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Research Article

Development of Augmented Reality Teaching Materials Integrating Local Wisdom to Improve Junior High School Students' Cultural Literacy

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Abstract
Limited access to interactive and context-sensitive learning resources constrains junior high school students' engagement with local culture. This study developed and evaluated augmented reality (AR)-enhanced digital teaching materials integrating Rokan Hulu Malay local wisdom to support students' cultural literacy. The study followed the ADDIE model and involved three expert validators, a small-group trial (n = 10), and a large-group trial (n = 30) at SMP Negeri 1 Rambah, Indonesia. The large-group participants completed four 90-minute instructional sessions over two weeks and undertook cultural literacy pretests and posttests. Data were collected through validation sheets, student response questionnaires, and cultural literacy tests. Product validity was examined using Aiken's V, practicality through descriptive statistics, and score improvement through the Shapiro–Wilk test, a paired-samples t-test, and normalized gain analysis. The materials obtained a mean Aiken's V of 0.75. Practicality scores were 82.50% in the small-group trial and 82.03% in the large-group trial. Mean cultural literacy scores increased from 61.27 ± 8.15 to 83.43 ± 7.28, $t(29) = -13.542$, $p < .001$, with a moderate N-gain of 0.57. The findings indicate that the materials were valid and practical and were associated with improved cultural literacy; however, the one-group design limits causal interpretation.

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Introduction

Teaching local culture in junior high schools remains constrained by the limited range of instructional resources available to teachers and students. Local cultural content is commonly delivered through textbooks, static images, and lectures, producing learning experiences that are abstract and weakly connected to students' social contexts. Consequently, students may recognize cultural objects without adequately understanding their meanings, values, or relevance to regional identity and cultural preservation (Etuk, 2024).

Conventional materials also provide limited opportunities to examine cultural objects concretely and interactively. Augmented reality (AR) can address this limitation by superimposing three-dimensional virtual objects onto real-world environments in real time, enabling students to observe, rotate, enlarge, and explore cultural artifacts through digital devices (Akçayır & Akçayır, 2017). These visual, interactive, and contextual affordances can make local culture more accessible than text-only or two-dimensional representations and may strengthen students' understanding of cultural meanings, identity, and preservation.

Cultural literacy is an essential competence for participation in increasingly multicultural societies. It extends beyond recognizing cultural elements to include understanding cultural values, appreciating diversity, developing cultural identity, and participating in preservation efforts (Ervina

Anatasya et al., 2023; Miskiyyah et al., 2025; Sáez-Velasco et al., 2025; Sholikhah, 2022). In Indonesia, cultural literacy is included in the National Literacy Movement, which seeks to develop citizens who understand their cultural identities and interact constructively within a diverse society. Nevertheless, evidence indicates that many students have limited knowledge and appreciation of local culture (Alamsyah & Hidayati, 2025; Mursalim et al., 2025).

In this study, cultural literacy was operationalized with reference to the National Literacy Movement framework (Kementerian Pendidikan dan Kebudayaan, 2017) and prior cultural education research. The construct comprised five dimensions: knowledge of local culture, understanding of cultural values, cultural appreciation, cultural identity, and awareness of cultural preservation. These dimensions represent cognitive, affective, and behavioral aspects of cultural literacy and were translated into indicators for the cultural literacy test.

Integrating local wisdom into teaching materials offers one means of contextualizing cultural learning. Local wisdom encompasses the knowledge, values, traditions, and practices developed within a community and transmitted across generations (Mursalim et al., 2025; Suastra et al., 2021). When instructional content is connected to students' cultural backgrounds and everyday experiences, learning can become more meaningful while fostering pride in regional identity (Chusnur Rahmi et al., 2025; Septiani et al., 2025; Yusuf et al., 2025).

Rokan Hulu Regency has a rich Malay cultural heritage that includes traditional houses, the Malay tanjak, the traditional spinning-top game (gasing), Silek Tigo Bulan martial arts, Zapin dance, Malay proverbs and expressions (petatah-petitih), and customary traditions. A preliminary study conducted at SMP Negeri 1 Rambah in January 2026 involved classroom observations and interviews with two teachers responsible for local cultural instruction. The findings showed that instruction relied predominantly on textbooks, static images, and lectures. The teachers reported that students generally recognized cultural elements only at a basic level and had difficulty explaining their meanings, functions, and underlying values. They also identified the lack of interactive media as a major barrier to student interest and engagement.

