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ANDROID-BASED AUGMENTED REALITY INFORMATION SYSTEM WITH INTERACTIVE STORYTELLING FOR BATAK TOBA TRADITIONAL HOUSE LEARNING

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Abstract: *Traditional houses represent important cultural heritage and provide opportunities for integrating local knowledge into formal education. However, explaining their architectural features and cultural significance through conventional instructional media may limit students' opportunities to explore their structures visually. To address this limitation, the Android-based augmented reality (AR) application presented traditional houses through three-dimensional visualization, accompanied by textual cultural information and audio narration to support an interactive storytelling-based learning experience. This study examined changes in students' knowledge of Batak Toba traditional houses following the use of an Android-based augmented reality (AR) application. A pre-experimental, one-group pretest–posttest design was employed with 15 students from SMAN 6 Binjai, Indonesia. Students completed a knowledge test before and after participating in the AR-based learning intervention. Descriptive statistics were used to summarize test scores, while the Wilcoxon signed-rank test was selected for the primary inferential analysis because the paired differences were non-normally distributed and many students had unchanged scores. The mean score increased from 91.33 (SD = 9.90) before the intervention to 97.33 (SD = 4.58) afterward, representing a descriptive increase of 6.00 points. Five students (33.3%) improved their scores, ten (66.7%) maintained the same scores, and none experienced a decline. However, the two-sided exact Wilcoxon signed-rank test did not reach statistical significance at the 0.05 level (p = 0.0625). The findings indicate a descriptive increase in students' scores after the intervention, although the small sample, high initial scores, and absence of a control group limit the conclusions that can be drawn. Further research involving larger samples, comparison groups, and additional learning measures is needed to evaluate the educational contribution of AR-based cultural heritage learning.*

Keyword: *augmented reality; Android application; Batak Toba traditional house; cultural heritage education; student knowledge.*

INTRODUCTION

Education plays an important role in introducing students to cultural heritage and supporting the continuity of local knowledge across generations. Cultural heritage includes not only historical objects and monuments but also traditional architecture, cultural practices, symbols, and knowledge that reflect the identity of a community. In Indonesia, traditional houses provide valuable learning resources because their architectural forms, construction elements, and spatial arrangements can be examined in relation to the cultural contexts in which they developed.

One example is the traditional house of the Batak Toba community in North Sumatra, commonly associated with the term Rumah Bolon. These houses are significant architectural and cultural expressions that can help students explore local identity, traditional building practices, and the relationship between physical structures and cultural meaning. Previous studies have examined the architectural characteristics and cultural

dimensions of Batak Toba traditional houses, demonstrating their relevance as subjects of cultural and architectural study (Hermansyah et al., 2025; Ongkojoyo & Santoso, 2023; Rambe, 2019) . Introducing this heritage in secondary education may therefore support students' understanding of the cultural environment in which they live.

Traditional houses have also been explored as subjects for mobile augmented reality applications, indicating the potential of AR technology to support the presentation of architectural and cultural information in an interactive format (Ramzy & Fachrie, 2024). Similar approaches have been applied to cultural heritage learning in Indonesia, including AR-based educational media for introducing Indonesian cultural knowledge (Sudarmilah et al., 2020).

Despite this educational potential, teaching traditional architecture can present practical challenges. Photographs, textbooks, and verbal explanations can provide useful information, but they may not always allow students to examine architectural components from different perspectives or understand the relationships among those components. When students have limited opportunities to interact with visual representations, understanding the form and structure of a traditional building may depend heavily on the teacher's explanation and the quality of available learning materials. This situation encourages educators to consider learning media that can make cultural objects more accessible and visually engaging.

Mobile augmented reality has been explored in cultural heritage settings as a means of presenting digital information and supporting interaction with heritage content. Reviews of AR applications in cultural heritage have examined their implementation, user experience, and educational potential, while also highlighting the importance of evaluating how these applications are designed and used (Şenyer & Alzatma, 2025; Silva et al., 2023).

