



Development of augmented reality flashcards on cultural diversity to improve elementary students' learning outcomes

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Abstract: This research aims to develop, assess the feasibility, and test the effectiveness of Augmented Reality-based Flashcards on cultural diversity to improve elementary school students' learning outcomes. The research method used is Research and Development (R&D) using the Borg & Gall development model. The subjects of this research were fourth-grade students at Bringin 02 Semarang Elementary School. Data collection techniques included interviews, observations, questionnaires, tests, and documentation, which were conducted in November 2025. The research instruments consisted of interviews, documentation, needs and response questionnaires, pretest and posttest questions, and expert validation sheets. The pretest and posttest trial questions were analyzed using validity, reliability, item difficulty index, and item discrimination index calculations. Data analysis was performed using normality tests, T-tests, and N-gain tests. The results of this research include the creation of a feasible and effective augmented reality-based flashcard medium to improve fourth-grade students' learning outcomes in Natural and Social Sciences, specifically on Indonesian cultural diversity at Bringin 02 Elementary School. Therefore, this medium can be recommended as an innovative learning alternative for elementary schools to support interactive, meaningful learning in Natural and Social Sciences.

Keywords: AR-based flashcard, learning outcomes, natural and social sciences, educational medium

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Introduction

Education is a fundamental aspect of human life, as it contributes significantly to the development of regions, nations and societies at large (Fau et al., 2023). At the elementary level, it plays a crucial role in shaping students' growth during their early stages of development (Khotimah & Safirah, 2023). In Indonesia, Law Number 20 of 2003 on the National Education System defines education as a deliberate and systematic effort to create learning processes that enable students to actively develop their potential. To achieve this goal, education must be supported by careful planning and systematic implementation, particularly in fostering students' mastery of essential skills. In this context, science and technology have become integral to educational practices. The integration of technology offers various advantages, including facilitating more effective and accessible learning processes, such as through augmented reality (Czok & Weitzel, 2025). Moreover, Windiyani et al. (2025) explain that students today learn in environments increasingly shaped by technology. Therefore, educators, particularly teachers, are expected to adopt innovative and creative approaches, especially in utilizing learning media, to better address students' learning needs (Lindell & Stöhr, 2025).

In the Indonesian context, the integration of technology in education is accompanied by ongoing curriculum developments, including the merger of Natural Sciences (IPA) and Social Sciences (IPS) into Integrated Natural and Social Sciences (IPAS) at the elementary level. This policy continues to generate debate; however, Saputra et al. (2023) argue that IPAS can support students in developing critical thinking skills, particularly in solving problems related to their environment. Within the IPAS curriculum, one key topic is Indonesia's cultural diversity. Riyadi et al. (2024) define diversity as a

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social condition characterized by differences in religion, ethnicity, race and social groups. Meanwhile, culture refers to patterns of human activity and ways of life that develop over time and are passed down across generations (Lintang & Najicha, 2022). Therefore, cultural diversity in Indonesia reflects the wide range of differences in customs, local languages, religions, arts, traditional clothing and ways of life across regions (Sudirman et al., 2025). Despite the importance of cultural diversity as a key topic in IPAS learning, its implementation in the classroom still faces several challenges.

Based on initial observations at Bringin 02 Elementary School, several problems in the learning process were identified through interviews with fourth-grade teachers and direct classroom observation. Students demonstrated difficulty understanding materials on Indonesian cultural diversity, particularly in identifying cultural elements such as traditional houses, clothing, regional dances, musical instruments, songs, and local foods across different islands. These difficulties were reflected in students' learning outcomes, where a considerable number failed to meet the minimum passing criterion (KKM) of 75. Furthermore, the absence of varied and engaging learning media was evident, as teachers relied primarily on government-issued textbooks and occasional PowerPoint slides. Given that today's students are digital natives who are familiar with smartphones and other technologies, the lack of technology-based media limits their access to interactive learning experiences and contributes to low motivation and passive participation. However, technology-based media have not yet been effectively implemented in the classroom, which can lead to student disengagement. This situation highlights an urgent need for the development of innovative, technology-integrated learning media that can bridge the gap between abstract cultural content and students' concrete understanding.

To address these challenges, the researcher developed an interactive, technology-based learning medium aligned with contemporary educational needs by integrating augmented reality into a flashcard-based format. Putri and Sofyan (2020) define interactive learning media as multimedia tools that facilitate two-way communication between the system and learners, thereby simplifying the learning process and providing practical solutions aligned with 21st-century learning needs. The developed medium takes the form of augmented reality-based flashcards covering Indonesia's cultural diversity across six major islands, including Java, Sumatra, Kalimantan, Sulawesi, Bali and Papua. When scanned using a mobile device, each flashcard displays 3D animated content, including traditional houses, clothing, dances, musical instruments, regional songs and local foods (Rachmawati & Lestari, 2025). Through this medium, students are expected to gain more interactive and meaningful learning experiences that support both cognitive understanding and affective engagement. In turn, these experiences are expected to improve their learning outcomes in IPAS, particularly in understanding, appreciating and valuing Indonesia's cultural diversity.