AR-based digital teaching materials therefore offer a relevant response to the identified instructional need. Cultural objects can be presented as three-dimensional visualizations that students explore while reading contextual explanations and completing reflective activities. Previous research has associated AR-supported learning with stronger motivation, engagement, conceptual understanding, and learning outcomes (Akçayır & Akçayır, 2017; Cahyani et al., 2023; Ibáñez & Delgado-Kloos, 2018). However, limited research has examined AR materials that specifically integrate Rokan Hulu Malay local wisdom and assess multidimensional cultural literacy among junior high school students.

This study addresses three gaps. First, much AR research has emphasized achievement, motivation, or conceptual understanding rather than cultural literacy. Second, local wisdom-based learning studies have rarely assessed cultural knowledge, values, appreciation, identity, and preservation awareness within a single framework. Third, few studies have combined three-dimensional visualization, real-time interaction, and contextual exploration to teach local cultural heritage.

The contribution of this study lies in developing an AR-enhanced digital teaching material that connects Rokan Hulu Malay local wisdom with a multidimensional cultural literacy framework. The product combines cultural exploration, interactive visualization, contextual information, reflection,

and assessment. The study also provides evidence regarding the product's validity, practicality, and preliminary association with changes in students' cultural literacy scores.

Accordingly, this study aimed to (1) develop AR-based digital teaching materials integrating Rokan Hulu Malay local wisdom for junior high school students; (2) evaluate the materials' validity and practicality through expert review and student trials; and (3) examine changes in students' cultural literacy scores after using the developed materials.

Method

Research Design

This study employed a research and development approach using the ADDIE instructional design model, which comprises analysis, design, development, implementation, and evaluation (Branch, 2009). The approach was selected because the study sought to produce and evaluate AR-based digital teaching materials integrating Rokan Hulu Malay local wisdom. Each ADDIE phase generated specific outputs and evidence used to refine the product and assess its validity, practicality, and preliminary effectiveness.

ADDIE was selected because it provides a systematic yet flexible framework for identifying instructional needs, designing content and media, developing and validating a prototype, implementing the product with intended users, and evaluating the development process. Formative evaluation was conducted throughout the phases, while summative evaluation synthesized the final validity, practicality, and student outcome data. The development procedure followed the five ADDIE stages described below.

Analysis Stage

A needs assessment was conducted at SMP Negeri 1 Rambah in January 2026. Purposively selected participants included two teachers responsible for local cultural instruction. Data were obtained through classroom observations, semi-structured interviews, curriculum analysis, and a review of relevant literature. The observation protocol addressed instructional methods, learning resources, and student engagement, whereas the interviews explored teachers' perceptions of available materials, instructional challenges, and expectations for digital media. The data were analyzed descriptively to identify recurring instructional needs. The results informed the content, features, and learning activities included in the product.

Design Stage

The product was designed as a digital flipbook integrated with AR content through the Assemblr EDU platform. As shown in Figure 1, the home interface provides access to the learning menu and objectives. Each topic contains an AR activation button linked to a corresponding three-dimensional object, enabling students to observe, rotate, and enlarge cultural objects while reading the accompanying explanations. The learning sequence concludes with reflection activities and evaluation questions designed to reinforce cultural literacy and understanding of local wisdom.



Figure 1. Interface and navigation flow of the AR-integrated digital flipbook.

The digital teaching materials were designed for Android smartphones running Android 8.0 or later, with an ARM64 processor, at least 3 GB of RAM, and a minimum of 300 MB of available storage. A rear camera with autofocus was required to scan the QR codes embedded in the flipbook, and an internet connection was needed to access the AR content hosted on Assemblr EDU.

Development Stage

During development, the digital flipbook, AR objects, learning activities, and assessment components were produced and integrated. The prototype was then reviewed by one cultural content expert, one learning media expert, and one language expert. Their ratings and recommendations guided revisions before student implementation.

Implementation Stage

After expert review and revision, the product was implemented with junior high school students. The implementation phase examined ease of use, user acceptance, student responses, and changes in cultural literacy scores.

Evaluation Stage

Evaluation was conducted formatively during each ADDIE phase and summatively after implementation. The final evaluation integrated expert validation, student response, and pretest–posttest findings to determine the overall quality of the developed materials and identify priorities for further improvement.

