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Developing STEM-Oriented augmented reality activity books integrating candi pari sidoarjo for elementary literacy and numeracy learning

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Abstract

Background: Low literacy and numeracy achievement among elementary school students remains a significant challenge in primary education. At SDN Wadungasri, students' literacy performance showed a decline based on the 2024 educational quality report.
Aims: This study aimed to develop an Augmented Reality (AR) Activity Book integrating the local wisdom of Candi Pari to strengthen students' literacy and numeracy skills through contextual and interactive learning experiences. The novelty of this study lies in combining augmented reality technology with local cultural heritage content to support elementary learning.
Method: This study employed a Research and Development approach using the ADDIE model, consisting of analysis, design, development, implementation, and evaluation stages. The product was validated by media, language, and subject-matter experts and tested on elementary school students. Data were collected through validation sheets and student response questionnaires.
Results: The findings revealed that the AR Activity Book achieved a very high feasibility level, with an average validation score of 92.1%. Student responses also indicated a highly positive perception, with a satisfaction rate of 91%. Furthermore, the AR-based activity book increased students' engagement and participation during literacy and numeracy learning activities.
Conclusion: In conclusion, the AR Activity Book based on the local wisdom of Candi Pari is feasible and potentially effective in supporting literacy and numeracy learning in elementary schools.

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INTRODUCTION

The development of 21st-century education has encouraged schools to integrate digital technology into learning processes to improve students' literacy and numeracy competencies. Literacy and numeracy are considered fundamental skills that support students' academic achievement, critical thinking, and problem-solving abilities in everyday life (Pratiwi et al., 2024). Elementary education plays an important role in strengthening these competencies because students begin developing foundational cognitive and analytical skills during this stage (Alafnan, 2025; González-Salamanca et al., 2020; Kwangmuang et al., 2021). However, literacy and numeracy achievement among elementary school students in Indonesia remains a significant educational challenge. Educational evaluation reports have shown that many students still experience difficulties in reading comprehension, interpreting information, and applying mathematical concepts in contextual situations (Gomez et al., 2021; Krawitz et al., 2022; Manfreda Kolar & Hodnik, 2021). This condition indicates that students often struggle to connect abstract learning materials with real-life experiences. Learning activities in many elementary schools are still dominated by conventional teaching approaches that focus heavily on memorization and procedural exercises. Such learning

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environments frequently reduce students' participation, curiosity, and motivation during classroom instruction. The limited use of interactive learning media also contributes to the low effectiveness of literacy and numeracy learning processes. Therefore, innovative and contextual learning approaches are needed to create more meaningful and engaging learning experiences for elementary school students.

The rapid development of digital technology has encouraged educators to adopt innovative learning media that can support active and student-centered learning environments. One educational technology that has attracted considerable attention in elementary education is Augmented Reality (AR) (Afnan et al., 2021a; Alalwan et al., 2020; Hidayat et al., 2021; Yousef, 2021). AR technology combines digital objects with real-world environments to create immersive and interactive learning experiences for students. Through AR-based learning activities, students can visualize abstract concepts more concretely and interact directly with digital representations of learning materials. Previous educational practices have shown that interactive learning environments can improve students' motivation, engagement, participation, and conceptual understanding during classroom instruction (Agwu & Nmadu, 2023; Y.-C. Chen et al., 2021; Muir et al., 2022). In literacy learning, AR technology can support storytelling activities, reading comprehension, and contextual understanding through multimedia visualization (Abdulla & Ibrahim, 2023; Danaei et al., 2020; S. Liu et al., 2024; Nurjamin et al., 2025; Şimşek & Direkçi, 2023). In numeracy learning, AR-based activities can help students understand mathematical concepts through observation, simulation, and problem-solving experiences (Auliya et al., 2026; Pujiastuti et al., 2025; Volioti et al., 2023). Interactive digital learning also encourages students to participate more actively because they become directly involved in the exploration process. In addition, AR technology has the potential to reduce learning boredom by providing more attractive and immersive classroom activities. Therefore, the integration of AR into elementary learning represents a promising strategy for improving literacy and numeracy competencies in the digital education era.

Besides technological innovation, contextual learning through local cultural integration is also important in strengthening meaningful learning experiences for elementary school students. Learning activities connected to students' cultural environments can improve contextual understanding because students are able to relate academic materials to familiar social experiences (Anyichie et al., 2023; Shadiev et al., 2020). Local wisdom-based learning also contributes to cultural preservation and character education by introducing students to the values and identity of their communities (Sakti et al., 2024; Wijayanti et al., 2025). In the context of Sidoarjo, Candi Pari represents an important cultural heritage site that contains historical, architectural, and geometrical elements relevant to literacy and numeracy learning. The architectural structures and historical narratives of Candi Pari can be utilized to create contextual learning activities that support reading comprehension, observation skills, and mathematical reasoning. However, the integration of local cultural heritage into AR-based elementary learning media remains limited. Existing learning media related to local culture generally rely on printed modules or conventional worksheets that provide less interactive learning experiences for students. As a result, literacy and numeracy learning often becomes disconnected from students' cultural environments and daily experiences. Furthermore, the 2024 educational quality report at SDN Wadungasri revealed a decline in students' literacy and numeracy achievement, particularly in interpreting information, comparing ideas across texts, and applying mathematical reasoning. Therefore, integrating AR technology with the local wisdom of Candi Pari represents a relevant and innovative approach for developing contextual, interactive, and culturally responsive learning media in elementary education.

