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Design and Validation of a Science Learning Module Integrated with Augmented Reality (AR) and Adiwiyata Projects to Improve Junior High School Students' Scientific Literacy

Suliati [1], Fatni Mufit [2], Fuja Novitra [3], Diah Putri Anggun [4]
[123] Department of Physics, Universitas Negeri Padang, Indonesia
[4] Doctor of Philosophy, The University of Auckland, New Zealand
fatni_mufit@fmipa.unp.ac.id

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***Correspondence Address:**
fatni_mufit@fmipa.unp.ac.id

Abstract:
Students' scientific literacy is important to develop so that students are able to understand phenomena and use scientific knowledge when dealing with everyday-life problems. Adiwiyata schools have potential as contextual learning environments; however, teaching materials that integratively connect scientific literacy, technology, and Adiwiyata activities remain limited. This study aims to produce a science learning module integrated with Augmented Reality (AR) and Adiwiyata Projects that is valid and practical for supporting junior high school students' scientific literacy. The study employed Educational Design Research using the Plomp model. The module was validated by **[X] validators**, and its validity was analyzed using Aiken's V. The practicality of the module was evaluated through a one-to-one evaluation involving **[X] students** and a small group evaluation involving **[X] students**. The validation results yielded an average Aiken's V of 0.92, categorized as very valid. The practicality test results showed that the module was in the very practical category. Thus, the science learning module integrated with AR and Adiwiyata Projects is valid and practical for use as teaching material to support students' scientific literacy.

Introduction (مقدمة)

Scientific literacy is an important competence in science learning because it enables students to understand scientific phenomena, apply scientific knowledge, evaluate investigations, interpret data and evidence, and make informed decisions when dealing with problems in everyday life. The importance of this competence becomes increasingly evident as students encounter environmental issues such as climate change, pollution, energy crises, resource management, and environmental health. Consequently, science learning needs to move beyond the transmission of scientific concepts and provide opportunities for students to apply those concepts to authentic problems in their surroundings. Recent studies continue to indicate the importance of contextual and problem-oriented learning in strengthening students' scientific literacy, particularly when scientific concepts are connected with environmental issues and supported by interactive learning resources (Hindun et al., 2024; Kuswandi et al., 2025).

Adiwiyata schools provide a relevant context for this type of learning because their environmental programs, facilities, and daily activities can serve as authentic science learning resources. Previous studies have shown that Adiwiyata programs and school environments are associated with students' environmental knowledge, attitudes, behavior, and environmental literacy (Astuti & Aminatun, 2020; Nurwaqidah et al., 2020; Nurwidodo et al., 2020; Rushayati et al., 2023). However, environmental activities conducted within schools do not automatically develop scientific literacy. Students need learning activities that explicitly require them to identify scientific problems, investigate environmental conditions, collect and interpret evidence, and construct explanations based on scientific concepts. Thus, the potential of Adiwiyata schools needs to be systematically incorporated into science instruction rather than being treated only as a school environmental program.

One approach that can strengthen this connection is problem- and project-based science learning. Through projects based on authentic environmental issues, students can observe conditions in their surroundings, formulate questions, collect information, analyze causes, and propose solutions based on scientific evidence. Hindun et al. (2024) found that Project-Based Learning can improve junior high school students' scientific literacy and collaboration skills, while Sobach et al. (2023) reported that Project-Based Learning supported by digital modules contributed to the scientific literacy of Grade IX students. More recently, Kuswandi et al. (2025) demonstrated that Problem-Based Learning supported by interactive digital modules significantly enhanced junior high school students' scientific literacy in the context of environmental pollution. In Adiwiyata schools, Safrizal et al. (2022) also showed that scientific literacy can develop through the learning environment, academic culture, and investigative activities available at school. These findings suggest that environmental contexts have greater educational value when students are required not only to perform environmental actions but also to investigate, explain, and evaluate those actions scientifically.