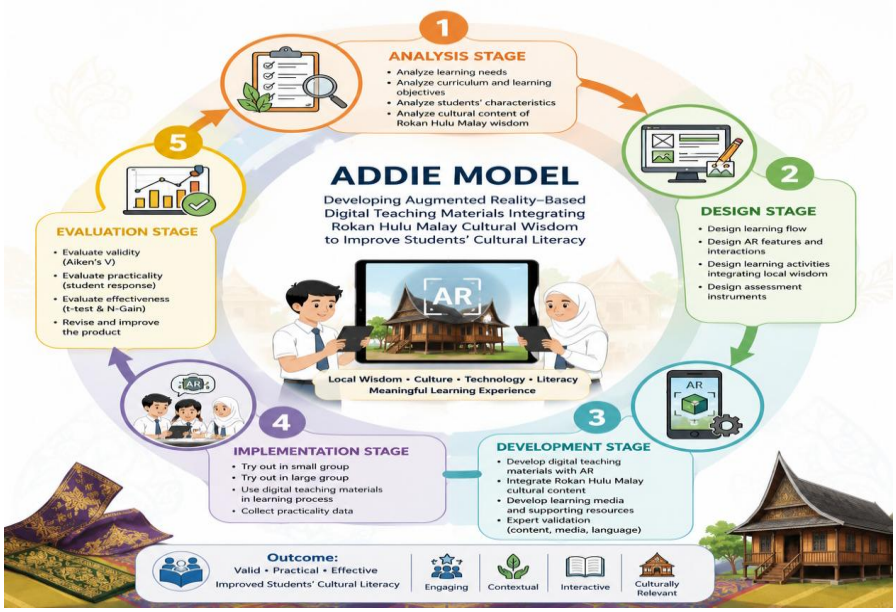


Figure 2. ADDIE-based development procedure.

Table 1. ADDIE development stages

Stage	Activities
Analysis	Analysis of students' needs, teachers' needs, curriculum requirements, and Rokan Hulu Malay cultural materials
Design	Development of storyboards, teaching material design, AR object design, and research instruments
Development	Product development and expert validation
Implementation	Small-group and large-group trials
Evaluation	Formative and summative evaluation of the developed product

Research Setting and Participants

The study was conducted at SMP Negeri 1 Rambah, Rokan Hulu Regency, Riau Province, Indonesia, during the 2026/2027 academic year. Participants included three expert validators and eighth-grade students selected purposively. A small-group trial involved 10 students and examined initial practicality. A separate group of 30 students participated in the large-group trial and the one-group pretest–posttest assessment. Students in the small-group trial were not included in the large-group trial.

Data Collection Instruments

Three instruments were used: expert validation sheets, student response questionnaires, and a cultural literacy test. The validation sheets assessed content, media, and language quality on a four-point scale from 1 (poor) to 4 (excellent). The student response questionnaire assessed ease of use, visual attractiveness, content quality, AR interactivity, learning motivation, engagement, understanding of Rokan Hulu Malay culture, and cultural literacy, also using a four-point scale. The cultural literacy test measured knowledge of local culture, understanding of cultural values, cultural appreciation, cultural identity, and preservation awareness before and after implementation.

Product Feasibility Criteria

Product feasibility was examined using expert ratings and student responses. Scores on the four-point scale were converted to percentages using the following formula (Arikunto, 2018), product feasibility percentage:

$$\textit{Percentage} = (\textit{obtained score} / \textit{maximum possible score}) \times 100\%$$

The resulting percentages were interpreted using the criteria presented in Table 2.

Table 2. Product feasibility criteria

Percentage (%)	Category
81–100	Very Feasible
61–80	Feasible
41–60	Moderately Feasible
21–40	Less Feasible
≤20	Not Feasible

The percentage criteria in Table 2 were used to interpret feasibility and practicality ratings. Content validity was examined separately using Aiken's V. Following Retnawati (2016), coefficients of 0.70 or higher were treated as acceptable evidence of content validity.

Data Analysis

Data were analyzed using IBM SPSS Statistics 26. Before implementation, the student response questionnaire and cultural literacy test were subjected to item validity and internal consistency analyses. Item validity was examined using Pearson product–moment correlations at $\alpha = .05$, and Cronbach's alpha values of .70 or higher were considered acceptable (Sugiyono, 2019; Taber, 2018). Expert ratings were analyzed using Aiken's V to evaluate the content validity of the product (Retnawati, 2016). Validation ratings were also summarized as percentages. Student response data were analyzed descriptively using means and percentages to evaluate practicality and acceptance.