Previous studies have demonstrated that augmented reality (AR) technology can improve learning engagement, active participation, and conceptual understanding in educational contexts, particularly in cultural heritage learning and primary education (Kleftodimos et al., 2023; Xu et al.,

2024). Several studies also reported that AR-based learning supports literacy and numeracy development through interactive and immersive learning experiences (Cahyana et al., 2023; Hendrik et al., 2026), while local wisdom integration has been recognized as an important approach for strengthening contextual and sustainability-oriented education (Lestari et al., 2024; Ramdiah et al., 2020). However, previous studies generally examined AR technology, cultural heritage education, literacy–numeracy learning, and local wisdom integration as separate domains. Limited studies have specifically developed AR-based activity books that integrate local cultural heritage with literacy and numeracy competencies in elementary education. Furthermore, the integration of local wisdom through immersive AR learning media remains underexplored in elementary classroom contexts. Therefore, this study addresses the gap by developing an Augmented Reality Activity Book based on the local wisdom of Candi Pari to support contextual, interactive, and technology-enhanced literacy and numeracy learning for elementary school students.

This study aims to develop an Augmented Reality Activity Book based on the local wisdom of Candi Pari to support literacy and numeracy learning among elementary school students. The developed learning media is designed to integrate immersive AR technology with contextual cultural content to create meaningful classroom learning experiences. This study also aims to encourage students' active participation during literacy and numeracy activities through interactive exploration and visualization features. The activity book is intended to help students improve reading comprehension, information interpretation, and mathematical reasoning skills through contextual learning tasks. In addition, the study seeks to strengthen students' understanding and appreciation of local cultural heritage through technology-enhanced learning experiences. The integration of local wisdom into AR-based learning activities is expected to create stronger connections between academic content and students' daily cultural environments. This study also aims to provide an innovative learning medium that supports student-centered learning in elementary education. Furthermore, the research evaluates the feasibility and practicality of the developed AR Activity Book through expert validation and classroom implementation. The novelty of this study lies in combining augmented reality technology with culturally contextualized activity-based learning specifically designed for literacy and numeracy instruction in elementary schools. Therefore, this study contributes to the development of interactive, contextual, and culturally responsive learning media for elementary education in the digital learning era.

LITERATURE REVIEW

Literacy and numeracy are essential competencies that support students' academic achievement, critical thinking, communication abilities, and problem-solving skills in the 21st century. Literacy is not only related to reading and writing abilities but also involves the capacity to interpret, evaluate, and communicate information effectively in various contexts (Alneyadi et al., 2023; Damaianti et al., 2020). Numeracy refers to the ability to apply mathematical understanding, reasoning, and quantitative skills in solving real-life problems. In elementary education, literacy and numeracy learning serve as foundational competencies that influence students' future academic performance and lifelong learning readiness (Grotlüschen et al., 2020). Students with strong literacy and numeracy skills tend to demonstrate better analytical thinking, decision-making abilities, and learning adaptability. However, many elementary school students still experience difficulties in understanding texts critically and applying mathematical concepts contextually. This condition often occurs because learning activities remain focused on procedural exercises rather than meaningful exploration and conceptual understanding. Effective literacy and numeracy learning requires instructional approaches that actively engage students in contextual, interactive, and student-centered learning environments (Bhardwaj et al., 2025; Ginting et al., 2024). Learning media also

play an important role in supporting students' understanding because appropriate instructional tools can make abstract concepts more concrete and meaningful. Therefore, innovative learning approaches are needed to improve literacy and numeracy achievement among elementary school students.

The integration of digital technology into education has become an important strategy for improving learning quality and student engagement. One educational technology that has gained increasing attention in elementary learning is Augmented Reality (AR) (Afnan et al., 2021b; Alalwan et al., 2020; Hidayat et al., 2021). AR technology combines virtual objects with real-world environments, allowing students to interact directly with digital information in immersive learning settings (AlGerafi et al., 2023; Serrano-Ausejo & Mårell-Olsson, 2024). In educational contexts, AR can provide visual and interactive representations of abstract concepts, thereby improving students' conceptual understanding and learning motivation (Aldeeb & Qasem, 2022; Q. Liu et al., 2023; Mokmin et al., 2024; Moser & Lewalter, 2024; Singh et al., 2024). The use of AR-based learning media has been associated with increased classroom participation, collaborative learning, and active exploration among students. AR technology also supports multisensory learning experiences because students can observe, manipulate, and explore digital objects in real time. In literacy learning, AR applications can enrich storytelling activities, reading comprehension, vocabulary development, and contextual interpretation through interactive multimedia features. In numeracy learning, AR technology can support mathematical reasoning and problem-solving activities by visualizing geometrical forms, numerical relationships, and mathematical simulations. Furthermore, immersive digital learning environments can reduce students' learning boredom and encourage more meaningful classroom interaction. Therefore, AR technology has considerable potential to become an innovative learning solution for strengthening literacy and numeracy competencies in elementary education.

Activity books are widely used in elementary education because they provide structured learning activities that encourage active student participation and independent learning. Unlike conventional worksheets, activity books are designed to combine instructional content with exploration-based tasks, observation activities, and problem-solving exercises. Activity-based learning enables students to engage directly with learning materials through interactive and hands-on experiences (Hamad & Al-Harrasi, 2026; John & Alaaraj, 2024; Kibga et al., 2022; Naik et al., 2024). In literacy learning, activity books can support reading comprehension, vocabulary development, and critical thinking through contextual reading tasks and reflective activities (Medranda-Morales et al., 2023; Sari & Prasetyo, 2021). In numeracy learning, activity books help students develop mathematical reasoning skills through exercises involving patterns, calculations, geometrical exploration, and problem-solving tasks (Seepiwsiw & Seehamongkon, 2023; Torres-Peña et al., 2025). The integration of digital technology into activity books further enhances students' learning experiences because learners can access interactive visualizations and multimedia content during learning activities. AR-based activity books allow students to combine printed instructional materials with immersive digital interactions, creating more attractive and engaging classroom environments. Such learning media also support student-centered learning because students become active participants in exploring information and completing learning tasks. Therefore, AR-based activity books represent a promising instructional medium for improving literacy and numeracy learning in elementary schools.

