



## Development of an Augmented Reality–Based Science Module Integrated with Mbojo Ethnoscience to Improve Junior High School Students’ Scientific Skills and Environmental Awareness

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**Abstract:** This study aims to develop and evaluate an Augmented Reality (AR)–based science module integrated with Mbojo ethnoscience to enhance junior high school students’ scientific skills and environmental awareness. The study involved 52 Grade VII students (25 experimental; 27 control) and employed a Research and Development (R&D) method using the ADDIE model combined with a quasi-experimental design. Data were collected through expert validation, student practicality questionnaires, scientific skills tests, and environmental awareness measures, and were analyzed using descriptive statistics and independent-samples t-tests. The module was classified as highly valid (mean = 3.21) and highly practical (89.8% positive responses). The quasi-experimental findings revealed statistically significant improvements in scientific skills ( $t = 4.215$ ;  $p < 0.001$ ) and environmental awareness ( $t = 4.475$ ;  $p < 0.001$ ) compared to conventional instruction. These findings suggest that the AR–Mbojo ethnoscience module constitutes a valid, practical, and empirically effective instructional innovation for contextual and sustainability-oriented science learning.

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## Introduction

Scientific skills are one of the essential components of twenty-first-century education and play a crucial role in shaping educated, critical individuals who are able to respond to various global challenges. These skills encompass not only the mastery of scientific concepts, but also the ability to observe phenomena, formulate hypotheses, conduct experiments, analyse data, and draw conclusions logically and objectively. Furthermore, scientific skills contribute to the development of awareness of environmental sustainability and social responsibility amid climate change, ecosystem degradation, and natural resource crises (Ülger, 2021). This is because core scientific processes such as observation, data analysis, and inference help students make sense of ecological phenomena and evaluate human impacts on the environment.

Empirical evidence shows that junior secondary science learning in Indonesia still faces fundamental problems, reflected in stagnant PISA science performance and the need for more inquiry-based, contextual, and reflective approaches. This aligns with the Merdeka Curriculum’s goal of fostering the Pancasila Student Profile—students who are critical, collaborative, culturally aware, and environmentally responsible. Many students struggle to identify scientific problems, design experiments, collect and analyse data, and relate concepts to real-life contexts, creating a gap between classroom learning and everyday experience. These findings support research indicating that science curricula, including in Indonesia,



continue to emphasise memorisation and textbook use over practical and contextual learning (Fernández et al., 2022; Shana & Abulibdeh, 2020).

This condition is closely linked to students' low concern for environmental issues. Observations and interviews indicate limited participation in waste management, school cleanliness, greening programmes, and other environmental activities, suggesting that science learning has not effectively fostered environmental care as a core objective. A key factor is the dominance of teacher-centred approaches, where instruction relies on lectures and routine tasks focused mainly on cognitive outcomes, with few opportunities for inquiry, independent investigation, or exploration of local environmental phenomena (Coşkunserçe, 2021; Fitzgerald & McKeen, 2020). In contrast, research shows that inquiry-based, student-centred, and experience-oriented science learning more effectively develops science process skills and interest in science (Valls et al., 2021; Taş et al., 2022).

Developments in digital technology offer opportunities to address some of these problems. One innovation that has attracted considerable attention is the use of Augmented Reality (AR) in science learning. AR allows virtual objects to be integrated into the real environment in real time, thereby supporting the visualisation of abstract concepts, the simulation of scientific phenomena, and the creation of immersive and interactive learning experiences (Anderson & Cheong, 2021; Systkowski et al., 2024). Various empirical studies report that AR-based science learning can enhance learning motivation, conceptual understanding, student engagement, as well as critical thinking and problem-solving skills (Jiang et al., 2021; Demircioğlu et al., 2022). Thus, AR has the potential to function not only as a visual aid, but also as a catalyst for the realisation of more active, constructive, and meaningful science learning.