Changes in cultural literacy scores were examined using a one-group pretest–posttest design (Salsabila & Muchlis, 2024). The Shapiro–Wilk test was first applied to the pretest and posttest distributions at $\alpha = .05$ (Shapiro & Wilk, 1965). Values above .05 were interpreted as evidence that the normality assumption was not violated.

Pretest and posttest means were then compared using a paired-samples t-test at $\alpha = .05$. Normalized gain (N-gain) was calculated to describe the magnitude of score improvement. Because the study did not include a control group, the analyses were interpreted as evidence of within-group change rather than definitive causal effects.

Result and Discussion

Analysis Stage

The analysis stage identified the instructional need for AR-based digital teaching materials integrating Rokan Hulu Malay local wisdom. Evidence was obtained from classroom observations, teacher interviews, curriculum analysis, and the literature review, as summarized in Table 3.

Table 3. Data sources and findings from the needs analysis

Component	Data Source	Evidence Collected	Key Findings
Classroom Observation	2 classroom observations	Observation notes	Teaching was dominated by textbooks and lecture-based instruction; limited use of interactive media
Teacher Interviews	2 teachers	Semi-structured interviews	Teachers reported difficulties in presenting local culture concretely and interactively
Curriculum Analysis	Merdeka Curriculum documents, learning outcomes, and teaching modules	Document review	Local culture content supports cultural literacy objectives but lacks specific Rokan Hulu Malay cultural materials
Literature Review	Previous studies on AR and cultural literacy	Scientific literature	AR has potential to enhance engagement, visualization, and cultural understanding

The needs analysis showed that local culture instruction relied mainly on textbooks and lectures and offered limited opportunities for interactive, contextual learning. The available materials did not position Rokan Hulu Malay culture as a central learning resource. Teachers also reported that students were more responsive to technology-supported media than to conventional materials. Together, these findings supported the development of an AR-enhanced resource designed to increase engagement with local cultural content.

Curriculum analysis indicated that local cultural content was aligned with learning outcomes related to character development, cultural identity, and literacy. Cultural elements selected for the product included the Malay tanjak, traditional Malay houses, Silek Tigo Bulan, gasing, petatah-petitih, and community traditions. Selection was based on educational relevance, familiarity to students, and suitability for three-dimensional visualization.

The analysis therefore established a clear need for teaching materials that were interactive, contextually grounded, and aligned with current educational technology.

Design Stage

Based on the needs analysis, the content structure, interface, learning sequence, and AR objects were designed to support students' cultural literacy. The design incorporated the selected Rokan Hulu Malay cultural elements and specified learning objectives, explanatory content, interactive exploration, reflection activities, and assessment tasks. Expert validation sheets, student response questionnaires, and the cultural literacy test were also drafted. The principal outputs were the storyboard, interface design, AR object specifications, and instrument blueprints.

Development and Validation Stage

The prototype integrated cultural content, AR objects, learning activities, and cultural literacy assessments. Content, media, and language experts evaluated the product; Table 4 reports the Aiken's V coefficients, and Table 5 summarizes the recommended revisions.

Table 4. Expert validation results

Validator	Aiken's V Value	Category
Content Expert	0.75	Valid

Media Expert	0.76	Valid
Language Expert	0.74	Valid
Average	0.75	Valid

Table 5. Validator recommendations and revisions

Aspect	Validators' Recommendations	Revisions Implemented
Content	Add more information regarding the historical background of Rokan Hulu Malay culture.	The content was expanded by adding historical information in the introductory section.
Media	Increase the size of the AR menu icons.	The AR menu icons were enlarged to improve visibility and usability.
Language	Simplify overly long sentences.	The sentences were revised to better suit the characteristics and comprehension level of junior high school students.

Implementation Stage

The small-group trial involved 10 eighth-grade students and examined initial practicality, ease of use, and user responses. After using the materials, students completed an eight-indicator response questionnaire. The results are presented in Table 6.