Contextual learning through local wisdom integration is increasingly recognized as an important approach for creating meaningful educational experiences. Local wisdom-based learning enables students to connect academic concepts with the cultural values, traditions, and social environments surrounding their daily lives (Ahmar & Azzajjad, 2025b, 2025a; Hanapi et al., 2025). The integration of cultural heritage into learning activities can also support character education and

strengthen students' appreciation of local identity. In elementary education, contextual learning environments help students understand abstract concepts more effectively because learning materials become more familiar and relevant to their experiences. One local cultural heritage site with strong educational potential is Candi Pari, which contains historical, architectural, and geometrical elements relevant to literacy and numeracy instruction (Lestari et al., 2025). The architectural structures of Candi Pari can be utilized to introduce mathematical concepts such as geometry, symmetry, measurement, and spatial reasoning. Historical narratives related to Candi Pari can also support literacy learning through reading comprehension, storytelling, observation, and interpretative activities. Integrating local cultural heritage into educational media can simultaneously strengthen students' cultural awareness and academic competencies. However, local wisdom integration in elementary learning is often implemented through conventional instructional materials that provide limited interactivity for students. Therefore, combining local wisdom with immersive AR technology offers significant opportunities for developing more engaging and contextual learning experiences in elementary education.

Several previous studies have demonstrated that AR technology can improve students' learning engagement, motivation, conceptual understanding, and classroom participation in various educational contexts. Research related to cultural heritage learning has also shown that AR applications can enhance students' cultural awareness and contextual understanding through immersive learning experiences. Other studies reported that literacy and numeracy learning can be improved through interactive digital media that encourage active exploration and collaborative learning. In addition, local wisdom-based education has been recognized as an effective approach for strengthening contextual learning and cultural identity among students. However, many previous studies examined AR technology, literacy–numeracy learning, and local wisdom integration as separate educational domains. Existing research concerning AR in elementary education often focuses on science or mathematics visualization without integrating local cultural heritage into learning activities. Similarly, studies related to local wisdom integration generally utilize printed modules or traditional instructional media rather than immersive digital technologies. Research specifically combining AR technology, activity-book-based learning, literacy and numeracy instruction, and local cultural heritage integration in elementary education remains limited. This condition indicates the need for innovative learning media that integrate immersive digital technology with contextual cultural content to support elementary learning. Therefore, the development of an Augmented Reality Activity Book based on the local wisdom of Candi Pari represents an innovative contribution to literacy and numeracy learning in elementary education.

METHOD

Research Design

This study employed a Research and Development (R&D) approach aimed at developing an Augmented Reality (AR) Activity Book integrated with the local wisdom of Candi Pari to support literacy and numeracy learning among elementary school students. The development process focused on creating valid, practical, and effective instructional media for descriptive text literacy learning and numeracy competencies in three-dimensional shapes, scale, and data presentation. The development model used in this study was the ADDIE model, which consists of five stages: Analysis, Design, Development, Implementation, and Evaluation. The ADDIE model was selected because it provides a logical, systematic, and flexible framework for developing technology-based instructional media. In addition, the model allows continuous evaluation at every stage of development to improve product quality progressively. During the analysis stage, the researchers identified literacy and numeracy learning problems, student characteristics, curriculum requirements, and the relevance of

ethnomathematics content derived from Candi Pari. The design stage focused on preparing learning objectives, AR activity book storylines, visual elements, literacy and numeracy missions, AR integration, and evaluation instruments. The development stage involved transforming the design into an interactive AR-based activity book equipped with three-dimensional visualizations and ethnomathematics content from Candi Pari. The implementation stage involved pilot testing with elementary school students in real classroom learning situations to identify the practicality and effectiveness of the media. The evaluation stage included formative and summative evaluations conducted continuously throughout the development process to ensure that the developed product met validity, practicality, and feasibility criteria. The process of developing instructional materials in this study followed the ADDIE model systematically, as illustrated in Figure 1.

Figure 1. *The ADDIE Model*

Participants

The participants in this study consisted of media experts, content experts, language experts, teachers, and elementary school students. The research was conducted at SDN Wadungasri Waru Sidoarjo, Indonesia, because the school experienced declining literacy and numeracy achievement based on the 2024 educational quality report. The student participants involved in the pilot testing were sixth-grade elementary school students selected purposively according to the characteristics of the intended users of the developed learning media. The pilot testing was conducted on a small scale involving approximately 10–15 students to evaluate the readability, usability, and practicality of the AR Activity Book from the students' perspective. Media experts participated in evaluating visual presentation, AR functionality, interactivity, and gamification elements embedded in the developed media. Content experts assessed the relevance of literacy and numeracy materials, the integration of ethnomathematics concepts, and the suitability of learning content for elementary education. Language experts evaluated readability, clarity, language appropriateness, and communication effectiveness within the instructional materials. Teachers were also involved in providing feedback regarding classroom implementation, student participation, and instructional suitability of the developed media. The involvement of multiple participant groups was intended to ensure the validity, feasibility, practicality, and educational appropriateness of the AR Activity Book. Therefore, the participants contributed comprehensive information regarding the strengths, weaknesses, and implementation quality of the developed learning media.

