AR Learning*, including the Augmented Reality visualization and contextual learning materials that support technology-enhanced science learning.

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(a) (b)

Figure 3. Core Learning Features of *SciTin AR Learning*: (a) Augmented Reality Visualization and (b) Learning Materials.

Figure 3 illustrates the core instructional components of *SciTin AR Learning*. The Augmented Reality feature enables students to visualize environmental pollution phenomena and local tin mining contexts through interactive three-dimensional objects, whereas the learning materials provide contextual scientific explanations that support students in understanding concepts before participating in problem-solving activities. Together, these features facilitate meaningful learning by integrating technological, pedagogical, and contextual dimensions.

Expert Validation of SciTin AR Learning

To ensure the quality and appropriateness of *SciTin AR Learning* before classroom implementation, the developed application was evaluated by four validators consisting of science education experts, educational technology experts, and professional science teachers. The validation process focused on two major dimensions, namely content validity and media validity, to evaluate both the instructional quality and technical performance of the developed application.

Prior to interpreting the validation scores, the content validity of the validation instruments was examined using Aiken's V coefficient based on the judgments of the four validators. The analysis showed that both instruments demonstrated high content validity. The content validation instrument obtained Aiken's V coefficients ranging from 0.917 to 1.000 with an average value of 0.987, while the media validation instrument obtained coefficients ranging from 0.917 to 1.000 with an average value of 0.979. These findings indicate a high level of

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agreement among the validators regarding the relevance and appropriateness of all validation items, confirming that both instruments were suitable for evaluating the quality of *SciTin AR Learning*. Table 4 presents the results of the Aiken's V analysis for both validation instruments.

Table 4. Aiken's V Results of the Validation Instruments

Validation Instrument	Number of Items	Aiken's V Range	Mean Aiken's V	Interpretation
Content Validation	32	0.917-1.000	0.987	High Validity
Media Validation	20	0.917-1.000	0.979	High Validity

Following the confirmation of instrument validity, the quality of *SciTin AR Learning* was evaluated through expert validation of its instructional content and media design. Table 5 summarizes the results of the content validation conducted by the expert validators.

Table 5. Content Validation Results

Validation Aspect	Mean Score	Category
Content Appropriateness	3.96	Very Good
Scientific Accuracy	4.00	Very Good
Local Tin Mining Integration	4.00	Very Good
Problem-Based Learning	3.95	Very Good
Language	3.90	Very Good
Presentation	3.95	Very Good
Overall Mean	3.96	Very Good

The content validation yielded an overall mean score of 3.96, indicating that the instructional content of *SciTin AR Learning* possesses a Very Good level of validity. The highest ratings were obtained for Scientific Accuracy and Local Tin Mining Integration, demonstrating that the learning materials accurately represent scientific concepts while effectively incorporating authentic local environmental issues into science learning. Meanwhile, the Language aspect received the lowest score (3.90), although it remained within the Very Good category. Based on the validators' recommendations, several revisions were made, including simplifying instructional sentences, improving the consistency of scientific terminology, and refining language usage to enhance readability and students' comprehension.

These findings are consistent with the principles of contextual science learning, which emphasize that scientific concepts become more meaningful when connected with authentic problems encountered in students' daily lives (Kumar et al., 2024; Nida et al., 2021; Teshager et al., 2021; Wiyarsi et al., 2021). By integrating local tin mining issues into science learning, *SciTin AR Learning* enables students to relate abstract scientific concepts to real environmental challenges, thereby supporting the development of scientific literacy and environmental literacy (Ardoin et al., 2020; Guerrero & Sjöström, 2025). This result is also aligned with the Problem-Based Learning (PBL) framework, which encourages students to construct knowledge through authentic problem investigation, collaborative inquiry, and evidence-based reasoning (Funa, 2021; Tawfik et al., 2020). Consequently, the high ratings obtained for scientific accuracy and local context integration indicate that the instructional content

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successfully reflects the pedagogical characteristics required for effective PBL implementation in science education. To facilitate the interpretation of the validation results, Figure 4 presents the mean scores for each content validation aspect.