Nevertheless, some scientific phenomena related to environmental issues cannot be directly observed because they occur at microscopic or macroscopic scales, develop over long periods, or involve processes that are difficult to reproduce in the classroom. Augmented reality (AR) offers a potential solution by allowing digital objects and information to be superimposed on real-world environments. Chen and Liu (2020) showed that AR activities involving active student interaction produced better outcomes in conceptual understanding and learning interest than demonstration-centered AR use, while Sahin and Yilmaz (2020) reported positive effects of AR-based science teaching materials on students' achievement and attitudes toward science. More recent evidence also supports the educational potential of AR. Arici (2024) found that AR-supported science education contributed to environmental literacy, self-regulation, and motivation to learn science. Furthermore, a systematic review by Ladykova et al. (2024) concluded that AR has considerable potential in environmental education through its contributions to learning, affective outcomes, and learner interaction. However, the review also indicates that the existing literature is dominated by particular learner groups and learning outcomes, suggesting that further research is needed to examine how AR can be pedagogically integrated with authentic environmental learning activities.

Recent development studies have also demonstrated the potential of AR-based science learning materials. Salsabila et al. (2024) developed an AR-based science e-module using Assemblr Edu and reported feasible results based on expert and user assessments. Wicaksono et al. (2025) developed an AR-assisted science module for junior high school students and reported that the module was valid, practical, and effective in supporting scientific literacy. Other studies have also demonstrated the potential of AR for environmental education and environmental literacy (Arici, 2024; Ladykova et al., 2024). These findings confirm that AR can enrich science learning by visualizing scientific phenomena and facilitating students' interaction with scientific information.

Despite these developments, an important research gap remains. Existing studies have generally investigated the three components relevant to this study separately. Studies on Adiwiyata and environmental-based learning have primarily emphasized environmental knowledge, attitudes, behavior, or literacy; studies on project- and problem-based learning have focused on the effects of authentic problems and projects on scientific literacy; and AR-based studies have largely emphasized visualization, conceptual understanding, learning outcomes, motivation, or AR-assisted science modules. Although recent studies have begun to connect AR with scientific literacy or environmental education, limited attention has been given to integrating AR visualization, scientific-literacy competencies, and authentic Adiwiyata projects within a single structured science module for junior high school students. In particular, there is still a need for teaching materials in which AR is not used merely to display digital objects and Adiwiyata activities are not treated merely as environmental actions, but both are pedagogically connected through scientific investigation, evidence interpretation, and problem solving.

Therefore, this study develops a science learning module that integrates three complementary elements within one learning sequence: augmented reality, scientific literacy, and Adiwiyata projects. AR is used to support the visualization and exploration of scientific phenomena that are difficult to observe directly, while the Adiwiyata school environment and its programs provide authentic contexts for investigation and project activities. Scientific literacy serves as the connecting framework through activities that require students to explain phenomena scientifically, evaluate investigations, and interpret data and evidence in relation to environmental problems. This integration represents the distinctive contribution of the proposed module compared with learning materials that employ AR, environmental projects, or scientific-literacy activities independently. Accordingly, this study aims to design and produce a science learning module integrated with AR and Adiwiyata projects that meets valid and practical criteria for supporting junior high school students' scientific literacy.

Method (منهج)

This study is Educational Design Research (EDR) using the Plomp development model. This model was selected because it allows educational product development to be conducted through gradual processes of design, evaluation, and revision (Plomp & Nieveen, 2013). The study reported in this article focuses on two phases, namely preliminary research and the prototyping phase, to produce a science learning module integrated with AR and Adiwiyata projects that meets valid and practical criteria.