Instruments

The data collection methods used in this study aimed to obtain comprehensive information regarding learning needs, product development processes, and user responses toward the AR

Activity Book. Data collection techniques included questionnaires, interviews, observations, documentation, and expert validation sheets. The questionnaire served as the primary data collection instrument and was administered to teachers and students systematically to collect measurable responses regarding learning needs and media practicality. The questionnaires used in this study consisted of a needs analysis questionnaire, student response questionnaire, and teacher response questionnaire. Interviews were conducted using semi-structured techniques involving teachers and several students to obtain deeper information and validate questionnaire findings. Observations were carried out during classroom implementation to examine student participation, interactions with the AR Activity Book, learning engagement, and teacher facilitation during instructional activities. Documentation was utilized to collect supporting information related to learning implementation, research administration, instructional materials, and classroom activities. Research instruments consisted of observation sheets, questionnaires, and expert validation sheets designed according to research indicators and tested for validity and reliability to ensure scientifically accountable data collection. The expert validation sheets were used by media experts, content experts, and language experts to assess instructional quality, AR integration, language appropriateness, and ethnomathematics content suitability. Validation results and participant responses were utilized as the basis for revising and improving the developed learning media before implementation in classroom instruction.

Data Analysis

Data analysis techniques in this study were conducted using quantitative and qualitative approaches to evaluate the feasibility and practicality of the AR Activity Book integrated with the local wisdom of Candi Pari. Quantitative data were obtained from expert validation results, teacher response questionnaires, and student response questionnaires. The questionnaires employed a four-point Likert scale consisting of Strongly Agree, Agree, Disagree, and Strongly Disagree categories. Each response category was assigned a numerical score to measure the level of feasibility and practicality of the developed learning media systematically. The scoring categories used in this study are presented in Table 1.

Table 1. Likert Scale

Category	Scale
Completely Agree	4
Agree	3
Disagree	2
Totally Disagree	1

The questionnaire data were analyzed by calculating the total score obtained for each assessment item and converting the results into percentages. The percentage calculation formula used in this study is presented as follows:

$$P = \frac{\Sigma \mathcal{X}}{\Sigma \mathcal{X}i} \times 100\%$$

Description:

- P = Eligibility percentage
- $\Sigma \mathcal{X}$ = Total score of validator responses (actual score)
- $\Sigma \mathcal{X}i$ = Total score of highest-scoring answers (expected score)

The resulting percentages were interpreted according to instructional material validation criteria presented in Table 2.

Table 2. Validation Criteria

Percentage (%)	Eligibility Criteria

81% – 100%	Very Suitable
61% – 80%	Suitable
41% – 60%	Quite Decent
21% – 40%	Not Suitable
0% – 20%	Unsuitable

Learning materials were considered suitable for implementation if they achieved a minimum score of 85% within the suitable category. If the results fell below the acceptable category, revisions and improvements were conducted before classroom implementation. Qualitative data were collected through observations, interviews, expert feedback, recommendations, and participant comments regarding the developed media. Qualitative data analysis followed the interactive model consisting of data reduction, data presentation, and conclusion drawing to identify patterns, strengths, weaknesses, and implementation findings related to the AR Activity Book.

Procedure

The research procedure in this study followed the five stages of the ADDIE development model systematically. The first stage was analysis, which involved identifying literacy and numeracy learning problems, analyzing student characteristics, evaluating curriculum requirements, and examining the relevance of ethnomathematics content from Candi Pari for elementary education. During this stage, the researchers also conducted needs analysis related to descriptive texts, three-dimensional shapes, scale, and data presentation learning materials suitable for integration into the AR Activity Book. The second stage was design, which focused on developing learning objectives, instructional indicators, storylines, AR visualization concepts, literacy and numeracy missions, evaluation instruments, and visual elements highlighting Candi Pari cultural characteristics. The third stage was development, where the designed product was transformed into an interactive AR Activity Book equipped with three-dimensional AR visualizations and contextual ethnomathematics content. At this stage, the product underwent validation by media experts, content experts, and language experts to evaluate instructional quality, usability, and content suitability. Suggestions and recommendations from validators were used as the basis for revising and improving the developed media. The fourth stage was implementation, which involved conducting pilot testing with sixth-grade elementary school students in classroom learning activities. During implementation, students interacted directly with the AR Activity Book while teachers facilitated literacy and numeracy learning activities related to descriptive texts, geometry, scale, and data presentation. The final stage was evaluation, which consisted of formative and summative evaluations conducted to assess the validity, practicality, and feasibility of the developed instructional media comprehensively. Therefore, the systematic ADDIE procedure enabled the researchers to develop contextual, interactive, and technology-enhanced learning media suitable for elementary literacy and numeracy education.