Several researchers have examined the development of augmented reality-based flashcards and technology-based learning media at the elementary level. Ananta and Isdaryanti (2025) developed a QR-embedded, augmented reality-based flashcard medium for Indonesian cultural diversity in IPAS and found it both feasible and effective, with small-scale and large-scale mastery reaching 100% and 95%, respectively, and N-gain scores of 72.26% and 71.29%. Similarly, Maulana (2025) developed a QR code-integrated flashcard for the same topic at the fourth-grade level and found that students' learning outcomes improved from 40% to 86% after its implementation. Rahayu et al. (2025) also reported a significant improvement in learning outcomes, with an N-gain score of 0.71, categorized as high. In addition, Musyaffa and Isdaryati (2024) developed an augmented reality-based application for IPAS cultural diversity and found it to be effective, with a high N-gain score of 0.7346. Selang et al. (2025) further confirmed the feasibility of augmented reality-based flashcards for cultural diversity material at the fifth-grade level with validation scores of 95% for both media and content.

While the aforementioned research confirms the feasibility and effectiveness of augmented reality-based flashcard media for cultural diversity learning, most have focused on application-based or single-format media, with limited integration of physical flashcards and QR-based AR technology into a unified instructional medium. In addition, few researchers have addressed how such integration can support the visualization of cultural diversity across multiple Indonesian regions within a single validated medium for fourth-grade students. To address this gap, this research introduces a novel augmented reality-based flashcard medium that combines physical flashcards embedded with QR codes and 3D animated AR content for fourth-grade IPAS learning. This approach allows students to explore Indonesia's cultural diversity across 6 major islands through an engaging digital format. Unlike previous researches that relied solely on application-based AR media, this research utilizes physical medium

combined with digital content. It offers a more engaging learning experience for fourth-grade students while aligning with their familiarity as digital natives.

Given the learning challenges and research gap, this research aims to develop, validate and evaluate this medium for fourth-grade students at Bringin 02 Semarang Elementary School. The objectives of this research are to: (1) design an augmented reality-based flashcard medium for the IPAS topic of Indonesian cultural diversity, (2) evaluate its feasibility through expert validation and practicality assessment and (3) examine its effectiveness in improving students' learning outcomes. This research offers both theoretical and practical contributions. Theoretically, it contributes to the expanding literature on augmented reality-based educational media by providing empirical evidence of the effectiveness of physically integrated augmented reality-based flashcards in IPAS learning. In practice, it offers a ready-to-use, validated learning medium that teachers can implement in class, particularly for topics that require concrete visualization of abstract cultural content, such as Indonesian cultural diversity.

Methods

This research, driven by quantitative methods, employs a Research and Development (R&D) approach as its main methodological framework. The development aspect lies in the implementation of interactive flashcard medium combined with augmented reality (AR) for the fourth-grade IPAS topic of Indonesian cultural diversity. The research was conducted in November 2025 and involved fourth-grade students at Bringin 02 Semarang Elementary School. This research adopted the Borg and Gall development model, which consists of ten stages: (1) identification of research potential and problems through initial observation, (2) data collection and needs analysis, (3) product planning and design, (4) design validation through expert review, (5) design revision based on validation results, (6) product testing to determine feasibility, (7) product revision based on initial testing results, (8) usage testing in a broader learning context, (9) final product revision and (10) finalization and production of the developed medium. However, due to practical considerations, the research was limited to the eighth stage, the usage testing stage.

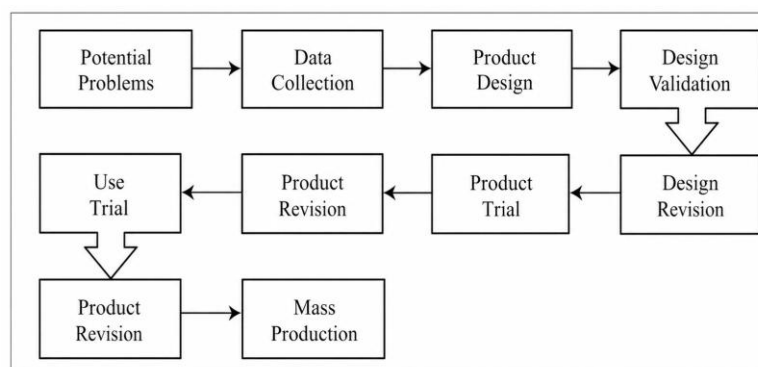


Figure 1. Borg & Gall (2003) Model in (Sugiyono, 2023)

The first step involved identifying potential research problems through initial observation. This stage included interviews with teachers, document analysis and direct classroom observation of fourth-grade students' learning activities. The interviews were conducted to obtain an overview of existing challenges, while classroom observations were carried out to verify whether the identified problems occurred in practice. The second step was to gather supporting data to plan product development through questionnaires designed based on the identified problems and the needs of both teachers and students. Following questionnaire collection and analysis, the product was then designed based on what they both need, including its design and the materials used. The developed medium was then subjected to validation by experts in relevant fields. The validation process involved two groups of expert validators, each consisting of two experts: media experts and content experts, who assessed the product using validation sheets based on a Likert scale. Subsequently, the validated product is then revised based on feedback from the expert validators. A small-scale trial was conducted with 10 fourth-grade students

selected through purposive sampling based on different cognitive ability levels. They consist of 3 high-achieving students, 4 with moderate ability and 3 with lower ability. The revised product was used during this trial. Teachers and students then completed response questionnaires to evaluate the practicality, attractiveness and usefulness of the medium in the learning process. A large-scale product trial was followed by written tests in the form of pretests, followed by posttests, aimed at comparing differences before and after using the medium. This stage served as the final step of the research and aimed to evaluate the effectiveness of the developed medium based on the learning outcomes of the fourth-grade students at Bringin 02 Semarang Elementary School.