During preliminary research, a needs and context analysis and a literature review were conducted as the basis for designing the module. The needs and context analysis involved the school principal, Adiwiyata coordinator, science teachers, and students at Adiwiyata schools in Bogor Regency. Data were collected through teacher and student needs questionnaires, interviews with the school principal and Adiwiyata coordinator, school observation sheets, scientific literacy tests, and document analysis. The information obtained was used to identify the conditions of science learning, teaching-material needs, student characteristics, scientific literacy ability, technology utilization, and the potential of the Adiwiyata program and school environment as contexts for science learning.

The prototyping phase began with the preparation of the module prototype based on the results of preliminary research. The module was designed by integrating science content, scientific literacy activities, AR-based visualization, and Adiwiyata project activities. The resulting prototype then underwent formative evaluation referring to Tessmer's evaluation, including self-evaluation, expert review, one-to-one evaluation, and small group evaluation. Self-evaluation was conducted to identify initial deficiencies in content, presentation, language, design, readability, AR integration, and the relationship between project activities and the Adiwiyata program. The evaluation results were used as the basis for improvement before the module was submitted to validators.

Module validity was assessed through expert review involving four validators. The assessment covered three main aspects: content substance, media/design, and language. Validator feedback was used to revise the prototype before the practicality test. Validation data were analyzed using Aiken's V formula: $V = \Sigma s/[n(c-1)]$, where $s = r - lo$, r is the score given by the validator, lo is the lowest score on the rating scale, c is the highest score, and n is the number of validators.

The practicality test was conducted in stages through one-to-one evaluation and small group evaluation. One-to-one evaluation involved three students representing high, medium, and low academic ability. Students used the module individually to provide information concerning ease of use, readability, clarity of instructions, presentation, and the use of AR and project activities. After revision, the small group evaluation involved nine students, consisting of three students each with high, medium, and low academic ability. The practicality assessment covered ease of use, learning implementation, module usefulness, AR integration, Adiwiyata Projects, and readiness of facilities and infrastructure. Practicality data were analyzed quantitatively and descriptively using the percentage formula $P = (f/N) \times 100\%$, where P is the practicality value, f is the score obtained, and N is the maximum score. The validity and practicality analysis results were used as the basis for gradual revisions until a science learning module integrated with AR and Adiwiyata Projects that was valid and practical for supporting junior high school students' scientific literacy was obtained.

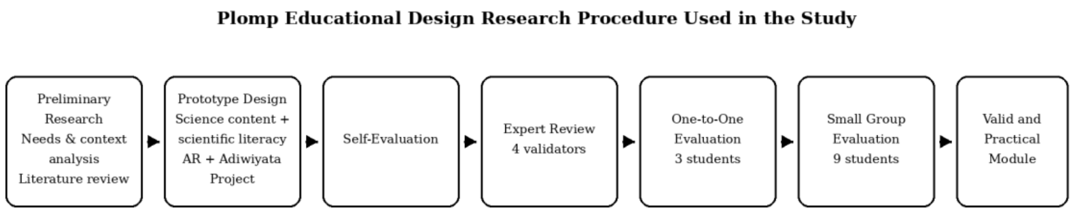

Figure 1. Module Development Procedure.

Result (نتائج) and Discussion (مناقشة)

Learning Module Design

This study produced a science learning module on environmental issues for grade IX junior high school/MTs students. The module was designed by integrating three main components: scientific literacy as the competency orientation, AR as a means of exploring and visualizing phenomena, and Adiwiyata projects as contextual activities for applying science concepts to environmental problems. The module content includes environmental health, global warming, and the energy crisis. In each section, students are directed to connect science concepts with environmental phenomena close to everyday life.

The scientific literacy orientation is realized through activities that develop the ability to explain phenomena scientifically, evaluate and design scientific investigations, and interpret data and evidence scientifically. This integration does not appear only in end-of-unit exercises, but is embedded in the learning process. For example, in an activity on clean-water availability, students observe a water-cycle model through AR, record their observations, connect them with clean-water availability, and then answer questions based on aspects of knowledge, context, competence, and attitude.