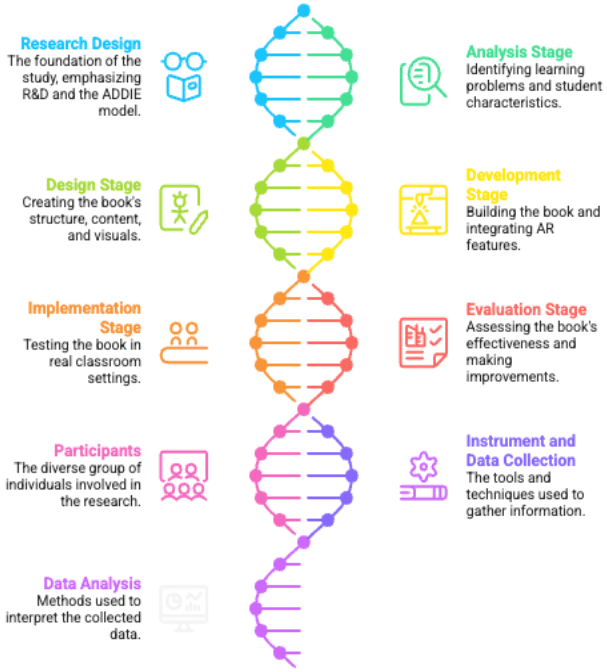


Figure 2. Research Method Flow

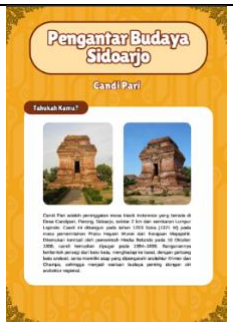
RESULTS AND DISCUSSION

Results

Development of the Augmented Reality Activity Book

The development process resulted in an Augmented Reality (AR) Activity Book integrated with the local wisdom of Candi Pari to support literacy and numeracy learning among elementary school students. The activity book was designed to combine contextual cultural content, literacy activities, numeracy exercises, and immersive AR-based visualization into a single instructional medium. The developed product introduced students to the historical background, architectural characteristics, and cultural significance of Candi Pari through illustrations, descriptive texts, and interactive multimedia elements. In addition, the activity book integrated geometrical concepts derived from the temple structure, including two-dimensional shapes, three-dimensional forms, scale, symmetry, and spatial reasoning activities. The AR feature was implemented using QR codes embedded within the activity book pages, enabling students to access three-dimensional visualizations of Candi Pari through smartphone devices. When the QR codes were scanned, students were able to observe realistic AR representations of the temple structure interactively. The activity book also contained literacy-based tasks requiring students to read information texts, interpret descriptions, and answer comprehension questions related to Candi Pari. Numeracy activities involved contextual mathematical exercises requiring students to identify geometrical patterns, calculate measurements, and solve spatial reasoning problems derived from the temple structure. The integration of local cultural heritage with AR technology was intended to create contextual and engaging learning experiences that support elementary literacy and numeracy competencies. The developed product therefore combined cultural learning, immersive technology, and activity-based instruction within a single learning medium suitable for elementary education contexts.

Table 3. *Features of the Augmented Reality Activity Book*

Feature	Description	Figure
Historical Introduction	Provides information regarding the history, architecture, and cultural significance of Candi Pari	
Geometrical Integration	Introduces geometrical concepts found in the structure of Candi Pari	
AR Technology	Utilizes QR-code-based AR visualization accessible through smartphones	
Interactive Visualization	Displays three-dimensional representations of Candi Pari	
Literacy Activities	Includes reading comprehension and descriptive text interpretation tasks	

Numeracy Activities	Includes geometry, scale, and measurement problem-solving exercises	

Product Validation Results

The developed AR Activity Book underwent expert validation involving language experts, content experts, and media experts to evaluate its feasibility, instructional suitability, readability, and technological functionality. The language expert validation yielded a percentage score of 89.33%, indicating that the language structure, readability, instructional clarity, and sentence construction were appropriate for elementary school students. The content expert validation produced a score of 91%, demonstrating that the literacy and numeracy materials, ethnomathematics integration, and curriculum alignment were highly suitable for elementary learning objectives. Meanwhile, the media expert validation generated the highest score of 96%, indicating that the visual appearance, layout organization, AR integration, and interactive media features effectively supported elementary classroom instruction. The overall average validation result reached 92.1%, placing the developed product within the "highly feasible" category. These findings indicate that the AR Activity Book fulfilled pedagogical, linguistic, visual, and technological quality standards required for instructional implementation. The high media validation score suggests that the AR visualization and multimedia integration successfully created attractive and interactive learning environments for students. Furthermore, the validation results demonstrate that integrating local cultural heritage into AR-based instructional media is pedagogically relevant and technologically feasible for elementary education contexts. Although the product achieved highly feasible criteria, several recommendations were provided by validators regarding optimization of AR scanning sensitivity and refinement of several instructional components before wider classroom implementation. Therefore, expert validation confirmed that the developed AR Activity Book was appropriate for limited classroom implementation and further instructional evaluation.

Table 4. Product Validation Results

No.	Validator	Validation Percentage	Criteria
1	Language Expert	89.33%	Highly Feasible
2	Content Expert	91%	Highly Feasible
3	Media Expert	96%	Highly Feasible
Average		**92.1%**	**Highly Feasible**

Table 5. Product Validation Comparison

Validation Aspect	Percentage
Language Validation	89.33%
Content Validation	91%
Media Validation	96%

Limited Trial Results

The implementation of the AR Activity Book in limited classroom trials demonstrated positive responses from elementary school students regarding usability, engagement, literacy–numeracy support, and AR interactivity. The limited trial involved sixth-grade elementary school students who interacted directly with the AR-based learning media during literacy and numeracy

learning activities. The overall practicality score obtained from the limited trial reached 91%, indicating that students responded positively toward the developed instructional media. The highest score was observed in the AR interactivity aspect, suggesting that students found the immersive visualization features attractive and easy to use during classroom learning. Students were able to independently scan QR codes and interact with three-dimensional visualizations of Candi Pari using smartphone devices. This interactivity reduced students' dependence on teacher explanations because students could directly observe visual representations of geometrical structures and cultural objects. Literacy activities encouraged students to read descriptive texts, interpret contextual information, and answer reading comprehension questions related to Candi Pari. Numeracy activities required students to identify geometrical shapes, analyze measurements, and solve contextual mathematical problems derived from the temple structure. Observation results further indicated that students demonstrated higher participation, curiosity, and classroom engagement during AR-based learning sessions compared to conventional learning activities. However, several technical limitations were identified, including AR scanning sensitivity and device compatibility issues affecting visualization stability for some students. Therefore, the limited trial results indicate that the AR Activity Book has strong potential to support interactive and contextual literacy–numeracy learning in elementary schools.