However, technology alone does not guarantee relevant and contextual learning. In Indonesia's culturally diverse context, integrating modern technology with local wisdom is essential. Ethnoscience—incorporating local knowledge and practices into science education—offers a meaningful approach. Mbojo ethnoscience, rooted in the Bima–Dompu communities, includes traditional knowledge of cropping patterns, land management, medicinal plants, environmental conservation, and ecological social values (Dewi et al., 2019; Rasyid & Jamar, 2021). When integrated into science learning, it can bridge modern science with students' lived experiences, enhance learning relevance, and simultaneously preserve local wisdom while strengthening students' ecocultural identity (Lestari et al., 2024).

The integration of AR-based visualization with Mbojo ethnoscience—particularly traditional maize cultivation and the design of the Uma Lengge raised granary—creates interactive, contextual, and culturally as well as ecologically meaningful learning experiences. Through an AR-based science module, students observe simulations of land selection, planting time, intercropping, drying processes, and the architectural features of Uma Lengge, including the use of local materials and natural ventilation. These representations connect local practices with scientific concepts such as soil properties, water and nutrient cycles, and food preservation. This approach not only deepens conceptual understanding and science process skills but also fosters environmental awareness and reflection on sustainability values embedded in community traditions.

A review of the literature indicates that research on AR in science education and the integration of ethnoscience has developed largely as separate strands, with few studies explicitly combining both. Research integrating AR-based science modules with Mbojo ethnoscience to enhance junior high school students' scientific skills and environmental concern—particularly in Eastern Indonesia—remains limited (Dewi et al., 2019; Jiang et al., 2021; Systkowski et al., 2024). This gap highlights the need for innovative teaching materials



that systematically integrate AR technology with Mbojo local wisdom. Previous efforts were constrained by limited infrastructure, inadequate teacher training, and rigid curricula. This study moves beyond simply adding AR, proposing a paradigm that connects advanced technology with cultural narratives to promote engagement and sustainability awareness.

Based on these considerations, the present study focuses on developing an AR-based science module that integrates Mbojo ethnosience to improve junior high school students' scientific skills and environmental concern. Specifically, the objectives of this research are: (1) to design and develop a science module that combines AR visualisation with Mbojo ethnosience content; (2) to examine the validity and practicality of the module based on expert judgement and students' responses; and (3) to investigate the effectiveness of the module in enhancing students' scientific skills and environmental concern. The scientific novelty of this study lies in the synergy between AR technology and Mbojo local wisdom within a structured junior high school science module, which is expected to contribute to the development of contextual, character-oriented, and sustainability-oriented science education. Theoretically, this study contributes to science education by offering an integrated instructional model that aligns digital immersion with sociocultural context, thereby supporting the development of sustainability-oriented science pedagogy grounded in ecological identity and cultural relevance.

### **Research Method**

This study employed a Research and Development (R&D) approach using the ADDIE instructional design model, which consists of five main phases: Analysis, Design, Development, Implementation, and Evaluation. This model was selected because of its systematic structure, which facilitates the development of instructional materials in a focused and measurable manner, aligned with students' needs and with the context of technology-based and local wisdom-based science learning. Previous studies have also shown that the ADDIE model is effective for developing technology-based instructional products (Widianto et al., 2020; Fitriah et al., 2021; Adnan et al., 2025).

In this study, the ADDIE model was utilised as a framework to develop a science teaching module based on Augmented Reality (AR) and Mbojo ethnosience aimed at enhancing junior high school students' basic scientific skills and environmental awareness. In the Implementation and Evaluation phases, the effectiveness of the module was examined through a quasi-experimental approach using a Non-Equivalent Control Group Design, involving both pretest and posttest measurements to compare scientific skills and environmental awareness between an experimental class using the AR and Mbojo ethnosience-based module and a control class receiving conventional instruction.

The module was developed using the ADDIE model (Analysis, Design, Development, Implementation, and Evaluation). The analysis phase identified students' low scientific skills and environmental awareness through literature review, classroom observation, and interviews, while examining relevant Mbojo ethnosience elements for contextual integration. In the design phase, learning objectives, indicators, inquiry-based learning sequences integrating AR (Assemblr Edu), and research instruments were formulated. The development phase produced an AR-based module prototype featuring 3D simulations accessed via QR codes, which was validated by four experts and revised accordingly.