Table 6. Student responses in the small-group trial (n = 10)

Indicator	Mean	Percentage (%)	Category
Ease of Use	3.3	82.5	Very Good
Visual Attractiveness	3.4	85	Very Good
Content Quality	3.2	80	Good
AR Feature Interactivity	3.5	87.5	Very Good
Learning Motivation	3.1	77.5	Good
Student Engagement	3.2	80	Good
Understanding of Rokan Hulu Malay Culture	3.4	85	Very Good
Cultural Literacy	3.3	82.5	Very Good
Average	3.3	82.5	Very Good

As shown in Table 6, the small-group trial produced a mean score of 3.30, equivalent to 82.50%, and was classified as very good. AR feature interactivity received the highest rating (M = 3.50; 87.50%). Visual attractiveness and understanding of Rokan Hulu Malay culture each received 85.00%.

The small-group findings indicate that the materials were generally easy to use, engaging, and helpful for understanding local culture. The product was therefore considered sufficiently practical to proceed to the large-group trial.

The revised materials were subsequently evaluated in a large-group trial involving 30 students. The results are presented in Table 7.

Table 7. Student responses in the large-group trial (n = 30)

Indicator	Mean	Percentage (%)	Category
Ease of Use	3.20	80.00	Good
Visual Attractiveness	3.50	87.50	Very Good
Content Quality	3.15	78.75	Good

Indicator	Mean	Percentage (%)	Category
AR Feature Interactivity	3.55	88.75	Very Good
Learning Motivation	3.10	77.50	Good
Student Engagement	3.20	80.00	Good
Understanding of Rokan Hulu Malay Culture	3.40	85.00	Very Good
Cultural Literacy	3.15	78.75	Good
Average	3.28	82.03	Very Good

In the large-group trial, the materials achieved a mean score of 3.28 (82.03%), which was classified as very good. AR feature interactivity again received the highest rating (M = 3.55; 88.75%). Ease of use, content quality, learning motivation, student engagement, and cultural literacy were rated as good, indicating areas for further refinement. Overall, the large-group results support the practicality and acceptability of the materials for local culture instruction.

Effectiveness Analysis

Descriptive Statistics

Pretest and posttest cultural literacy scores are summarized in Table 8.

Table 8. Descriptive statistics for cultural literacy scores

Test	N	Mean	Standard Deviation
Pretest	30	61.27	8.15
Posttest	30	83.43	7.28

As shown in Table 8, the mean cultural literacy score increased from 61.27 (SD = 8.15) on the pretest to 83.43 (SD = 7.28) on the posttest. The difference represents a substantial within-group improvement after the instructional sessions.

Normality test

The Shapiro–Wilk results are presented in Table 9.

Table 9. Shapiro–Wilk normality test results

Variable	Sig.	Interpretation
Pretest	.112	Normally Distributed
Posttest	.087	Normally Distributed

The pretest (p = .112) and posttest (p = .087) values exceeded .05, indicating that the normality assumption was not violated. A paired-samples t-test was therefore used for the mean comparison.

Paired-samples t-test

The paired-samples t-test results are presented in Table 10.

Table 10. Paired-samples t-test results

t	df	Sig. (2-tailed)
-13.542	29	< .001

The analysis showed a statistically significant difference between pretest and posttest scores, $t(29) = -13.542$, $p < .001$. This result indicates a reliable within-group score increase after students used the AR-based materials; however, it does not by itself establish causality.

Normalized gain analysis

Normalized gain was calculated to describe the proportional improvement in cultural literacy scores. The result is presented in Table 11.

Table 11. Normalized gain result

Mean N-Gain	Category
0.57	Moderate

Evaluation Stage

The mean N-gain was 0.57, which was classified as moderate. This value provides preliminary evidence of improvement but should be interpreted cautiously because the one-group design cannot rule out alternative explanations. The magnitude of gain may also have been constrained by relatively high posttest scores among some students.

Overall, expert validation produced a mean Aiken's V of 0.75, indicating acceptable validity. Practicality scores were 82.50% in the small-group trial and 82.03% in the large-group trial, both within the very good category. The pretest–posttest comparison and moderate N-gain further indicated meaningful within-group improvement in cultural literacy.

Taken together, the findings show that the developed materials met the study's validity and practicality criteria and provided an interactive, contextual, and technology-enhanced learning experience. Further controlled evaluation is required before stronger claims about instructional effectiveness can be made.