Table 6. Summary of Limited Trial Results

No.	Assessment Criteria	Number of Items	Score	Maximum Score
1	Ease of Use of Media	5	21	25
2	Engagement and Learning Motivation	5	23	25
3	Literacy and Numeracy Support	5	23	25
4	AR Interactivity	5	24	25
	Total	**20**	**91**	**100**

$P = \frac{\Sigma \mathcal{X}}{\Sigma \mathcal{X} i}$ x 100%

$P = \frac{91}{100}$ x 100%

P = 91%

Table 6. Limited Trial Assessment Results

No	Assessment Aspect	Percentage
1	Ease of Use	84%
2	Engagement and Motivation	92%
3	Literacy and Numeracy Support	92%
4	AR Interactivity	96%

Student Response Results

Student response analysis demonstrated that the AR Activity Book was perceived positively in terms of attractiveness, usability, learning motivation, AR interactivity, and literacy–numeracy support. The overall student response score reached 93%, indicating a highly positive perception toward the developed learning media. Students reported that the combination of illustrations, colors, AR visualizations, and contextual cultural content increased their interest and curiosity during classroom learning activities. The AR-based three-dimensional representations enabled students to interact directly with visual learning objects, thereby improving learning engagement and attention. Students also indicated that the literacy activities helped them better understand descriptive texts related to Candi Pari because the learning materials were connected to real cultural objects. In numeracy learning, students found it easier to identify geometrical forms and solve mathematical problems through contextual AR-based visualization. The contextual integration of local cultural

heritage also strengthened students' understanding of their surrounding cultural environment. Observation findings further indicated that students became more active during classroom discussions, exploration activities, and problem-solving sessions. However, some students required additional adaptation time to operate AR scanning features effectively. Overall, student responses indicate that the developed AR Activity Book successfully created attractive, interactive, and contextual learning experiences supporting literacy and numeracy learning in elementary schools.

Table 7. Summary of Student Response Scores

No.	Assessment Criteria	Number of Items	Score	Maximum Score
1	Media Attractiveness	4	19	20
2	Ease of Use	4	18	20
3	AR Interactivity	4	19	20
4	Learning Motivation	4	18	20
5	Literacy and Numeracy Understanding	4	19	20
	Total	20	93	100

$P = \frac{93}{100} \times 100\%$
$P = 93\%$

Facilitator Response Results

Facilitator responses demonstrated that the AR Activity Book was considered highly practical, relevant, and supportive of literacy and numeracy instruction in elementary classrooms. The facilitators evaluated the media positively in terms of usability, AR interactivity, contextual learning integration, and student engagement. The overall facilitator response score reached 93%, indicating that the developed media was highly appropriate for classroom implementation. Facilitators reported that AR visualization simplified the explanation of geometrical concepts and descriptive literacy materials because students could directly observe three-dimensional representations of Candi Pari structures. The integration of local cultural content was also considered effective in strengthening students' contextual understanding and cultural awareness. Facilitators observed that students became more active in asking questions, exploring learning materials, and participating in classroom activities during AR-based instruction. Furthermore, the activity-based learning approach encouraged student-centered learning environments where students explored information independently through interactive media. Despite these positive findings, facilitators highlighted several technical limitations related to internet stability, smartphone quality, and AR scanning sensitivity. Facilitators also recommended adding more varied literacy and numeracy exercises to strengthen instructional effectiveness beyond motivational aspects. Therefore, facilitator responses indicate that the AR Activity Book possesses strong pedagogical potential for contextual and technology-enhanced literacy–numeracy learning in elementary education.

Table 8. Summary of Facilitator Response Scores

No.	Assessment Criteria	Number of Items	Score	Maximum Score
1	Ease of Media Use	4	18	20
2	Material Relevance	4	19	20
3	AR Media Interactivity	4	19	20
4	Student Motivation and Engagement	4	18	20
5	Media Attractiveness	4	19	20
	Total	**20**	**93**	**100**

$P = \frac{93}{100} \times 100\%$
$P = 93\%$

Discussion

The findings of this study demonstrate that the Augmented Reality (AR) Activity Book integrated with the local wisdom of Candi Pari possesses strong pedagogical potential for supporting literacy and numeracy learning in elementary education. The high validation scores obtained from language experts, content experts, and media experts indicate that the developed learning media fulfilled important instructional quality standards, including content relevance, readability, visual attractiveness, and technological functionality. The overall validation score of 92.1% suggests that integrating AR technology with contextual cultural content can produce highly feasible instructional media for elementary school students. The highest validation score was observed in the media aspect, indicating that AR visualization and interactive features were highly compatible with elementary students' learning characteristics. This finding aligns with previous studies reporting that AR-based instructional media can increase learning attractiveness and improve user engagement through immersive visualization and interactive multimedia environments (AlGerafi et al., 2023; Alhazzaa & Yan, 2025; Ji et al., 2025). Previous research concerning AR in elementary education also found that students tend to demonstrate higher motivation and participation when learning activities involve digital interaction and visual exploration. In the present study, students interacted directly with three-dimensional representations of Candi Pari, allowing them to explore geometrical structures and literacy materials more concretely than conventional printed materials. This condition supports constructivist learning theory, which emphasizes that meaningful learning occurs when students actively construct knowledge through direct interaction with learning resources. Compared to traditional worksheets, the AR Activity Book created more student-centered learning experiences because learners became active participants in observing, interpreting, and solving contextual literacy and numeracy tasks. Therefore, the validation findings indicate that combining immersive AR technology with local cultural heritage can create instructional media that are pedagogically, visually, and technologically appropriate for elementary education contexts.