Implementation involved a quasi-experimental field trial with two Grade VII classes (experimental  $n = 25$ ; control  $n = 27$ ) over four sessions. Posttests were administered to assess scientific skills and environmental awareness. The evaluation phase integrated validation, practicality, and effectiveness results to determine overall feasibility and guide



final refinements. This study was conducted at SMPN 1 Manggalewa, West Nusa Tenggara, Indonesia. The research participants were Grade VII students selected randomly from the population of all Grade VII classes in the current academic year. The field trial involved 25 students from Class VII A and 27 students from Class VII B.

This study employed several instruments to assess the module's validity, practicality, and effectiveness. Validity was evaluated using a questionnaire completed by four validators (two university lecturers and two science teachers) on a 1–4 rating scale, covering content accuracy, presentation, language clarity, and AR media design, and the module was classified as highly valid. Practicality was measured through a student response questionnaire based on Likert-scale items addressing content, language, and usefulness, which showed predominantly positive responses and placed the module in the highly practical category. Effectiveness was examined using a validated context-based scientific skills test ( $r = 0.61$ – $0.78$ ;  $\alpha = 0.84$ ) and an environmental awareness questionnaire assessing ecological awareness, attitudes, behavior, and social participation.

Data were analysed using qualitative descriptive and quantitative approaches. Validity analysis was conducted by calculating the mean scores from expert validation questionnaires for each aspect, converting them into percentages, and classifying them into validity categories according to established criteria. Experts' comments and suggestions were analysed qualitatively to inform module revisions. Practicality analysis involved calculating the percentage of students' responses for each Likert-scale category and interpreting them into corresponding practicality levels. Effectiveness was examined by comparing posttest scores of scientific skills and environmental awareness between the experimental and control groups. A normality test was performed prior to inferential analysis, and when the normality assumption was met, independent samples t-tests were conducted. Statistically significant differences ( $p < 0.05$ ) were interpreted as evidence of the module's effectiveness.

## Results and Discussion

### Analysis Phase

Initial observations in Grade VII at SMPN 1 Manggalewa indicated that students' scientific skills and environmental awareness were still at a low level. Science learning was dominated by lecture-based teaching and routine exercises, with assessment focusing more on cognitive aspects than on inquiry activities, experimentation, or exploration of local environmental phenomena. Interviews with teachers and students revealed that science lessons were perceived as monotonous, less engaging, and insufficiently connected to Mbojo local wisdom. This situation contributed to low learning motivation, limited basic scientific skills, and suboptimal development of pro-environment attitudes. These findings underscore the need to develop an Augmented Reality (AR)–based learning medium grounded in Mbojo ethnoscience that is practical, interactive, and contextual to strengthen students' inquiry engagement and environmental literacy through meaningful local contexts.

### Design Phase

Building on the needs analysis, the design phase focused on formulating the specifications of the AR media to be used in science learning. At this stage, learning objectives were defined, along with indicators of basic scientific skills (observing, measuring, classifying, predicting, interpreting data, and communicating results) and targeted indicators of environmental awareness. A science learning sequence was then designed that integrates AR media with the context of Mbojo ethnoscience, particularly traditional maize cultivation practices and the use of *Uma Lengge* as a traditional food storage granary. The media design included selecting objects and events to be visualised in AR (e.g., land selection, planting



patterns, drying processes, and storage mechanisms), specifying student–media interaction scenarios, and preparing worksheets and assessment instruments aligned with the goals of enhancing scientific skills and environmental awareness through inquiry-based tasks and contextual environmental reflection activities.

### Development Phase

The development phase aimed to translate the design into an AR-based prototype grounded in Mbojo ethnoscience that was ready for validation and field testing. The main activities in this phase included: (1) developing text content, illustrations, and science learning activities integrated with Mbojo ethnoscience narratives; (2) creating 3D models, animations, and AR-based simulations that depict local Mbojo practices related to maize cultivation and the management of *Uma Lengge*; and (3) generating markers or quick response (QR) codes for each AR object so that they can be accessed through an AR application on students’ mobile devices. The media prototype was then packaged as a coherent science learning module designed to foster both scientific skills and environmental awareness, and subsequently submitted to content and media experts for validation prior to classroom implementation to ensure the accuracy of both scientific concepts and ethnoscientific representations.