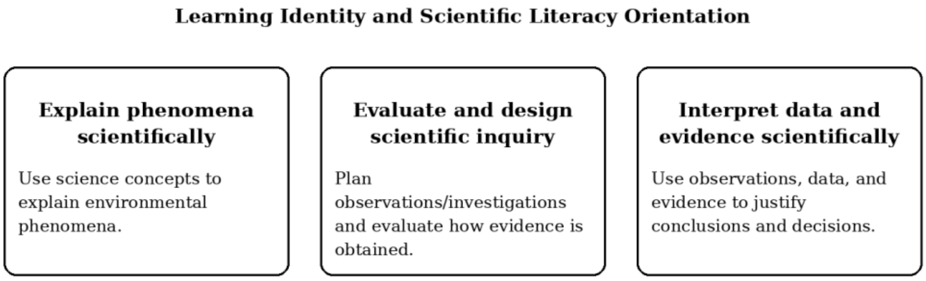

Figure 2. Learning Identity and Orientation

Figure 2 shows the learning identity and orientation that form the basis of the module design. Scientific literacy indicators are used to direct student activities toward three competencies: explaining phenomena scientifically, evaluating and designing scientific investigations, and interpreting data and evidence scientifically. Thus, scientific literacy is not only positioned as an expected learning outcome but is translated into activities performed by students while using the module. The implementation of these indicators is then combined with the use of AR in exploration activities. One form of AR activity design in the module is presented in Figure 3.

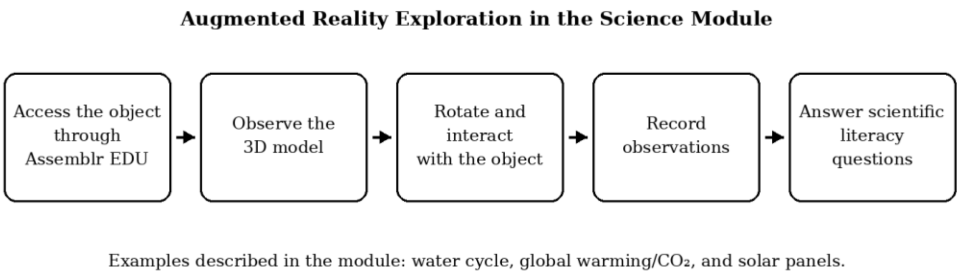

Figure 3. Augmented Reality Exploration Display in the Science Module

Figure 3 shows that AR is designed as part of the exploration process, not merely as an additional visual medium. Students access objects through Assemblr EDU, observe three-dimensional models, rotate the objects, and obtain information through the available features. The observations are then used to answer scientific literacy questions. In water-cycle exploration, for example, students observe the stages of evaporation, condensation, precipitation, and infiltration through AR, then connect the observations with clean-water availability and actions that can be taken to preserve it. The same design is applied to other topics by adjusting it to the characteristics of the phenomenon. In the global-warming topic, students use AR exploration results to analyze patterns of temperature change under different CO_2 concentration conditions and use the data as evidence in drawing scientific conclusions. In the alternative-energy topic, students observe solar panels through AR and analyze differences in electrical energy produced in the morning, afternoon, and night based on the operating principle of solar panels.

These characteristics are important because the benefits of AR in learning are not determined merely by the presence of three-dimensional representations, but by the cognitive activities that accompany them. Chen and Liu (2020) found that using AR through hands-on activities produced better outcomes in conceptual understanding and interest in science than more demonstration-centered use. Wong et al. (2021) also showed that students' ability to view, rotate, and interact with three-dimensional representations through AR can support understanding and learning experience. Among secondary-school students, Sahin and Yilmaz (2020) found that AR-based science teaching materials had a positive impact on achievement and attitudes toward science learning.