Discussion

The present study sought to develop and evaluate augmented reality (AR)-based digital teaching materials integrating Rokan Hulu Malay local wisdom and to examine their validity, practicality, and association with students' cultural literacy. The findings show that the product achieved an average Aiken's V coefficient of 0.75, indicating acceptable expert-judged content validity, while the small- and large-group practicality scores reached 82.50% and 82.03%, respectively. Interactivity consistently received the strongest student response, suggesting that the opportunity to rotate, inspect, and manipulate three-dimensional cultural objects constituted a central affordance of the materials. In addition, students' mean cultural literacy score increased from 61.27 before instruction to 83.43 after four sessions, with a moderate N-gain of 0.57 and a statistically significant paired comparison. Taken together, these results indicate that the materials were feasible for classroom use and were associated with meaningful short-term improvement in cultural literacy among the participating students. Nevertheless, because the study employed a one-group pretest–posttest design, the observed gain should be interpreted as preliminary evidence of instructional promise rather than definitive proof that AR alone caused the improvement.

The improvement in cultural literacy can be explained by the interaction between technological visualization and culturally contextualized content. Three-dimensional representations enabled students to examine traditional houses, clothing, games, martial arts, and

cultural expressions more concretely than would normally be possible through verbal descriptions or static illustrations. This affordance likely supported the cultural knowledge dimension by making the physical characteristics of cultural objects more observable. However, visualization alone would not necessarily promote deeper cultural literacy. The contextual explanations accompanying each object were equally important because they connected visible features with social functions, cultural values, identity, appreciation, and preservation. This interpretation is consistent with Garzón et al. (2020), whose meta-analysis demonstrated that the educational impact of AR varies according to the pedagogical approach in which it is embedded. It also aligns with Chang et al. (2022), who synthesized 134 experimental and quasi-experimental studies and found positive effects of AR across learner response, knowledge and skills, and performance outcomes. Thus, the present findings are more plausibly attributed to the alignment of three-dimensional visualization, guided interaction, and culturally meaningful explanation than to technological novelty alone. also correspond with recent global research on AR-supported motivation and cultural-heritage learning. Prasetya et al. (2024) reported that AR learning experiences can strengthen attention, perceived relevance, confidence, and satisfaction, which helps explain why interactivity received the highest practicality rating in both trials. The current result is particularly compatible with the relevance dimension because students were not exploring culturally neutral virtual objects but representations of practices and artifacts from their own sociocultural environment. In cultural-heritage research, Boboc et al. (2022) identified education, three-dimensional reconstruction, digital heritage, intangible heritage, user experience, and gamification as prominent areas of AR application. More recently, Chatsiopoulou and Michailidis (2025) concluded that effective cultural-heritage AR depends on the relationship among technology, learning design, and culture rather than on a universally optimal technical format. Pireva Nuci and Shatri (2026) similarly found that immersive technologies could improve learning outcomes, although students rated ease of use lower than perceived usefulness and behavioral intention. This pattern reinforces the importance of user-interface quality, instructional guidance, and technical support. The present study supports these international findings by demonstrating that cultural content and AR functioned as complementary components. At the same time, its moderate rather than high N-gain suggests that a short intervention cannot fully develop the multidimensional knowledge, values, identity, appreciation, and preservation components of cultural literacy. Indonesia further supports the importance of contextual grounding. Suastra et al. (2021) found that integrating indigenous science into formal learning could strengthen local-wisdom-based character and higher-order thinking, while Adeningsih et al. (2024) reported that locally grounded e-modules improved science learning outcomes. Mursalim et al. (2025) similarly demonstrated that a local-wisdom-based learning model improved elementary students' cultural literacy and reported a moderate N-gain, a pattern comparable to the present study. Septiani et al. (2025) also showed that local-wisdom-based digital modules could enhance students' interest and achievement. More directly, Sapta et al. (2025) developed AR media for learning Indonesian local wisdom, confirming the feasibility of representing culturally diverse material through interactive digital objects. The present study extends these Indonesian findings by focusing specifically on Rokan Hulu Malay heritage and by treating cultural literacy, rather than general achievement or technology acceptance, as the principal learning outcome. Differences in the magnitude of improvement across these studies may reflect variation in students' prior cultural exposure, instructional duration, teacher facilitation, assessment