### Implementation Phase

Before being used by students, the AR- and ethnoscience-based science teaching module underwent a validation process using feasibility questionnaires completed by four validators, consisting of two university lecturers and two science teachers. The validation instrument employed a 1–4 rating scale and covered four main aspects: (1) accuracy and correctness of the science content and Mbojo ethnoscience, (2) quality and organisation of content presentation, (3) clarity and readability of the language, and (4) media design and overall appropriateness of the AR displays to ensure that the AR features (3D visualization, QR accessibility, and interactive simulation) were pedagogically suitable for Grade VII students..

The recapitulation of the validation results is presented in Table 1. Overall, the module obtained an average score of 3.21, falling into the “very valid” category. Two validators assigned scores in the 3.24–3.34 range (very valid), while the other two gave scores around 3.00 (valid), accompanied by several minor revision notes, such as simplifying sentence structure, condensing the historical description of *Uma Lengge*, adding links to supporting ethnoscience videos, and utilising QR codes to access supplementary information to strengthen students’ understanding of both scientific concepts and local ecological practices.

These results indicate that the content, presentation, language, and media design of the module were judged to be appropriate for use in junior high school science learning, with only minor revisions required based on expert suggestions. Accordingly, the AR- and Mbojo ethnoscience-based science teaching module was deemed to meet validity criteria and could be advanced to the field trial stage with students as a feasible instructional product for inquiry-based and culturally responsive science learning.

**Table 1. Expert Validation Results of the AR- and Ethnoscience-Based Science Teaching Module**

Validator	Mean Score	Validity Category	Brief Remarks
X1	3.26	Very valid	Please revise sentence structure (subject–predicate–object) and enlarge font size.
X2	3.34	Very valid	The historical content of <i>Uma Lengge</i> does not need to be

			explained in too much detail.
X3	3.00	Valid	It would be more effective if a supporting video related to ethnoscience is added.
X4	3.24	Very valid	Ethnoscience content can be accessed via QR code that links to the historical information.
Average	3.21	Very valid	The module is feasible to use with minor revisions based on validators' suggestions.

Theoretically, these results are consistent with quality instructional material criteria that emphasize content consistency, coherence among components, and a strong theoretical foundation. The findings also align with Fitriah et al. (2021) and Adnan et al. (2025), indicating that the ADDIE model can produce well-designed and valid technology-based instructional products when implemented systematically.

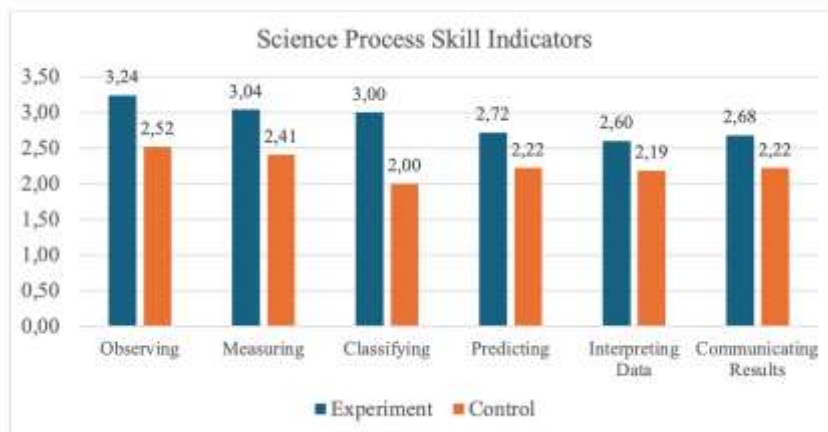
**Table 2. Percentage of Students' Responses to the Practicality of the AR- and Mbojo Ethnoscience-Based Science Teaching Module**