The limited trial results further demonstrate that the AR Activity Book positively influenced students' learning engagement, participation, and classroom interaction during literacy and numeracy activities. The practicality score of 91% indicates that students perceived the learning media as easy to use, interactive, and supportive of contextual learning experiences. Students showed enthusiasm when interacting with the AR features because the visualization enabled them to observe cultural objects and geometrical structures in more realistic forms. This finding is consistent with previous studies showing that AR-based learning environments improve students' attention and reduce learning boredom through interactive visualization (Mokmin et al., 2024). Earlier studies in mathematics and science learning also reported that AR technology supports students' conceptual understanding by transforming abstract concepts into observable digital representations (Coștu, 2025; Q. Liu et al., 2023; Mansour et al., 2025; Sofroniou, 2025; Zoya et al., 2026). In the present study, students were able to identify geometrical patterns, calculate measurements, and analyze spatial structures directly from the AR representation of Candi Pari. The contextual visualization helped students connect mathematical concepts with real-world cultural objects, thereby improving the meaningfulness of learning activities. In literacy learning, students interacted with descriptive texts related to Candi Pari while simultaneously observing AR-based visual representations, which supported reading comprehension and contextual interpretation. Similar findings from previous studies suggested that combining text-based instruction with multimedia visualization can strengthen literacy comprehension and information retention among elementary students.

Therefore, the implementation results indicate that AR-based contextual learning media can support active learning processes and improve students' engagement in literacy and numeracy instruction.

Another important finding of this study concerns the integration of local cultural heritage into literacy and numeracy learning activities. The incorporation of Candi Pari as the main contextual learning content enabled students to connect academic materials with familiar cultural environments. This contextual integration contributed to students' cultural awareness while simultaneously strengthening literacy and numeracy competencies. Previous studies regarding culturally responsive learning emphasized that contextual learning environments can improve students' understanding because learning materials become more relevant to their social and cultural experiences. In the present study, the use of Candi Pari narratives, geometrical structures, and historical information created authentic learning situations that encouraged students to explore cultural heritage while completing literacy and numeracy tasks. This finding supports earlier studies indicating that local wisdom integration can improve student motivation and strengthen meaningful learning experiences in elementary education. However, unlike many previous studies that relied mainly on printed modules or conventional worksheets, this study integrated local cultural content with immersive AR technology (Lim & Lee, 2025). The AR visualization enabled students to observe cultural objects dynamically, thereby increasing learning interactivity and contextual understanding simultaneously. Furthermore, the integration of ethnomathematics concepts derived from the structure of Candi Pari provided students with opportunities to learn mathematical reasoning through authentic cultural contexts. Therefore, the findings suggest that combining local wisdom with immersive digital technology can simultaneously strengthen academic learning, contextual understanding, and cultural appreciation among elementary school students.

The positive student and facilitator responses observed in this study also indicate that AR-based learning media can support student-centered and exploratory learning environments. Students reported that the AR Activity Book was attractive, interactive, and enjoyable because it allowed them to participate actively in literacy and numeracy activities. Facilitators similarly observed that students became more independent during classroom instruction because they could explore learning materials directly through AR visualization. These findings are consistent with previous studies demonstrating that AR technology encourages inquiry-based learning and increases students' exploratory behavior in educational contexts (C.-H. Chen & Chu, 2024; F. Chen & Chen, 2025; Liao et al., 2025; Lin et al., 2023; Pedaste et al., 2020; Wen et al., 2023, 2024). In the present study, students did not merely receive information passively from teachers but instead actively interacted with digital representations, contextual tasks, and problem-solving activities. The AR feature therefore functioned not only as a visual attraction but also as a cognitive support tool facilitating conceptual understanding and independent exploration. Earlier research also suggested that immersive learning environments improve collaborative learning because students become more engaged in discussion and knowledge-sharing activities. Similar conditions were observed during the implementation stage, where students demonstrated greater enthusiasm in discussing geometrical structures, historical narratives, and literacy tasks related to Candi Pari. Nevertheless, facilitators identified several technical limitations associated with smartphone quality, internet stability, and AR scanning sensitivity. These findings indicate that although AR technology offers significant pedagogical benefits, technological readiness and infrastructure remain important considerations for successful classroom implementation. Therefore, future AR-based learning development should focus not only on instructional quality but also on technological accessibility and implementation stability across diverse educational environments.

Despite the positive findings, this study has several limitations that should be considered in interpreting the results and planning future research. First, the effectiveness of the AR Activity Book was primarily evaluated through expert validation, observational findings, and participant

perceptions rather than objective measurements of literacy and numeracy achievement. Although students and facilitators reported positive learning experiences, the study did not comprehensively examine learning gains through experimental pre-test and post-test designs. Previous studies investigating AR-based learning effectiveness often utilized quasi-experimental methods to measure cognitive improvement quantitatively, suggesting that future studies should adopt similar approaches to strengthen empirical evidence regarding learning outcomes. Second, the implementation stage was conducted on a limited scale involving a relatively small number of participants, which may limit the generalizability of the findings to broader educational contexts. Third, several technical constraints related to AR scanning sensitivity and device compatibility affected the stability of visualization during implementation. Similar technical limitations have also been identified in previous AR-based educational studies, particularly in schools with limited technological infrastructure. Nevertheless, the present study contributes important findings regarding the integration of AR technology, local wisdom, literacy instruction, and numeracy learning within a single instructional medium for elementary education. The study also extends previous research by demonstrating that cultural heritage sites such as Candi Pari can function not only as historical learning objects but also as contextual sources for literacy and numeracy learning activities. Furthermore, the combination of ethnomathematics concepts, immersive visualization, and activity-based instruction provides a novel contribution to technology-enhanced contextual learning in elementary schools. Therefore, future research should expand implementation contexts, improve technological stability, and investigate the long-term effects of AR-based culturally responsive learning media on students' literacy, numeracy, and cultural understanding.