The data collection techniques used in this research are interviews, observation, questionnaires, tests and documentation. Interviews were conducted with fourth-grade teachers to obtain research data and identify current learning challenges encountered in IPAS classes (Înoue, 2022). Observation was conducted during classroom activities to collect data on students' engagement and learning processes. Questionnaires were used to assess the validity of the developed medium and to gather responses from both teachers and students regarding the AR-based flashcard. Tests were administered to evaluate the feasibility of the developed medium through students' learning outcomes. Documentation was used to support and triangulate the collected data by recording students' learning activities and behavioral responses during the implementation of the medium.

In this research, students' learning outcomes in fourth grade on Indonesian cultural diversity at Bringin 02 Semarang Elementary School were treated as the dependent variable, while the AR-based interactive flashcard served as the independent variable. Primary data were the main source of information and were obtained directly through interviews, observations, and other relevant data collection techniques (Ningrum & Sa'diyah, 2023). Both test and non-test techniques were employed to obtain comprehensive data. The test instrument consisted of 20 multiple-choice questions, while non-test data were collected through interview instruments, questionnaires, observation sheets and documentation. The data obtained from the test were analyzed for validity, reliability, difficulty level, and discrimination index. Data from the pretests and posttests were further analyzed using several statistical techniques to evaluate improvements in students' learning outcomes. These included normality tests, t-tests, feasibility tests and N-gain tests to determine the extent of learning improvement in the IPAS topic of Indonesian cultural diversity

Results and Discussion

Results

The overall findings focus primarily on the implementation of AR-based flashcards for the Indonesian Cultural Diversity topic in IPAS for fourth-grade students at Bringin 02 Elementary School. This research aims to design, validate and evaluate the medium through an R&D approach to support a more effective classroom environment. The findings are categorized into four main outcomes. First, the research successfully develops a systematic design for AR-based Indonesian cultural diversity flashcards that addresses students' needs, teachers' challenges, and curriculum requirements. Second, the feasibility evaluation indicates that the medium meets the criteria for classroom use, as confirmed by expert validation and participants' positive responses. Third, the practicality tests show that the medium receives highly positive responses from both teachers and students, confirming its ease of use and suitability for implementation. Fourth, the effectiveness analysis demonstrates a significant improvement in students' learning outcomes in the IPAS topic of Indonesian cultural diversity. The findings indicate that the AR-based flashcards are systematically designed, feasible, practical and effective in improving students' learning outcomes. Detailed explanations of each outcome are presented in the following sub-sections.

Design of Flashcard Medium Development Based on Augmented Reality

Based on the month-long research process, the AR-based flashcard on Indonesian cultural diversity serves as an interactive and educational learning medium to improve students' understanding and learning outcomes. The main component of the tool is an augmented reality-based flashcard box measuring 15.6×10 cm, designed to store the flashcard. The box also includes left and right-side panels

measuring 15.6×1.3 cm. A QR code is placed on the left panel, providing access to usage instructions through scanning. The design of the flashcard box is presented below.



Figure 2. Box Flashcard Based on Augmented Reality

Another core component of the AR-based flashcard is the educational content, which is presented in the form of physical cards accompanied by a user instruction card. In terms of content, the flashcard display the cultural diversity of major Indonesian islands, with Bali included as an additional island. The islands covered are Java, Sumatra, Kalimantan, Sulawesi, Bali and Papua. The AR-based flashcard design is presented below.



Figure 3. Augmented Reality-based Flashcard Medium

Feasibility of Augmented Reality-Based Flashcard Medium

The AR-based flashcard developed subsequently underwent content validation to ensure its quality and suitability prior to implementation. The validation instrument is evaluated by four expert validators, consisting of two media experts and two content experts. The Aiken's V method is used to calculate the validation scores obtained from the experts. The following table presents a summary of the feasibility assessment based on the scores and evaluations provided by the validators.

Table 1. Expert Validation Recap of Augmented Reality-Based Flashcard Medium

Grain	Appraiser				s1	s2	s3	s4	Σs	V	Description
	I	II	III	IV							
Grain 1-20	78	87	96	93	58	67	76	73	274	0.85625	Tall

Based on the table presented, the AR-based flashcards are highly feasible for implementation, with an overall Aiken's V score of 0.85625. This result indicates that the developed medium meets the criteria for use in fourth-grade IPAS learning, particularly on the topic of Indonesian cultural diversity.

Revision of Augmented Reality-based Flashcard Design

The AR-based flashcard revisions are conducted to improve its design and functionality based on feedback and suggestions from media experts and subject matter experts. The revisions made are summarized in Table 2.