No	Indicator	Strongly Agree	Agree	Dis-agree	Strongly Disagree
<b>Content Aspect</b>					
1	The learning material is aligned with the stated learning objectives.	89	7	4	0
2	The sequence of presentation in the AR-based Teaching Module is systematic and easy for students to follow.	77	15	8	0
3	The activities in the AR-based Teaching Module are engaging and relevant because they are directly connected to students' everyday experiences.	71	15	6	8
<b>Language Aspect</b>					
4	The AR-based Teaching Module is easy to read.	76	16	5	3
5	The material is presented in language that is easy to understand.	65	19	13	3
6	The language used is communicative.	61	27	9	3
7	The user guide, learning objectives, and activities in the AR-based Teaching Module are presented clearly enough.	61	27	7	5
<b>Usefulness Aspect</b>					
8	The AR-based Teaching Module is easy to use.	79	11	6	4
9	The AR-based Teaching Module motivates me to study more diligently.	61	27	11	1
10	The augmented reality visualisation provides meaningful support and facilitates student engagement in practicum activities.	76	18	5	1
<b>Avarage</b>		<b>71,6</b>	<b>18,2</b>	<b>7,4</b>	<b>2,8</b>

Table 2 presents students' responses regarding the practicality of the AR- and Mbojo ethnoscience-based science module across content, language, and usefulness dimensions. Overall, 71.6% of students selected "Strongly Agree" and 18.2% selected "Agree," resulting in more than 85% positive responses. Negative responses were minimal (7.4% "Disagree" and 2.8% "Strongly Disagree"), indicating a high level of perceived practicality.

Across dimensions, the results suggest that the module was systematically organized, linguistically clear, and functionally useful for supporting science learning. Students reported that the AR visualizations enhanced engagement and facilitated interaction during practicum activities. Based on the predefined criteria, the module was classified as highly practical.

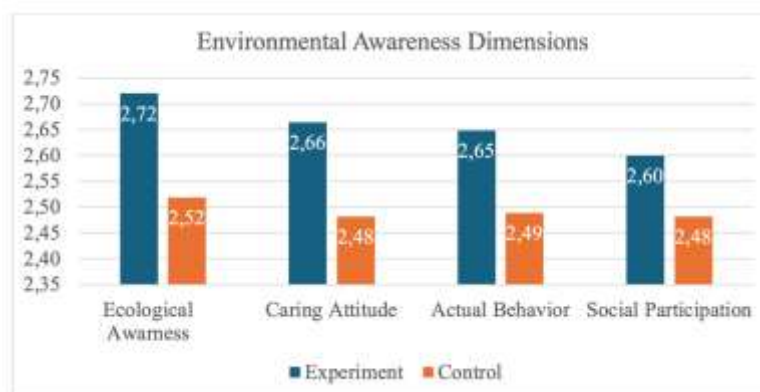
These findings are consistent with Jiang et al. (2021) and Demircioğlu et al. (2022), who reported that AR-based learning media are perceived as practical and engaging due to their integration of interactive visualizations with conceptual content. The results also align with Maulana et al. (2025), emphasizing that user-centered design contributes to high levels of learner acceptance and usability.



**Figure 1. The mean scores for each science process skill indicator**

Figure 1 displays the mean scores for each science process skill indicator in the experimental and control classes. For the experimental class, the average scores for observing, measuring, classifying, predicting, interpreting data, and communicating results were 3.24, 3.04, 3.00, 2.72, 2.60, and 2.68, respectively. In contrast, the control class obtained mean scores of 2.52 for observing, 2.41 for measuring, 2.00 for classifying, 2.22 for predicting, 2.19 for interpreting data, and 2.22 for communicating results.