The digital exploration is then connected with real activities through Adiwiyata projects. For example, after studying global warming, students investigate sources of substances that cause global warming in the school environment by observing roads around the school, the school yard, and classrooms using tools such as CO_2 sensors and thermometers. In the energy-crisis topic, students are directed to design LAMBOLS (Solar-Panel Bottle Lamps) as a simple solution that utilizes solar energy. Thus, the learning structure moves from phenomena, AR exploration, scientific analysis, environmental investigation, to projects/solutions. The use of AR in the context of environmental education is supported by Balcha et al. (2025), who showed that structured AR-assisted environmental learning can support learners' learning experiences.

The integration of the project is relevant to the findings of Hindun et al. (2024), which showed that Project-Based Learning resulted in higher scientific literacy and collaboration skills than conventional learning among junior high school students. In the context of Adiwiyata schools, Safrizal et al. (2022) also showed that scientific literacy development can be supported through the environment, academic culture, and investigative activities available at school. Thus, the main characteristic of the developed product lies in the relationship between digital technology and real environmental experience, rather than in the separate use of AR or projects.

Learning Module Validity

Validation was conducted to determine the feasibility of the module before it was used by students. Expert assessment covered content substance, media/design, and language. The validation results are summarized in Table 1.

Table 1. Validation Results

Validity Aspect	Aiken's V	Category
Content substance	0.92	Very valid
Media/design	0.90	Very valid
Language	0.96	Very valid
Average	0.92	Very valid

The results in Table 1 show that the module obtained an average Aiken's V of 0.92, categorized as very valid. All three aspects obtained high values, with language validity as the highest aspect, followed by content substance and media/design. These results indicate that the material structure, visual presentation, language use, AR activities, scientific literacy, and Adiwiyata Project context have adequate feasibility to proceed to user evaluation.

Content validity is important because integrating technology into a module must not reduce conceptual accuracy or the relationship among objectives, content, and learning activities. In this module, AR is used in sections that require representations of processes or phenomena, while activities following AR direct students to use the observations. An and Holme (2021) showed that students in AR environments tend to pay greater attention to information directly related to the task being performed. This supports the module design that connects each AR exploration with a specific observation table or question rather than positioning AR as a stand-alone feature.

The feasibility of media/design can also be understood from the characteristics of AR, which allow students to access visual representations interactively. Wong et al. (2021) found positive responses to AR use and improved learning outcomes when the technology was used to help students understand representations that are difficult to visualize with conventional media. The experimental study by Sahin and Yilmaz (2020) among secondary-school students also showed that students using AR-based science booklets achieved higher results and demonstrated more positive attitudes toward learning. These findings reinforce that presenting AR in print/digital teaching materials can bridge textual information and phenomena that require visualization.

In an environmental context, Safitri et al. (2025) showed that the use of AR in environmental education can support engagement, retention, and understanding of ecological concepts. Experimental studies of biodiversity learning also found that location-based AR produced higher theoretical knowledge and environmental exploration than non-digital learning resources, although it did not automatically produce changes in all affective aspects of the environment. This finding provides an important reason why the developed module does not rely on AR alone but continues with Adiwiyata projects as real experiences in the school environment.

Thus, module validity does not merely indicate the feasibility of the product format, but also demonstrates that three components that previously had different functions can be placed within one learning design: AR to support exploration of phenomena, scientific literacy to direct scientific thinking processes, and Adiwiyata projects to apply knowledge in an environmental context.

Learning Module Practicality

After validation and revision, module practicality was evaluated in stages through one-to-one evaluation and small group evaluation. The staged evaluation was used to determine whether the module structure that had been declared valid could be understood and used by students in learning situations.

Table 2. Module Practicality Results

Aspect	One-to-one (%)	Small Group (%)
Ease of use	83.33	86.11
Learning implementation	89.58	87.50
Module usefulness	94.44	87.11
AR integration	78.33	81.67
Adiwiyata Project	94.44	93.52
Facilities and infrastructure readiness	88.89	86.11

The practicality results show that the module can be used well by students, while also revealing a pattern that is important for product development. The Adiwiyata Project received very high responses at both stages, whereas AR integration was the relatively lower aspect. In the one-to-one evaluation, AR integration obtained 78.33%, which increased to 81.67% in the small group evaluation. The improvement after revision indicates that ease of technology use is influenced by the clarity of instructions and the way digital features are positioned in the learning sequence.