Implications

The findings of this study have important implications for the development of technology-enhanced and culturally responsive learning media in elementary education. The successful integration of Augmented Reality (AR) technology with the local wisdom of Candi Pari demonstrates that contextual digital learning media can support literacy and numeracy learning more interactively and meaningfully. This study indicates that immersive visualization and activity-based instruction can improve students' engagement, participation, and motivation during classroom learning activities. The integration of local cultural heritage into literacy and numeracy instruction also contributes to strengthening students' contextual understanding and cultural awareness simultaneously. From a pedagogical perspective, the AR Activity Book supports student-centered learning by encouraging students to explore information independently through interactive and exploratory activities. The findings further suggest that ethnomathematics and culturally contextualized literacy materials can make abstract academic concepts more concrete and relevant to students' real-life experiences. In addition, the implementation of AR-based learning media provides opportunities for teachers to create more innovative and collaborative classroom environments that support active learning processes. This study also contributes to the growing discourse regarding the integration of digital technology and local wisdom in elementary education, particularly within literacy and numeracy learning contexts. From a practical perspective, the developed AR Activity Book may serve as an alternative instructional medium for schools seeking to integrate immersive technology into classroom learning without eliminating local cultural identity. The findings additionally imply that educational institutions should consider technological readiness, device accessibility, and teacher digital competence as important factors in implementing AR-based learning successfully. Furthermore, this study provides a foundation for future educational innovation involving the integration of augmented reality, ethnomathematics, literacy instruction, and contextual cultural learning within a unified instructional framework. Therefore, the present study contributes not only to the advancement of technology-based elementary learning media but

also to the promotion of culturally meaningful and contextually relevant education in the digital learning era.

Limitations and Suggestions for Future Research

This study has several limitations that should be considered when interpreting the findings and planning future research. First, the implementation of the Augmented Reality (AR) Activity Book was conducted on a limited scale involving a relatively small number of sixth-grade elementary school students, which may restrict the generalizability of the findings to broader educational contexts. Second, the evaluation of learning effectiveness primarily relied on expert validation, observation results, and perception-based responses from students and facilitators rather than objective measurements of literacy and numeracy achievement. Although the findings demonstrated positive responses regarding engagement, motivation, and interactivity, the study did not comprehensively measure students' cognitive improvement using experimental pre-test and post-test designs. Third, several technical limitations related to smartphone quality, internet stability, and AR scanning sensitivity affected the consistency of visualization performance during classroom implementation. These technical constraints indicate that the effectiveness of AR-based learning media remains highly dependent on technological infrastructure and device compatibility within school environments. In addition, the literacy and numeracy activities developed in this study were limited to descriptive texts, geometry, scale, and data presentation, indicating opportunities for broader content integration in future developments. The implementation period was also relatively short, making it difficult to examine the long-term effects of AR-based contextual learning on students' academic achievement and cultural understanding. Future research is therefore recommended to employ larger participant samples and experimental research designs to examine the effectiveness of AR Activity Books more objectively and comprehensively. Further studies should also investigate the long-term impact of immersive and culturally responsive learning media on literacy development, numeracy achievement, critical thinking skills, and student motivation. In addition, future researchers are encouraged to improve AR system stability, optimize device accessibility, and integrate more varied literacy and numeracy activities to strengthen instructional effectiveness across diverse educational settings. Future developments may also explore the integration of other local cultural heritage contexts into AR-based learning media to support culturally responsive and contextually meaningful elementary education. Therefore, continued research and technological refinement are necessary to maximize the educational potential of AR-based contextual learning media in elementary schools.

CONCLUSION

This study successfully developed an Augmented Reality (AR) Activity Book integrated with the local wisdom of Candi Pari to support literacy and numeracy learning among elementary school students. The developed learning media combined contextual cultural content, literacy activities, numeracy exercises, and immersive AR visualization within a single instructional framework. The findings demonstrated that the AR Activity Book fulfilled important instructional quality standards based on validation conducted by language experts, content experts, and media experts. The overall validation score of 92.1% indicated that the developed product was highly feasible in terms of language clarity, content relevance, visual presentation, and technological functionality. The implementation results further revealed that students responded positively to the AR-based learning media, particularly regarding interactivity, engagement, learning motivation, and contextual understanding. Students were able to interact directly with three-dimensional visualizations of Candi Pari while simultaneously participating in literacy and numeracy learning activities. The integration of local cultural heritage into AR-based learning successfully created more meaningful and culturally

responsive learning experiences for elementary school students. In addition, the use of AR technology contributed to increased classroom participation, exploratory learning behavior, and student-centered learning activities during implementation. Facilitator responses also confirmed that the developed media supported instructional delivery and helped students understand literacy and numeracy concepts more concretely through interactive visualization. The findings indicate that combining immersive technology with contextual cultural content can strengthen literacy and numeracy learning in elementary education. Although several technical limitations related to AR scanning sensitivity and device compatibility were identified, the developed media still demonstrated strong potential as an innovative instructional tool for elementary classrooms. Therefore, this study concludes that the AR Activity Book integrated with the local wisdom of Candi Pari represents a promising approach for developing interactive, contextual, and culturally responsive literacy and numeracy learning media in the digital education era.

AUTHOR CONTRIBUTIONS STATEMENT

Azis Farkhan was responsible for the research conceptualization, development of the Augmented Reality (AR) Activity Book, integration of STEM-oriented and local wisdom-based learning content, classroom implementation, data collection, and drafting of the manuscript. Agung Pramujiono contributed to research supervision, methodological validation, instructional design evaluation, interpretation of the research findings, and critical revision of the manuscript. Via Yustitia contributed to the development of literacy and numeracy learning activities, validation of instructional materials, analysis and triangulation of qualitative and quantitative data, and refinement of the AR-based learning media. All authors participated in the development of the theoretical framework, evaluation of the learning media, interpretation of research results, and final manuscript review. All authors actively discussed the findings, approved the final version of the manuscript, and agreed to be accountable for all aspects of the research.

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