Table 2. Revision of Augmented Reality-based Flashcard Design

Expert	Input	Advice
Media	The AR-based flashcard appearance indicates that the flashcard box still uses standard ivory paper. In addition, the author's biodata is incomplete, and the placement of the QR code needs adjustment to improve the overall design and usability.	Improvements are suggested by redesigning the flashcard box using 230 gsm ivory paper with glossy lamination for a more attractive appearance. The author's biodata is recommended to be completed and the QR code is suggested to be repositioned to the center of the card to achieve better alignment and visual balance.

Practicality of Augmented Reality-based Flashcard

Following the small-scale trial, both teachers and students are asked to complete response questionnaires to assess the practicality of the AR-based flashcard in terms of its ease of use, attractiveness and suitability for classroom implementation. The teacher questionnaire covers aspects such as the medium's effectiveness, ease of use, and its contribution to students' understanding of Indonesian cultural diversity, while the student questionnaire assesses the attractiveness, content clarity, and overall learning experience. The results are presented in the following table.

Table 3. Results of Teachers' and Students' Responses to Augmented Reality-Based Flashcard

Respondent	%	Description
Teacher	98%	Very Good
Student	93.48%	Very Good

Based on the table above, both the teacher's and the student's responses to the AR-based flashcard are categorized as "Very Good," with scores of 98% and 93.48%, respectively. These results confirm that the medium is practical, easy to use, and suitable for fourth-grade IPAS learning activities related to Indonesian cultural diversity.

Effectiveness of Augmented Reality-based Flashcard

Students are required to complete both pretest and posttest assessments to measure the effectiveness of the medium. The pretest is administered before the tool is implemented, while the posttest is conducted after students have used the AR-based flashcard and the cultural diversity material has been fully delivered. In the small-scale trial, the pretest yields an average score of 53.5, while the posttest achieves an average score of 84. The score gap indicates a significant improvement in student performance. A normality test is then conducted to determine whether the data are normally distributed. The Shapiro-Wilk test is applied using SPSS version 25. In the small-scale trial, the normality test results for pretest scores yield a p-value of 0.269, while those for posttest scores yield a p-value of 0.232.

Table 4. Small Scale Normality Test

Tests of Normality						
	Kolmogorov-Smirnov ^a			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Pretest	.221	10	.182*	.908	10	.269
Posttest	.176	10	.200*	.902	10	.232

The table presents the results of the normality test for both pretest and posttest scores in the small-scale trial. The pretest scores yield a significance value of 0.269. Since this value exceeds the threshold of 0.05, the pretest data are considered normally distributed. Similarly, the posttest scores show a p-value of 0.232, which exceeds 0.05, indicating that the posttest data are normally distributed. Overall, both pretest and posttest scores demonstrate a normal distribution.

Table 5. Large Scale Normality Test

Tests of Normality						
	Kolmogorov-Smirnov ^a			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Pretest	.197	15	.122*	.927	15	.244
Posttest	.167	15	.200*	.925	15	.231

Based on the table above, the pretest scores in the large group are normally distributed, as the significance value of 0.244 exceeds the 0.05 threshold. Similarly, the posttest scores show a p-value of 0.231, which exceeds 0.05, indicating that the posttest data are normally distributed. Therefore, subsequent calculations use parametric statistical techniques.

After confirming a normal data distribution, a paired-samples t-test is conducted to examine whether there are significant differences between the pretest and posttest scores. The analysis is performed using SPSS version 25 to determine the mean difference between the two sets of scores. The alternative hypothesis (H_a) is accepted if the calculated t-value exceeds the critical t-value (t-table) and rejected if it is lower.

Table 6. Pretest and Posttest T-Test for Small Scale

Paired Samples Test									
Paired Differences									
		Mean	Std. Deviation	Std. Error	95% Confidence Interval of the Difference		T	df	Sig. (2-tailed)
				Mean	Lower	Upper			
Pair 1	Pretest-Posttest	-30.500	11.168	3.532	-38.489	-22.511	-8.636	9	0.000

Based on the table above, the statistical analysis of pretest and posttest scores for the difference in means yields a two-tailed significance value of 0.000. In a paired-sample t-test, a significance value below 0.05 indicates a statistically significant difference. Therefore, there is a significant difference between the pretest and posttest scores on the IPAS topic of Indonesian cultural diversity. This finding suggests that students' learning outcomes improve after the treatment is administered.

Table 7. Large-Scale Pretest and Posttest T-Test

Paired Samples Test									
Paired Differences									
		Mean	Std. Deviation	Std. Error	95% Confidence Interval of the Difference		T	df	Sig. (2-tailed)
				Mean	Lower	Upper			
Pair 1	Pretest-Posttest	-27.000	9.024	2.330	-31.997	-22.003	-11.588	14	0.000

Based on the table above, the t-test for the difference in means between the pretest and posttest scores yielded a two-tailed p-value of 0.000. In a paired-sample t-test, a two-tailed significance value

below 0.005 indicates a statistically significant difference. Therefore, the comparison between pretest and posttest scores shows a significant variation in students' understanding of Indonesian cultural diversity. The t-test results confirm that the difference is statistically significant, as the two-tailed p-value is less than 0.005.