This finding can be explained by the characteristics of AR as an interactive technology. Technology that can produce good visualization is not necessarily immediately easy to use when the access procedures and tasks to be performed by students are unclear. An and Holme (2021) found that students' patterns of AR use were related to the relevance of information to the task being performed. Chen and Liu (2020) also showed that the design of activities accompanying

AR influences its use. Therefore, the increase in AR practicality after revision indicates that formative evaluation plays a role in aligning technology with user needs.

The Adiwiyata Project aspect showed a different pattern. Its value was already high in the one-to-one evaluation (94.44%) and remained high in the small group evaluation (93.52%). This condition indicates that activities using objects and problems from the school environment are relatively easy for students to understand because the context is close to their lives. In the module, students are not merely asked to make a product. Project activities involve problem identification, observation design, data collection and interpretation, solution selection, action implementation, and reflection. In the clean-water project, for example, students identify potential pollution, design observations, analyze evidence, determine solutions, carry out actions, and document the project results.

These results are consistent with Hindun et al. (2024), who found that project-based learning was effective in improving junior high school students' scientific literacy because students were involved in problem-solving and collaboration. Safrizal et al. (2022) also showed that the Adiwiyata school environment provides opportunities for scientific literacy development through environmental and investigative activities. This means that the Adiwiyata context becomes more meaningful when environmental activities do not stop at habituation but are connected with the process of obtaining and using scientific evidence.

Practicality based on teacher responses strengthens the findings from students. The results are presented in Table 3.

Table 3. Module Practicality Based on Teacher Responses

Aspect	Percentage (%)	Category
Ease of use	87.50	Very practical
Learning implementation	88.89	Very practical
Module usefulness	97.92	Very practical
Integration of AR and Adiwiyata Project	83.42	Very practical
Facilities and infrastructure readiness	80.00	Practical

Module usefulness received the highest assessment from teachers, while readiness of facilities and infrastructure received the lowest score. This pattern indicates that teachers recognize the pedagogical benefits of integrating AR and Adiwiyata projects, but its implementation still requires device support and appropriate technical conditions. This is an important note because the success of educational technology is determined not only by the design of teaching materials but also by access to the required devices. Studies of AR among secondary-school students show that students have positive acceptance of AR-based teaching materials, but characteristics of use and the learning environment still need to be considered in implementation.

Overall, the validity and practicality results show that the module has met the development objectives at this stage. The main finding of the study is not merely the achievement of the very valid and very practical categories, but the formation of a learning design that connects digital experiences and real environmental experiences. Students first interact with phenomena or representations through AR, use the observations to perform scientific literacy activities, and then apply their understanding through investigations and Adiwiyata Projects. This pattern distinguishes the module from the use of AR that functions only as visualization and from Adiwiyata activities that stand separately from science learning. Thus, the module has the potential to serve as teaching material that bridges technology, scientific literacy, and the school environmental context within a single learning sequence.

Conclusion (خاتمة)

The science learning module integrated with AR and Adiwiyata projects has been successfully developed as teaching material that connects technology, environmental contexts, and scientific literacy-oriented activities within a single learning sequence. The validation results indicate that the module meets the very valid criteria, while the practicality evaluation shows that the module is highly practical for use in junior high school science learning. These findings demonstrate that the developed module is feasible in terms of content, design, and usability as an alternative teaching material, particularly in Adiwiyata school contexts. However, this study did not examine the effectiveness of the module in improving students' scientific literacy. Therefore, further research is needed to evaluate its effectiveness, long-term implementation, and applicability across broader science topics, student populations, and school contexts.

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