Across all six indicators, the experimental group consistently outperformed the control group, with particularly large differences on classifying (3.00 vs. 2.00) and observing (3.24 vs. 2.52). The integration of AR with Mbojo ethnosience appears particularly effective in improving observation and classification because these skills were directly linked to tasks such as identifying traditional maize planting techniques, distinguishing growth stages through 3D visual cues, and comparing the design features of the Uma Lengge granary. In contrast, skills such as interpreting data and predicting outcomes may require more abstract reasoning and extended practice, which could not be fully achieved during the limited intervention period. This pattern suggests that the AR- and Mbojo ethnosience-based teaching module was more effective than conventional instruction in fostering students' science process skills in observing, measuring, classifying, predicting, interpreting data, and communicating results.



**Figure 1. The Mean Scores Of Students' Environmental Awareness**

Figure 2 presents the mean scores of students' environmental awareness across four dimensions in the experimental and control classes. For ecological awareness, the experimental group obtained a mean score of 2.72, higher than the control group's 2.52. On the caring attitude dimension, the experimental group scored 2.66, while the control group scored 2.48. A similar pattern appears for actual behavior, with means of 2.65 (experimental) and 2.49 (control). Finally, for social participation, the experimental class reached a mean of 2.60, compared with 2.48 in the control class.

Overall, the experimental group outperformed the control group on all four dimensions, indicating that the AR- and Mbojo ethnoscience-based teaching module was more effective than conventional instruction in fostering students' ecological awareness, caring attitudes, pro-environmental behaviors, and social participation in environmental activities.

To provide a more detailed picture of the differences in achievement between the two groups, the descriptive statistics for scientific skills and environmental awareness in the experimental and control classes are presented in Table 3.

**Table 3. Descriptive statistics**

	Class	N	Mean	Std. Deviation	Std. Error Mean
Scientific_Skills	Experiment	25	17.60	2.363	.473
	Control	27	14.56	2.806	.540
Enviromental_Awareness	Experiment	25	53.16	2.982	.596
	Control	27	49.85	2.332	.449

Table 3 presents the descriptive statistics for scientific skills and environmental awareness in both research groups. For the scientific skills variable, the experimental group, consisting of 25 students, achieved a mean score of 17.60 with a standard deviation of 2.363, whereas the control group (27 students) obtained a mean score of 14.56 with a standard deviation of 2.806. This difference in mean values indicates that students who participated in the Augmented Reality- and Mbojo ethnoscience-based learning showed higher scientific skill achievement compared to those who received conventional instruction.

For the environmental awareness variable, the experimental group recorded a mean score of 53.16 with a standard deviation of 2.982, while the control group obtained a mean score of 49.85 with a standard deviation of 2.332. This pattern, consistent with the previous variable, demonstrates that the learning intervention not only improved scientific skills but also strengthened students' environmental awareness. The relatively small standard errors of the mean (0.473–0.596) indicate that the estimated means are stable and adequately represent the characteristics of the sample.

In order to ensure that the subsequent inferential analyses could be conducted using parametric statistical tests, it was necessary to examine whether the distribution of the scientific skills and environmental awareness scores met the assumption of normality. Therefore, following the descriptive comparison between the experimental and control groups, a normality test was performed to determine whether the data were normally distributed and appropriate for further analysis using the independent samples t-test. The results of the normality assessment are presented in Table 4.

**Table 4. Tests of Normality**

Class	Kolmogorov-Smirnov <sup>a</sup>			Shapiro-Wilk			
	Statistic	df	Sig.	Statistic	df	Sig.	
Scientific_Skills	Experiment	.087	25	.200*	.953	25	.287

	Control	.104	27	.200*	.971	27	.617
Enviromental_Awarness	Experiment	.171	25	.056	.934	25	.107
	Control	.161	27	.070	.953	27	.250

\*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

The results of the normality test are presented in Table 3. The Kolmogorov–Smirnov test indicates that the significance values for scientific skills in the experimental and control groups were 0.200 and 0.200, respectively, while the values for environmental awareness were 0.056 and 0.070 (all  $p > 0.05$ ). These findings are further supported by the Shapiro–Wilk test, which also produced significance values above 0.05 for both groups. Therefore, it can be concluded that the distributions of scientific skills and environmental awareness scores in both the experimental and control groups are normally distributed, thus meeting the normality assumption required for subsequent parametric analysis using the independent samples t-test.