Table 8. Small Scale N-gain Test

Average Difference	N-gain	Criteria
50.00	0.6786	Currently

A notable improvement in IPAS learning outcomes on Indonesian cultural diversity was observed in the small group, with N-gain analysis showing an improvement from a pretest score of 50.00 to a posttest score of 100.00. The average difference between the pretest and posttest scores was 50.00. The N-gain was calculated to be 0.6786. This value falls into the moderate category. The observed average increase demonstrates that AR-based flashcards are effective for fourth-grade students in understanding class material and meeting curriculum objectives.

Table 9. Large Scale N-gain Test

Average Difference	N-gain	Criteria
47.50	0.6376	Currently

The average increase (N-gain) in the large group of students' learning outcomes on Indonesian cultural diversity showed a substantial improvement, with the N-gain analysis revealing an increase from 40.00 in the pretest to 87.50 in the posttest, for an average difference of 47.50. It was reported that the average increase (N-gain) was 0.6376, which corresponded to a moderate category. This average improvement indicated that fourth-grade students effectively used the AR-based flashcard to improve their learning outcomes in Indonesian cultural diversity.

Discussion

Design Development of Augmented Reality-Based Flashcard

At the beginning of the development process, potential and problem identification served as the primary step in developing an AR-based flashcard medium for the IPAS learning, using observation techniques and interviews with fourth-grade teachers. The pre-research findings revealed several learning challenges, including students' difficulty understanding Indonesian cultural diversity and their low classroom engagement due to limited learning resources and instructional media. As a result, many students showed low learning achievement in IPAS, particularly in Indonesian cultural diversity, with many still below the minimum passing criteria. The lack of variation in instructional media further contributed to students' boredom during learning activities, which the teacher did not adequately address. These findings are consistent with research conducted by Musyaffa and Isdaryanti (2024), as well as Ananta and Isdaryanti (2025), both of whom similarly identified that the absence of engaging, technology-based media in fourth-grade classrooms was the primary contributor to students' low learning outcomes in cultural diversity material in their respective research areas. And thus, these challenges are not unique to Bringin 02 Semarang Elementary School but reflect a broader pattern in Indonesian elementary education. Kalemkuş (2025) states that the use of technology in learning can improve students' understanding of the material and their skills. Learning media play a key role in improving students' understanding of the material, as they can provide a fun, interactive, and meaningful learning experience and enhance students' memory of the material (Levido et al., 2025). In reality, however, teachers often seem reluctant to utilize a wider range of learning media, resulting in limited variation in classroom teaching methods. They tend to rely solely on conventional media, such as government-published textbooks, which makes lessons less engaging for teachers and less interesting for students. Given these challenges, an AR-based flashcard in IPAS learning could support students' learning progress, as the media is designed for group learning and provides real, interactive learning experiences. It has the potential to motivate students to interact more with teachers and to participate actively in the learning process. Arici (2024) argues that augmented reality provides an engaging learning experience by utilizing interactive 3D virtual models. This supports the development of the

AR-based flashcard in present research. The combination of physical cards and 3D animated content addresses students' need for concrete visual representations of cultural concepts, which would otherwise be difficult to be taught through conventional textbook-based instruction alone.

The AR-based flashcard features an attractive, interactive cover that highlights Indonesian cultural nuances. The cover design features 2D characters of children, batik motifs, wayang, and regional cultural icons in bright colors to pique students' interest. On the back of the flashcard box, the researcher's and supervising lecturer's biodata are included as a form of identity and academic accountability. A QR code is located on the side of the box, containing digital instructions for using the medium to help teachers and students operate it. Each flashcard features Indonesian cultural diversity, including traditional houses, clothing, dances, musical instruments, songs, and foods. Thus, each card is embedded with a QR code on the back to facilitate access to learning content. Pratiwi and Dzakiyah (2024) state that the use of QR codes makes material more accessible and increases student engagement in learning. This aligns with Maulana (2025), who similarly integrated QR codes into flashcards for cultural diversity learning and found that this approach effectively improved students' access to learning materials and increased their engagement during lessons. When the QR code is scanned with Google Lens or a mobile scanning app, the flashcard displays 3D content, such as animated characters in traditional clothing, traditional houses, musical instruments, regional specialties, and traditional dances or songs, which students can directly observe. Unlike Selang et al. (2025), whose AR flashcard medium was limited to application-based content without physical card components, the present research extends this approach by combining physical flashcard design with QR-based 3D animated content. It offers a more tangible and hands-on learning experience. Additionally, each card includes detailed information about cultural diversity from different islands. Therefore, students not only observe but also understand and learn cultural diversity in each region firsthand. Furthermore, physical instruction cards were also prepared to ensure that teachers and students can use the medium more easily during lessons. This design process directly addresses the first research objective, which is to develop an AR-based flashcard medium for IPAS learning on Indonesian cultural diversity, and confirms that the medium was successfully designed to address identified classroom needs.