instruments, and the extent to which cultural practices were discussed rather than merely displayed. , the results refine the application of ADDIE in culturally grounded digital learning. ADDIE provided a systematic sequence for needs analysis, product design, development, classroom implementation, and evaluation, but the model itself does not explain why students learn from AR. The findings suggest that its educational value depends on constructive alignment among the identified cultural-literacy needs, the selection of culturally authentic content, appropriate three-dimensional representations, guided interaction, and assessments that capture more than factual recall. In this sense, the study extends the understanding of AR-mediated contextual learning by showing that technological affordances become educationally meaningful when students can connect digital representations with familiar community knowledge and cultural identity. Pedagogically, teachers should therefore use AR as a stimulus for inquiry, discussion, comparison, reflection, and preservation-oriented projects rather than as a stand-alone visual display. Student engagement may be strengthened through collaborative exploration and peer explanation, while media literacy can be developed by asking students to evaluate the accuracy, sources, ownership, and ethical representation of digitized cultural content. Although culturally affirming materials may support students' sense of belonging and positive identity formation, emotional well-being was not measured in this study. Any psychosocial benefit should consequently be treated as a proposition for future investigation rather than a demonstrated outcome. level, the findings support the inclusion of locally developed digital cultural resources in school curricula and regional cultural-preservation programs. Education authorities could establish quality standards covering cultural authenticity, instructional alignment, accessibility, data privacy, and community participation in the digitization of local heritage. Schools also require teacher professional development, device-sharing strategies, offline or low-bandwidth alternatives, and continuing technical support so that AR implementation does not widen inequalities between well-resourced and less-resourced settings. Collaboration with cultural practitioners, customary leaders, museums, and local government would help prevent the simplification, decontextualization, or misrepresentation of cultural knowledge. The findings may also inform digital citizenship policies by encouraging students to approach online cultural representations critically, ethically, and respectfully. However, this study does not provide direct evidence concerning problematic social-media behavior, social-media regulation, or mental-health interventions. Policy claims in those domains would require separate measurements of online conduct, digital risks, emotional well-being, and psychological outcomes. novelty of the study lies in the integration of multiple dimensions of cultural literacy within a single AR learning resource centered on Rokan Hulu Malay local wisdom. Whereas much AR research prioritizes academic achievement, motivation, performance, or technology acceptance, this study positions cultural knowledge, cultural values, identity, appreciation, and preservation as its intended educational outcomes. Methodologically, it combines an ADDIE-based development process, expert validation, two-stage practicality testing, and pretest–posttest assessment. The contribution is therefore not merely the production of an AR application but a design proposition: culturally specific three-dimensional objects become more educationally valuable when embedded in explanatory narratives and learning activities that connect visual representation with cultural meaning and preservation. The study consequently broadens the role of educational technology from delivering conventional subject matter to supporting the intergenerational transmission of local cultural heritage. It also contributes empirical evidence from an underrepresented Indonesian cultural setting, addressing

the concentration of previous AR research on STEM achievement, museums, tourism, and technology acceptance. ations constrain the interpretation and generalizability of the findings. The study involved a small, purposively selected sample from one school, lacked a control or comparison group and random assignment, and measured outcomes immediately after only four instructional sessions. Consequently, the design cannot exclude testing effects, maturation, teacher influence, technological novelty, or students' prior familiarity with Rokan Hulu Malay culture as alternative explanations for the score increase. Practicality ratings may also have been affected by social-desirability bias, while smartphone compatibility and internet access may restrict implementation in disadvantaged settings. Future research should employ controlled or quasi-experimental designs, larger multisite samples, delayed posttests, and multilevel or mixed-method analyses. Subsequent studies should also examine changes in each cultural-literacy dimension separately, compare AR with non-AR local-wisdom materials, investigate the roles of teacher scaffolding and collaborative learning, and assess accessibility, cognitive load, emotional well-being, digital identity formation, and long-term cultural-preservation behavior.

Conclusion

This study developed AR-based digital teaching materials integrating Rokan Hulu Malay local wisdom through the ADDIE model. Expert review yielded a mean Aiken's V of 0.75, while small- and large-group practicality scores were 82.50% and 82.03%, respectively. Cultural literacy scores increased significantly from pretest to posttest, with a moderate N-gain of 0.57. These findings indicate that the materials were valid, practical, and associated with meaningful improvement in cultural literacy within the participating group. The product offers an interactive and contextually grounded approach to presenting local cultural knowledge, values, identity, appreciation, and preservation. Because the study involved one school and did not include a control group, the findings should be interpreted as preliminary. Future research should test the materials with larger, more diverse samples and controlled or quasi-experimental designs and should examine longer-term retention and dimension-specific changes in cultural literacy.

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