One technology that may support this purpose is augmented reality (AR). AR combines digital information with a view of the physical environment, allowing users to interact with or observe digital content in a real-world context. In educational settings, AR can present three-dimensional objects and additional information in ways that may support visual exploration and contextual learning. A systematic review by Sakr & Abdullah (2024) examined the use of virtual and augmented reality and learning analytics across educational contexts, illustrating the continuing research interest in immersive learning technologies. Nevertheless, the educational contribution of AR depends on how the technology is designed, the learning objectives, the instructional context, and the way students use the application.

In cultural heritage education, AR has increasingly been combined with storytelling and multimedia content to present cultural information through interactive digital experiences. Research on narrative-based AR has examined how narrative elements relate to user experience and learning outcomes, suggesting that storytelling is an important design consideration in heritage-oriented AR applications (Li et al., 2025; Xu & Xie, 2026). Digital storytelling research also discusses the potential of AR and VR to support the communication and interpretation of cultural heritage through immersive and interactive experiences (Adewojo, 2025).

AR may be particularly relevant to cultural heritage education because architectural objects can be represented through digital models and supporting explanations. For example, an AR application can potentially help students observe the form of a traditional house and examine selected structural elements without requiring direct access to a physical building. Research on an AR application for historical sites among Indonesian secondary-level students has also explored the use of mobile AR for

history and cultural heritage learning (Saputro et al., 2025). Such work provides a relevant context for investigating AR as a learning medium, while also emphasizing the importance of evaluating its outcomes within specific educational settings.

Research published by authors affiliated with Universitas Pembangunan Panca Budi (UNPAB) also provides nearby Indonesian examples of interactive learning and heritage-oriented media. Hermansyah et al. (2025) developed Android-based AR learning media for recognizing historical objects at the Deli Serdang Museum, including marker detection and 3D object viewing. Ritonga et al. (2022) reported an AR Smart Board learning medium for introducing animals to early-childhood learners. These studies are relevant as examples of AR-supported object recognition and learning-media development, although their participants and content differ from the present secondary-school cultural-literacy context.

Other UNPAB-affiliated projects illustrate mobile educational multimedia and spatially interactive applications. Hermansyah et al. (2024) developed the "Cinta Mangrove" mobile environmental education application and evaluated users' knowledge using pretest–posttest scores. Alvin et al. (2025) developed a virtual-reality campus tour, while Alfahrizi et al. (2026) designed an AR GPS-based campus-building guide. The latter two studies concern VR orientation and AR navigation rather than cultural learning outcomes; they are therefore cited here as examples of interactive application development, not as direct evidence of AR's educational effectiveness.

Previous studies have applied AR to cultural learning in different settings. AR-based cultural education has been investigated through Indonesian cultural learning activities (Sudarmilah et al., 2020; Wardaya et al., 2025), while other studies have examined AR applications for historical and architectural heritage in museum and heritage environments (Chatsiopoulou et al., 2025; Lapa et al., 2025). Research on multimedia-supported museum education has also explored the integration of visual, audio, and AR-based experiences for cultural learning (Yanar et al., 2025).

However, the potential of a technology should not be treated as proof that it produces improved learning outcomes in every context. Students may begin an intervention with different levels of prior knowledge, and test scores may be influenced by the difficulty of the assessment, the learning activities, and opportunities for practice. Evaluations therefore need to examine actual student performance rather than relying only on the technological features of an application or assumptions about student engagement.

Although previous studies have investigated AR applications for cultural heritage education, reported outcomes and evaluation approaches vary across contexts. Some studies have examined learning performance, whereas others have focused on usability, engagement, or user experience (Sakr & Abdullah, 2024; Şenyer & Alzatma, 2025) . Context-specific evaluations therefore remain important for understanding how AR-based cultural learning activities relate to students' knowledge outcomes in particular educational settings.