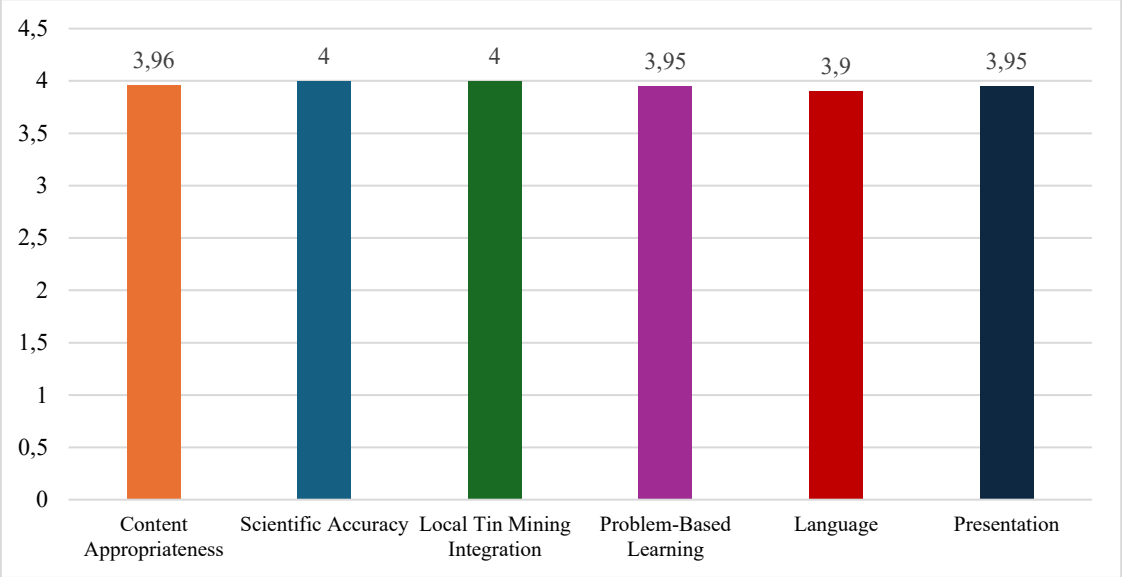


Figure 4. Mean Scores of Each Content Validation Aspect

Figure 3 illustrates that all content validation aspects achieved mean scores above 3.90, indicating consistently high quality across all instructional components evaluated by the validators. In addition to evaluating the instructional content, expert validation was also conducted to assess the technical quality and usability of the application. The results of the media validation are presented in Table 6.

Table 6. Media Validation Results

Validation Aspect	Mean Score	Category
Software Engineering	3.83	Very Good
Mobile Learning Design	4.00	Very Good
Augmented Reality	4.00	Very Good
Software Usability	4.00	Very Good
Interactivity	3.88	Very Good
Usefulness	3.88	Very Good
Overall Mean	3.94	Very Good

The media validation produced an overall mean score of 3.94, indicating that *SciTin AR Learning* meets the quality standards required for educational mobile learning media. The highest scores were achieved in Mobile Learning Design, Augmented Reality, and Software Usability, reflecting the application's attractive interface, effective integration of Augmented Reality, and reliable functionality. Although Software Engineering obtained the lowest score (3.83), it was still classified as Very Good. The validators identified several technical issues, including limited accessibility of the user guide and incomplete functionality of the Live Worksheet feature. These suggestions were subsequently addressed through technical revisions to improve navigation, software functionality, and the overall user experience.

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The positive evaluation of the media aspects also supports the theoretical foundations of mobile learning and Augmented Reality in science education (Palalas & Wark, 2020; Tilili et al., 2023). Mobile learning emphasizes flexibility, accessibility, and continuous learning beyond classroom boundaries, whereas Augmented Reality enhances conceptual understanding by visualizing scientific phenomena that are difficult to observe directly (Saputra, Wilujeng, Wiyarsi, et al., 2026). The high scores obtained for Mobile Learning Design, Augmented Reality, and Software Usability indicate that *SciTin AR Learning* successfully integrates these technological characteristics into a user-friendly learning environment. Rather than functioning merely as a digital repository of learning materials, the application combines interactive visualization, contextual learning activities, and problem-solving tasks that actively engage students throughout the learning process. Figure 5 provides a visual comparison of the mean scores obtained for each media validation aspect.