**Table 5. Independent Samples Test**

		Levene's Test for Equality of Variances		t-test for Equality of Means							
		F	Sig.	t	df	Significance One-Sided p	Significance Two-Sided p	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
										Lower	Upper
Scientific_Skills	Equal variances assumed	.416	.522	4.215	50	<.001	<.001	3.044	.722	1.594	4.495
	Equal variances not assumed			4.243	49.575	<.001	<.001	3.044	.718	1.603	4.486
Enviromental_Awarness	Equal variances assumed	3.256	.077	4.475	50	<.001	<.001	3.308	.739	1.823	4.793
	Equal variances not assumed			4.432	45.434	<.001	<.001	3.308	.746	1.805	4.811

The independent samples t-test results indicate that the AR-based science module integrated with Mbojo ethnoscience significantly improved students' scientific skills and environmental awareness. Levene's Test confirmed homogeneity of variance for both variables ( $p > 0.05$ ), allowing interpretation under the equal variances assumed condition. For scientific skills, a significant difference was found between the experimental and control groups,  $t(50) = 4.215$ ,  $p < 0.001$ , with a mean difference of 3.044 (95% CI [1.594, 4.495]). Similarly, environmental awareness showed a significant difference,  $t(50) = 4.475$ ,  $p < 0.001$ , with a mean difference of 3.308 (95% CI [1.823, 4.793]). These findings indicate that the AR–ethnoscience module was more effective than conventional instruction in enhancing both learning outcomes.

These findings align with Donatuto et al. (2020) and Lestari et al. (2024), who emphasize the role of local wisdom in fostering environmental awareness and eco-cultural



identity, and with Rosana et al. (2021), who highlight the value of interactive, culturally grounded technology in promoting pro-environmental attitudes. Consistent with Education for Sustainable Development (ESD), the results suggest that integrating AR and Mbojo ethnosience supports sustainability-oriented science learning. Therefore, this approach demonstrates pedagogical potential for enhancing students' scientific skills and environmental awareness within a culturally relevant context.

### **Evaluation Stage**

The evaluation stage, as the final phase of ADDIE, comprehensively assessed the AR- and Mbojo ethnosience-based science module by integrating expert validation, student responses, and effectiveness results on scientific skills and environmental awareness. It involved micro-level revisions (language, visuals, scaffolding) and macro-level alignment with contextual, cultural, and inquiry-based goals. The findings show that the module is highly valid, practical, and effective, and therefore appropriate for junior high school science learning.

Final revisions based on expert and student feedback included simplifying explanations, improving AR and QR interfaces, and strengthening inquiry and environmental reflection activities, in line with iterative development principles (Rosana et al., 2021) to ensure pedagogical coherence and accessibility. These enhancements reinforce scientific process skills while linking them to Mbojo cultural practices of environmental stewardship. Although the integration of AR and local wisdom effectively addresses the limitations of conventional, less contextual media, successful and large-scale implementation requires adequate teacher competence, digital literacy, device access, cultural adaptation, and sustained training support.

### **Conclusion**

This study concludes that an Augmented Reality (AR)-based science module integrated with Mbojo ethnosience was systematically developed by drawing on the local contexts of traditional maize cultivation and the Uma Lengge as a foundation for contextual learning. Expert evaluations classified the module as highly valid, and students' responses indicated very high practicality, suggesting that it is suitable for implementation in junior high school science instruction. The quasi-experimental results further showed that the AR-ethnosience module produced statistically significant improvements in students' scientific skills and environmental concern compared with conventional instruction.

### **Recommendation**

Science teachers are recommended to integrate the AR-ethnosience-based module to strengthen students' scientific skills and environmental concern through contextual learning. Schools should support implementation by providing adequate devices, stable internet connectivity, and sustained teacher professional development covering the use of AR applications, facilitation of inquiry-based learning, and strategies for integrating local wisdom. Future research should involve larger and more diverse samples, examine implementation across different school contexts and regions, and explore varied forms of local wisdom to enable broader and more contextually relevant adoption.



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