In this context, the present study investigated an Android-based AR application for learning about Batak Toba traditional houses among students at SMAN 6 Binjai, Indonesia. The study focused on changes in knowledge test scores between the pretest and posttest. Specifically, it addressed the following research questions:

What were the students' knowledge scores before and after using the Android-based AR application?

How did individual students' scores change following the learning intervention?

Was the observed pretest–posttest difference statistically significant according to a paired nonparametric

analysis?

The study contributes a context-specific evaluation of mobile AR in cultural heritage education. Given its one-group pre-experimental design, the study is intended to describe changes observed after the intervention rather than establish that AR alone caused those changes or outperformed another teaching method.

METHODS

This study employed a pre-experimental, one-group pretest–posttest design. The same group of students completed an assessment before and after participating in a teacher-guided learning activity using the Android-based AR-Storytelling application.

The design can be represented as follows:

$$O_1 \rightarrow X \rightarrow O_2$$

Where:

O_1 represents the pretest.
X represents the learning activity using the AR-Storytelling application.
O_2 represents the posttest.

The design allowed the researchers to compare scores within the same participants. However, because no control group was included, observed score changes cannot be attributed exclusively to the application. Other explanations, including familiarity with the test questions, recall, or ordinary variation in test performance, cannot be ruled out.

Research Setting and Participants

The study was conducted at SMAN 6 Binjai, Indonesia, and involved 15 Grade XII students from one existing class. The class was used as the participant group for the learning activity.

The school was approached through a formal activity permission letter. The study was limited to this small group and was not designed to produce a representative estimate for all secondary school students. Accordingly, the findings should be interpreted in relation to the participating class rather than generalized to a broader population.

AR-Storytelling Learning Application and Intervention

The learning intervention used an Android-based AR-Storytelling application designed to introduce students to Batak Toba traditional house.

The application included the following features:

1. Three-dimensional (3D) house model: A digital 3D representation of a traditional house.
2. Model rotation and multi-angle viewing: The ability to rotate or view the model from different sides.
3. Textual information: Written information about the traditional house.
4. Image marker for AR: An image-based marker used in the augmented reality experience.
5. Audio or narration: An audio-based narrative accompanying the cultural learning content.



Figure 1 Augmented Reality Visualization of the Batak Toba Traditional House

The learning activity was conducted in one teacher-guided session lasting approximately 25 minutes. During the session, the teacher guided students in using the application to explore the 3D house model and engage with the accompanying cultural story.

The intervention was intended to

introduce students to the architectural representation and cultural context of Rumah Bolon through a combination of visualization and narrative. The study did not separately evaluate the usability of the application or measure the time students spent interacting with each individual feature.

Research Instrument

Data were collected using a 10-item multiple-choice test titled Soal Pre-Test/Post-Test Literasi Budaya Lokal. Each item provided four response options, labeled A through D, with one intended correct answer.

The questions covered several areas:

1. Traditional houses as cultural heritage.
2. The cultural and philosophical significance of Batak traditional houses.
3. The relationship between architectural philosophy and community values.
4. The importance of cultural preservation.
5. The definition of augmented reality.
6. The combination of AR and storytelling.
7. The potential educational role of interactive learning.
8. Exploring a digital representation of a traditional house alongside a cultural narrative.
9. Appropriate attitudes toward knowing, appreciating, and preserving local culture.
10. Expected knowledge and appreciation following an AR-Storytelling learning activity.

The same set of questions was used for both the pretest and posttest. Each correct answer received 10 points, and each incorrect answer received 0 points. Total scores ranged from 0 to 100.

No formal instrument validation or reliability testing was conducted before the study. Consequently, the instrument's measurement properties have not been established. In addition, because the questions assessed both cultural knowledge and understanding of AR storytelling, the total score should be interpreted as performance on the specific test rather than as a validated, comprehensive measure of local cultural literacy.

Data Collection Procedure

Data collection followed three main stages. First, permission to conduct the research activity was requested from the school through a formal letter. Second, students completed the 10-item pretest. Third, students participated in the teacher-guided AR-Storytelling activity for approximately 25 minutes and then completed the same test as a posttest.