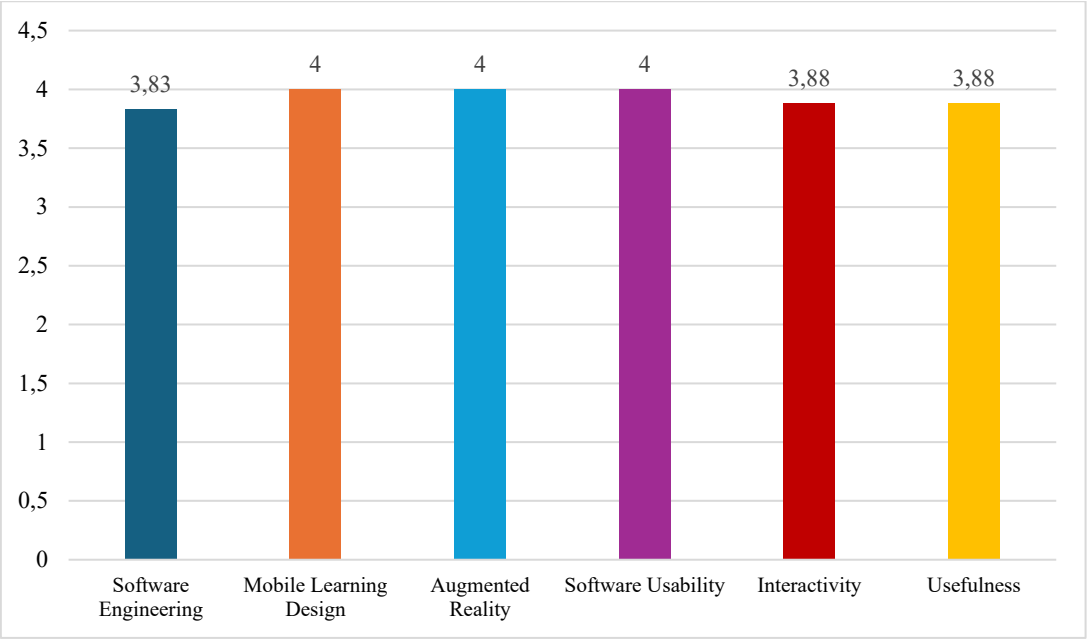


Figure 5. Mean Scores of Each Media Validation Aspect

Figure 5 shows that all media validation aspects were classified in the Very Good category, with mean scores ranging from 3.83 to 4.00, indicating that the application demonstrated high technical quality and usability. From the perspective of educational technology, these findings also demonstrate the successful integration of technology, pedagogy, and content knowledge within the developed application. According to the Technological Pedagogical Content Knowledge (TPACK) framework, effective educational technology should not simply incorporate digital tools but should meaningfully integrate technological features with appropriate pedagogical strategies and subject content (Schmidt et al., 2019; Yeh et al., 2021). *SciTin AR Learning* reflects this integration by combining Augmented Reality technology, the Problem-Based Learning model, and contextual science content related to local tin mining within a single instructional platform. The consistently high validation scores therefore indicate that the application possesses not only strong technical

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quality but also sound pedagogical and disciplinary alignment, which are essential characteristics of effective digital learning media.

Product Revision Based on Expert Feedback

The expert validation process generated not only quantitative validity scores but also qualitative feedback for improving the instructional and technical quality of *SciTin AR Learning*. All recommendations provided by the validators were carefully considered and incorporated into the revised version of the application. The revisions focused on improving application functionality, strengthening contextual learning content, enhancing literacy integration, and optimizing interactive learning features. A summary of the revisions made based on the validators' feedback is presented in Table 7.

Table 7. Product Revisions Based on Expert Validation

Aspect	Validator Feedback	Revision Implemented
Application Functionality	The user guide menu could not be accessed properly.	The navigation system was improved, enabling the user guide to be accessed and used properly.
Learning Content	An introductory overview of local tin mining activities should be added before the learning materials.	A contextual introduction describing local tin mining activities was incorporated before the learning content.
Literacy Integration	Scientific literacy and environmental literacy indicators should be presented more explicitly.	Explicit mapping of scientific and environmental literacy indicators was integrated into relevant learning activities.
Interactive Worksheet	The Live Worksheet feature could not save students' responses properly and several sections were inaccessible.	The Live Worksheet was optimized to support online completion and automatic submission of student responses.

The revisions demonstrate that expert validation functioned as a formative evaluation process for refining both the pedagogical and technical aspects of the application. Improvements to the learning content strengthened the contextual integration of local tin mining and explicitly highlighted scientific and environmental literacy components, whereas technical revisions enhanced application usability by improving navigation and optimizing the interactive worksheet feature. These refinements resulted in a more comprehensive and user-friendly version of *SciTin AR Learning*, supporting its readiness for subsequent classroom implementation.

Conclusion

This study successfully developed and validated *SciTin AR Learning*, a science mobile learning application integrating Augmented Reality, Problem-Based Learning, and the local potential of tin mining for junior high school science education. The validation instruments

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demonstrated high content validity, with Aiken's V coefficients ranging from 0.917 to 1.000, confirming that the instruments were appropriate for evaluating the quality of the developed application. Furthermore, expert validation indicated that *SciTin AR Learning* achieved a Very Good level of validity in both content (mean = 3.96) and media (mean = 3.94), demonstrating that the application satisfies the required standards in terms of instructional quality, scientific accuracy, pedagogical design, media functionality, and usability. Revisions based on expert feedback further improved both the instructional and technical aspects of the application, resulting in a more comprehensive and user-friendly learning resource. These findings suggest that *SciTin AR Learning* provides a promising framework for the development of technology-enhanced science learning media that integrate digital technology, student-centered pedagogy, and authentic local contexts to support meaningful science learning. Therefore, the application can be considered a valid instructional product and is ready for subsequent studies investigating its practicality and effectiveness in improving students' scientific literacy and environmental literacy in classroom settings.

Recommendation

Based on the validation results, *SciTin AR Learning* is recommended for implementation in junior high school science classrooms as a supplementary digital learning resource, particularly for teaching environmental pollution and other science topics that benefit from contextual and technology-enhanced learning. Science teachers may utilize the application to facilitate Problem-Based Learning activities, promote scientific literacy and environmental literacy, and connect scientific concepts with authentic local environmental issues. Future research should examine the practicality and effectiveness of *SciTin AR Learning* through classroom implementation involving larger and more diverse samples of junior high school students. Further studies are also recommended to investigate its impact on students' scientific literacy, environmental literacy, problem-solving skills, learning engagement, and long-term learning outcomes across different science topics and educational settings.

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