Feasibility Test of Augmented Reality-based Flashcard

The feasibility assessment of the AR-based flashcard was conducted by 4 experts: 2 media experts and 2 content experts. Each expert provided an evaluation of the medium's feasibility, covering aspects such as media usage, appearance, writing style, media presentation, and language. The feasibility assessment by Media Expert I and Media Expert II was carried out. Media validation was performed to assess the suitability of the medium's appearance. The results evaluated by the Media Expert Validator I indicated that the medium development received a "very feasible" rating which was recorded at 93%. Meanwhile, the evaluation results from Media Expert Validator II showed that the medium also received a "very feasible" rating of 96%.

The feasibility evaluation by Subject Matter Expert 1 and Subject Matter Expert 2 included aspects of the curriculum, content, evaluation, and the language used. Material validation was conducted to determine the suitability of the presented material. The assessment results by Expert Validator I in the subject matter indicated that the AR-based flashcard incorporating Indonesian cultural diversity achieved a "very feasible" rating, with a 90% score. Meanwhile, the assessment results from Expert Validator II indicated that the development of an AR-based flashcard medium for the IPAS topic of Indonesian cultural diversity met the "very feasible" criterion, with a score of 87%.

All assessments were calculated from 2 content experts and 2 media experts using Aiken's V to ensure that each instrument item was relevant, appropriate, and feasible in supporting the development of the learning medium, making it accountable (Mahatma et al., 2025). The result of the Aiken's V calculation was 0.85625, which was categorized as high. This score was slightly lower than the validation results reported by Ananta and Isdaryati (2025), who obtained media and content validation scores of 92% and 90%, respectively, and Selang et al. (2025), whose medium and content validation scores both reached 95%. The difference may be attributed to the more comprehensive scope of the developed medium, which covered 6 islands simultaneously and therefore posed greater challenges for content accuracy and consistency across cultural contexts. Nevertheless, Aiken's V score of 0.85625 still fell within the high category. This score indicated that the medium is not merely acceptable but genuinely well-suited for classroom use, meaning that both the design and content are perceived by

experts as pedagogically relevant for fourth-grade students. Practically, Aiken's V score suggested that the medium can be trusted to deliver the intended learning experience without causing confusion of the topic. The high feasibility rating can be attributed to the systematic development process that followed the Borg & Gall model. Each stage, from needs analysis to expert validation, was carefully executed. The involvement of both media and content experts further strengthened the validity of the instrument, as each aspect of the medium was evaluated from complementary perspectives. Therefore, the assessment instrument provided by 4 expert validators, 2 content experts and 2 media experts is considered highly valid and suitable for use in the research. These results directly addressed the second research objective, which was to evaluate the medium's feasibility through expert validation. The findings confirmed that the developed learning medium met the academic and pedagogical standards required for fourth-grade IPAS learning.

Results of the Teacher and Student Needs Survey

Based on an initial survey conducted with students and teachers prior to the research, an AR-based flashcard for the IPAS topic of Indonesian cultural diversity was developed. The survey results provided the foundation for designing the medium that addressed the identified learning challenges. Particular attention was given to aspects concerning the development of instructional medium (Morrell et al., 2025). The teacher and student needs survey contained indicators reflecting the requirements and expectations of both teachers and students regarding challenges encountered during the development of the medium.

The analysis of teachers' needs for an AR-based flashcard on the IPAS topic of Indonesian cultural diversity indicates that during lessons, teachers rarely use learning media. Thus, resulting in less engaging instruction. Teachers rely only on conventional textbooks as references during learning activities. Lai and Shi (2025) explain that in today's era of learning, teachers must take the initiative to develop interactive, engaging and effective mediums to increase students' engagement and involvement in class. This is consistent with the needs analysis findings of Musyaffa and Isdaryati (2024), who similarly found that teachers at the elementary level relied predominantly on conventional textbooks and lacked the initiative to develop technology-based mediums, which directly contributed to students' disengagement in learning. Therefore, teachers agree that the development of interactive, technology-based learning media in IPAS is useful in improving student achievement in the subject. The introduction of an AR-based flashcard for the IPAS topic of Indonesian cultural diversity is expected to increase students' motivation and engagement during learning activities. Furthermore, the medium is expected to facilitate a clearer understanding of the material being taught.

The student preferences questionnaires revealed that although most fourth-grade students enjoyed learning IPAS, they still struggled to remember cultural diversity elements such as traditional houses, clothing, dances, musical instruments, songs and foods. This difficulty was largely due to the lack of engaging visual media, as teachers relied solely on textbooks, PowerPoint slides, and concrete images during instruction. Rahayu et al. (2025) reported similar findings in their needs analysis, in which fourth-grade students expressed difficulties understanding cultural diversity material due to the absence of an interactive medium and strongly preferred AR-based flashcards over conventional instructional approaches. Most students strongly agreed with the suggestions implemented through the AR-based flashcard and recognized that this medium can significantly improve learning outcomes, particularly for topics such as Indonesian cultural diversity in the IPAS textbook. Tarmidzi et al. (2025) stated that augmented reality is suitable for educational contexts due to its potential to foster interest, improve learning outcomes, strengthen motivation, critical thinking, understanding, and students' creativity. These findings further support the second research objective regarding practicality assessment. The findings demonstrate that the medium is not only theoretically feasible but also practically viable, as evidenced by both teachers' and students' perspectives during learning activities.