The pretest and posttest scores were paired for each participant to examine individual changes. Using the same questions at both assessment points ensured that the score comparisons were based on identical items. However, it also introduced the possibility of a practice or recall effect, which was considered when interpreting the findings.

Data Analysis

Descriptive statistics were used to summarize the pretest and posttest scores, including the mean, standard deviation, median, minimum, and maximum. Individual score changes were calculated by subtracting each participant's pretest score from their posttest score.

The Shapiro–Wilk test was applied to the paired differences to assess whether they were consistent with a normal distribution. The test indicated a departure from normality ($W = 0.6742$, $p < .001$). Therefore, the exact two-sided Wilcoxon signed-rank test was used as the primary inferential analysis.

The significance level was set at $\alpha = .05$. The statistical result was interpreted alongside the descriptive findings, the small sample size, and the distribution of scores. Because many students already had high pretest scores, the possibility of a ceiling effect was also considered.

Ethical Considerations

Permission to conduct the research activity was requested from the school through a formal letter.

RESULT AND DISCUSSION

Descriptive Analysis of Pretest and Posttest Scores

The pretest and posttest scores of the 15 participants were analyzed to describe changes in knowledge test performance following the AR-based learning activity. The descriptive statistics are presented in Table 1.

Table 1 Descriptive statistics for pretest and posttest scores

Statistic	Pretest	Posttest
Number of students	15	15
Mean	91.33	97.33
Standard deviation	9.90	4.58
Median	90	100
Minimum	70	90
Maximum	100	100

As shown in Table 1, the mean score increased from 91.33 before the intervention to 97.33 afterward, representing a descriptive increase of 6.00 points. The median also increased, from 90 to 100. The posttest standard deviation was lower than the pretest standard deviation, indicating less variation in posttest scores within this sample.

The initial scores were already relatively high. Seven students achieved a pretest score of 100, while 11 students achieved a posttest score of 100. This pattern suggests a possible ceiling effect: students who began with the maximum score had no opportunity to demonstrate further improvement on a test capped at 100.

Individual Changes in Student Scores

The direction of change was examined for each participant. Table 2 summarizes the distribution of score changes.

Table 2 Distribution of individual score changes

Score-change category	Number of students	Percentage
Improved	5	33.3%
Unchanged	10	66.7%
Declined	0	0.0%
Total	**15**	**100.0%**

Five students improved their scores, ten maintained the same scores, and no students experienced a decline. Among the students whose scores changed, all changes were positive. The observed increases were 10, 10, 30, 20, and 20 points.

The mean paired difference, calculated as posttest minus pretest, was 6.00 points, with a standard deviation of 9.86 points. However, the median paired difference was zero because two-thirds of the participants had unchanged scores. Thus, the mean increase should be interpreted alongside the distribution of individual changes rather than as evidence that all students improved.

Normality Assessment and Wilcoxon Signed-Rank Test

The Shapiro–Wilk test indicated that the paired score differences departed from a normal distribution ($W = 0.6742$, $p < .001$). The exact two-sided Wilcoxon signed-rank test was therefore used as the primary inferential procedure.

Table 3 Statistical analysis of paired score differences

Analysis	Result
Mean paired difference	+6.00
Standard deviation of differences	9.86
Median paired difference	0
Shapiro–Wilk statistic	$W = 0.6742$
Shapiro–Wilk p-value	$p < .001$
Exact two-sided Wilcoxon signed-rank p-value	$p = .0625$
Significance level	$\alpha = .05$
Statistical decision	Not statistically

	significant

The Wilcoxon signed-rank test produced an exact two-sided p-value of .0625. Because this value exceeded the predefined significance level of .05, the result was not statistically significant.

This finding does not demonstrate that the learning activity had no educational value. Rather, the available data did not provide sufficient statistical evidence to conclude that the paired score differences differed from zero under the selected test and significance threshold. The small number of participants with nonzero differences and the high initial scores are important considerations in interpreting the result.

DISCUSSION

Changes in Students' Scores Following the Learning Activity

The descriptive results showed an increase in the mean score from 91.33 to 97.33 following the teacher-guided AR-Storytelling activity. Five of the fifteen students improved their scores, ten maintained the same scores, and no decreases were observed. These findings suggest that the posttest performance of the participating class was generally high and that some students demonstrated higher scores after the activity.

The increase should, however, be interpreted in the context of the students' initial performance. The pretest mean was already above 90, and seven students had achieved the maximum score before using the application. This left limited room for improvement among students who already answered every question correctly. The increase in the number of students scoring 100 on the posttest is consistent with this ceiling effect.

A ceiling effect can make it difficult for a test to distinguish between students with relatively high levels of knowledge. It may also reduce the ability to detect improvement when the assessment does not include sufficiently challenging items. Consequently, the high posttest mean should not be interpreted in isolation as evidence of substantial learning gains.

The use of the same assessment before and after the activity also means that students may have benefited from familiarity with the questions or recalled information from the pretest. The present design cannot separate these possible effects from changes associated with the learning experience.

AR Storytelling as a Cultural Learning Approach

The application combined a 3D representation of Batak Toba traditional house (Rumah Bolon) with a cultural narrative. This design offers a practical way to bring a digital representation of local architecture into a classroom activity. The 3D model provides a visual representation of the traditional house, while the narrative provides context for understanding its cultural significance.

This approach is consistent with the broader educational interest in using AR to present digital information in interactive and contextual ways. Sakr & Abdullah (2024) reviewed research on immersive technologies and reported potential benefits related to learner attention, understanding, and performance. Research on Batak Toba traditional houses has also highlighted the relationship between architectural forms and cultural values (Ongkojoyo & Santoso, 2023; Rambe, 2019).

The combination of visual representation and narrative is consistent with recent research on AR-based cultural heritage learning. Wardaya et al. (2025) examined AR as a tool for Indonesian cultural education using 3D models and voice narration. Li et al. (2025) investigated narrative-based AR in cultural heritage and compared narrative and non-narrative designs across learning and user-related outcomes. These studies provide relevant contexts for considering storytelling as a component of AR-supported cultural learning, although their findings should not be assumed to apply

directly to the present study.

The current study offers a context-specific example of how these areas can be brought together in a secondary school learning activity. However, it did not directly measure student engagement, motivation, usability, or the separate contribution of the 3D model and narrative. It therefore cannot determine which feature, if any, was most influential in students' performance.

The findings should consequently be understood as an initial examination of score changes following an AR-Storytelling activity, rather than definitive evidence that AR storytelling is more effective than conventional instructional methods.

Interpretation of the Statistical Findings

Although the mean score increased by 6.00 points, the exact two-sided Wilcoxon signed-rank test was not statistically significant at the .05 level ($p = .0625$). The distinction between descriptive change and statistical significance is important. An increase in a sample mean does not, by itself, establish that a consistent change exists beyond what might be observed because of sampling variation or other influences.

Only five students had nonzero differences, and all five differences were positive. The remaining ten students had zero differences. This pattern resulted in limited information for the paired inferential analysis. The high initial scores and the ceiling effect may also have restricted the range of possible changes.

The result should not be interpreted as proof of equivalence or proof that the application was ineffective. Instead, the study provides insufficient evidence to reject the null hypothesis using the selected test at the .05 significance level. A larger study with a more discriminating instrument may provide a clearer assessment of score changes.

Implications for Cultural Education

The study illustrates how an Android-based application can be incorporated into a short, teacher-guided classroom activity focused on local cultural heritage. The combination of a digital architectural representation and a cultural narrative offers an instructional format that teachers may consider when introducing traditional houses and their cultural contexts.

For educational practice, the application may serve as a supplementary learning resource rather than a replacement for teacher explanations, cultural sources, or direct engagement with local heritage. Teachers can connect the digital representation to classroom discussion, local history, community knowledge, and activities that encourage students to interpret cultural meanings.