Revision of Augmented Reality-based Flashcard Design

The product revision aimed to improve the AR-based flashcard based on suggestions from media experts, particularly regarding the use of ordinary ivory paper for its boxes. Additionally, the author's biodata needed to be completed, and the position of the QR barcode on the augmented reality-based flashcard needed to be improved to enhance its appearance. The suggested improvements included upgrading to 230gsm glossy-laminated ivory paper, completing the author's biodata neatly and

repositioning the QR code to the center of the card for a more aligned appearance. Bang et al. (2023) explain that attractive, well-designed media can increase students' interest and enthusiasm in learning. Therefore, the revision process in the present research focused not only on digital content but also on the physical quality of the flashcard materials, as the tangibility of the medium plays an important role in maintaining students' engagement during hands-on learning activities. This is in line with Ananta and Isdaryanti (2025) and Selang et al. (2025), who similarly implemented expert-driven revision stages focusing on the visual quality and usability of their AR-based flashcards before finalizing their products. However, unlike previous researches that primarily focused on digital content aspects, the revisions in the present research also addressed physical material quality, particularly the upgrade to 230gsm glossy-laminated ivory paper, which extended the scope of quality improvement beyond previous research.

The Effectiveness of Augmented Reality-based Flashcard

The effectiveness of the medium was observed based on the pretest and posttest results. In the small-group trial, there was a significant increase in students' academic performance in IPAS on Indonesian cultural diversity using AR-based flashcards. In the small-scale trial, the results revealed a significant improvement in students' performance. This increase in achievement was particularly evident in the classical mastery percentage: it was 10% in the pretest and 70% in the posttest. The data showed that students' learning outcomes regarding Indonesian cultural diversity improved from pre- to post-application of the AR-based flashcard for the IPAS topic.



Figure 4. Small-Scale Product Trial

During the large-scale trial, there was a significant change between the pretest and posttest. Based on the average pretest score of 58 and the average posttest score of 70, the results indicated an improvement in students' learning outcomes. In the pretest, students showed low achievement, while in the posttest, most students demonstrated better mastery of the material. A noticeable improvement in students' performance in science learning on Indonesian cultural diversity was observed after the application of the AR-based flashcard for the IPAS topic, compared to the pre-intervention condition.



Figure 5. Large-Scale Test

To assess the effectiveness of the learning medium, teachers were asked to complete a response questionnaire. The analysis showed that the AR-based flashcard achieved an average score of 98%, categorized as 'Very Good,' and was supported by positive teacher perceptions. The average rating for the medium by students reached 93.48%, also categorized as "Very Good," with positive responses. Therefore, it can be concluded that the medium was suitable for use in learning activities. Using an AR-

based flashcard provided positive responses from teachers and students due to its ease of use in learning (Rachmawati & Lestari, 2025).

Following the results of the pretest and posttest, a normality test was conducted. The purpose of the normality test was to verify the data's normality prior to further analysis (Khatun, 2021). Data that were normally distributed were analyzed using parametric statistical techniques. Data obtained from small-scale product trials and large-scale usage tests were analyzed to determine the effectiveness of the medium in learning. In the small group, the normality of the pretest and posttest scores was assessed using the Shapiro–Wilk test in SPSS version 25. Based on the results, the pretest scores had a significance value of 0.269, while the posttest scores had a significance value of 0.232. The results indicated that the pretest significance value of 0.269 was greater than 0.050. The value indicated that the data were normally distributed. Similarly, the posttest significance value of 0.232 was greater than 0.050, indicating that the data were normally distributed. This finding indicated that both pretest and posttest scores met the assumption of normality. This is meaningful because it validated the use of parametric statistical techniques in subsequent analyses, which ensured that the conclusions drawn from the t-test and N-gain calculations are statistically reliable. In the large group, the normality test was also performed using the Shapiro–Wilk test. The hypothesis-testing criteria stated that H_0 was accepted if the significance value (sig) was greater than 0.05, indicating that the data were normally distributed. Conversely, H_0 was rejected if the significance value was less than 0.05, indicating that the data were not normally distributed, whether in the pretest or posttest results. The results showed that the pretest significance value was 0.244 and the posttest significance value was 0.231. Both values were greater than 0.050, indicating that the data were normally distributed for both the pretest and posttest.