The use of mobile AR for cultural heritage education has also been discussed in research involving participatory learning, multimedia interpretation, and digital heritage experiences (Silva et al., 2023; Yanar et al., 2025). These approaches suggest that AR may be one component of a broader cultural learning experience that includes teacher explanation, discussion, and engagement with local heritage knowledge. In the present study, however, the application was evaluated through students' test scores, and participatory engagement or cultural appreciation was not measured directly.

The findings also highlight the importance of aligning assessments with the learning objectives. A test intended to measure cultural literacy should distinguish factual recognition from broader understanding, interpretation, and appreciation of cultural heritage. Future assessment instruments could include questions requiring students to explain architectural features, interpret cultural narratives, or apply their knowledge to unfamiliar examples.

Because this study involved one class and a short intervention, its findings should be treated as preliminary. Further research is needed to establish whether similar patterns occur in other classes,

schools, and learning contexts.

LIMITATIONS

Several limitations should be considered when interpreting the findings.

First, the study involved only 15 Grade XII students from one existing class at one school. The small, context-specific sample limits the generalizability of the findings to other students and educational settings.

Second, the one-group pretest–posttest design did not include a control group. Consequently, changes in scores cannot be attributed exclusively to the AR-Storytelling application. Familiarity with the assessment, recall, teacher guidance, and other factors may have contributed to the observed results.

Reviews of AR applications in cultural heritage have considered a range of evaluation approaches, including user experience and usability measures (Şenyer & Alzatma, 2025). The present study focused on knowledge test scores and did not include separate measures of usability, motivation, engagement, or long-term retention. Future studies could combine learning assessments with these additional measures to provide a more comprehensive evaluation of AR-based cultural heritage education.

Third, the intervention lasted approximately 25 minutes in one learning session. The study therefore examined performance immediately following a short activity rather than long-term learning or knowledge retention. No delayed posttest was conducted.

Fourth, the same 10-item multiple-choice test was used for both assessments. This may have introduced practice or recall effects. In addition, the instrument was not formally validated, and no reliability analysis was conducted. Since the test included both cultural knowledge and questions about AR storytelling, it should not be treated as a validated comprehensive measure of local cultural literacy.

Fifth, the students' initial scores were already high, and seven participants achieved a pretest score of 100. This ceiling effect limited the scope for further improvement and may have reduced the sensitivity of the test to changes in students' knowledge.

Finally, the study measured test performance but did not separately assess usability, student engagement, motivation, attitudes toward cultural heritage, or the individual contribution of the 3D model and narrative. The findings therefore cannot establish the effects of the application on these outcomes.

CONCLUSION

This study examined changes in students' scores following a teacher-guided learning activity using an Android-based AR-Storytelling application focused on Batak Toba traditional house (Rumah Bolon). Among the 15 Grade XII students who participated, the mean score increased from 91.33 on the pretest to 97.33 on the posttest, representing a mean increase of 6.00 points. Five students improved their scores, ten maintained the same scores, and none experienced a decrease.

However, the exact two-sided Wilcoxon signed-rank test did not indicate a statistically significant difference at the .05 level ($p = .0625$). The results should therefore be interpreted as a descriptive increase in scores following the learning activity, not as conclusive evidence that the application caused an improvement in learning.

The findings demonstrate the feasibility of incorporating an Android-based AR-Storytelling application into a short classroom activity on local cultural heritage. They also highlight the need for more rigorous evaluation. Future studies should involve larger and more diverse samples, validated assessment instruments, comparison groups, and delayed assessments to examine learning retention. Additional measures of usability, engagement, and cultural

understanding could also provide a broader evaluation of the application's educational contribution.

Overall, this study offers an initial classroom-based examination of AR storytelling for learning about Batak Toba traditional house (Rumah Bolon). Its results provide a starting point for further research into technology-supported approaches to local cultural education while emphasizing the importance of cautious interpretation and stronger research designs.

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