Based on the normality test results for the pretest and posttest data, the researcher conducted a paired-samples t-test to examine the mean difference between the scores. The difference in average scores between the pretest and posttest determined the AR-based flashcard for the IPAS topic of Indonesian cultural diversity effectiveness. The researcher used parametric statistical techniques, including the paired-samples t-test, assisted by SPSS version 25, to obtain the results of the mean difference test between pretest and posttest scores. If the calculated t-value was greater than the t-table value, the alternative hypothesis (H_a) is accepted, whereas if the calculated t-value was smaller than the t-table value, H_a is rejected. The small group trial results analyzed using SPSS version 25 showed a (2-tailed) significance value of 0.000. The criteria for the paired-sample t-test stated that if the sig (2-tailed) value was greater than 0.05, there is no significant difference between students' IPAS learning outcomes in Indonesian cultural diversity topic between the pretest and posttest. The results showed that the significance value (2-tailed) of 0.000 was less than 0.05, which indicated a significant difference between the pretest and posttest results. This means that the improvement in students' learning outcomes was not merely coincidental but was systematically influenced by the implementation of the medium, suggesting that the medium played a meaningful role in facilitating students' understanding of Indonesian cultural diversity. The large group trial results using SPSS version 25 also showed a significance value (2-tailed) of 0.000. If the significance value (2-tailed) was less than 0.05, there was a significant difference in students' improvement in science learning outcomes in Indonesian cultural diversity material between the pretest and posttest. The results indicated that the significance value (2-tailed) of 0.000 was less than 0.05, which confirmed a significant difference in students' learning outcomes. This finding reinforced the conclusion from the small-scale trial, which confirmed that the medium consistently improved students' learning outcomes across both trial scales, thereby strengthening the reliability of the effectiveness claim.

Following the t-test, the researcher performed an N-gain test to determine whether the average increased. In the small group, the average N-gain for students' learning outcomes on Indonesian cultural diversity increased from 50.00 (pretest) to 100.00 (posttest), resulting in an average difference of 50.00. The calculated N-gain was 0.67, which falls into the moderate category. This moderate result can be understood in light of the scope of cultural content covered, which spans 6 major islands simultaneously and creates a higher cognitive load than previous research focused on fewer cultural regions. Despite this, the improvement from pretest to posttest remains substantial. The improvement suggested that the AR-based flashcard successfully supported students' understanding even under complex content conditions. This result is slightly lower than the N-gain of 0.7346 reported by Musyaffa and Isdaryati (2024) and 0.71 reported by Rahayu et al. (2025), both of which are categorized as high. The difference

may be attributed to the broader scope of cultural content in the present research, which requires students to process more diverse material across major islands.

This result reflects the challenge of presenting diverse cultural content across multiple islands within a limited instructional time. Nevertheless, the improvement from pretest to posttest confirms that the AR-based flashcard effectively facilitated students' learning through interactive visual representations that made abstract cultural concepts more accessible and easier to remember. Based on the large group trial, there was an increase in the large group's N-gain in social studies learning outcomes on the topic of Indonesian cultural diversity, from a pretest score of 40.00 to a posttest score of 87.50, with an average difference of 47.50. The average N-gain was 0.6376, which fell into the moderate category. This result reflects the challenge of presenting diverse cultural content across major islands within a limited instructional time. Nevertheless, the improvement from pretest to posttest confirms that the AR-based flashcard effectively facilitated students' learning through interactive visual representations that made abstract cultural concepts more accessible and easier to remember. This result is comparable to the N-gain scores of 72.26% and 71.29% reported by Ananta and Isdaryati (2025), which suggest that AR-based flashcards consistently produced moderate-to-high learning outcomes improvements in fourth-grade students on Indonesian cultural diversity topics. This increase in the average demonstrates that the medium is effective in improving fourth-grade students' learning outcomes at Bringin 02 Elementary School.

The effectiveness of this medium is consistent with the research by Rahman et al. (2023). The study titled "The Effectiveness of Augmented Reality Using Flash Cards in Education to Learn Simple English Words as a Second Language" showed that the use of flashcards in learning was proven effective and resulted in a significant improvement in learning outcomes. As a result, the learning process became more effective, interactive, and enjoyable. Additionally, the research conducted by Ghosh et al. (2025) titled "Interactive augmented reality application using animal flashcards for education of children" proved that augmented reality-based flashcards improved students' conceptual understanding and learning outcomes, as well as increased learning engagement. Another study conducted by Chang et al. (2022) titled "Computers & Education: Ten years of augmented reality in education: A meta-analysis of (quasi-) experimental studies to investigate the impact" showed that augmented reality-based flashcard improved motivation, interest, understanding of the material, and influenced learning outcomes in the learning process. These findings collectively addressed the third research objective, which aimed to examine the AR-based flashcard effectiveness in improving students' learning outcomes. The findings confirmed that the medium successfully improved fourth-grade students' understanding of the IPAS topic of Indonesian cultural diversity at Bringin 02 Semarang Elementary School.

Conclusion

Based on research results from IPAS lessons at Bringin 02 Elementary School, it can be concluded that the development of an augmented reality (AR)-based flashcard for Indonesian cultural diversity was effective in improving fourth-grade students' learning outcomes. The developed medium consists of a flashcard box containing physical flashcards covering cultural elements from 6 major islands in Indonesia: Java, Sumatra, Kalimantan, Sulawesi, Bali, and Papua. Each flashcard includes a QR code that displays 3D animated content when scanned with a mobile device. This medium presents learning material in a more concrete, interactive, and engaging way, making it easier for students to understand Indonesian cultural diversity. In terms of feasibility, the medium received a "very feasible" rating from four expert validators with an overall Aiken's V score of 0.85625 and was rated "very good" by both teachers (98%) and students (93.48%) in the practicality assessment. The implementation of this medium not only improved cognitive aspects but also increased students' motivation and classroom activity during the learning process. Therefore, this medium is feasible to be used as an innovative and relevant learning alternative to support 21st-century education in elementary schools.

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