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Development of E-Teaching Materials for Science on the Topic of the Form of Matter and Its Changes Integrated with Ethnoscience with the Help of Augmented Reality to Improve the Learning Outcomes of Elementary School Students

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Abstract: This study aims to develop, test the feasibility, practicality, and effectiveness of e-teaching materials integrated with ethnoscience assisted by Augmented Reality (AR) in improving student learning outcomes. The type of research used is Research and Development (R&D) with the ADDIE model which includes the stages of analysis, design, development, implementation, and evaluation. The results of the study indicate that the developed e-teaching materials are declared very feasible based on validation by material, language, and media experts with an average score of 89%. The practicality of the media is demonstrated through the responses of teachers and students who are in the very positive category, with a percentage of 97% of teachers and 86% of students. The effectiveness of e-teaching materials is proven through the results of the paired sample t-test which shows a significance value of 0.000 (<0.05), which means there is a significant difference between learning outcomes before and after using the media. In addition, the results of the N-Gain test of 0.67 indicate a moderate category, which indicates an increase in student learning outcomes. Thus, the integrated ethnoscience e-teaching materials assisted by Augmented Reality are declared feasible, practical, and effective for use in science learning for grade IV elementary schools, especially on the material of states of matter and their changes.

Keywords: Augmented reality; E-teaching materials; Ethnoscience; Learning outcomes; Science

Introduction

Based on the latest Decree of the Ministry of Primary and Secondary Education of the Republic of Indonesia Number 1 of 2026 (Kemendikdasmen, 2026), the Independent Curriculum (Curriculum Merdeka) is established as the standard reference for the learning process in Basic Education in Indonesia, which is student-centered, contextual, and meaningful. In line with this, the implementation of deep learning is a highly relevant approach because it encourages students to understand concepts in depth through analysis of real-life problems and creative solutions (Lei Pan & Songco, 2023; Mystakidis, 2021; Weng et al., 2023). This deep learning demands a high level of cognitive engagement and reflective skills for sustainable learning (De Sarkar, 2023). This urgency is further strengthened in the context of developing 21st-century competencies, including communication, collaboration, critical thinking, and creativity (the 4Cs), as preparation for facing complex global dynamics. In the context of Natural and Social Sciences (IPAS) subjects in elementary schools, the application of in-depth learning through the integration of local culture or ethnoscience provides an authentic learning resource (Zuschaiya et al., 2024).

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The use of technology in IPAS is also crucial for presenting material visually and interactively and fostering understanding of abstract concepts, enabling local character to be integrated with global developments. However, in practice, significant challenges remain, as learning approaches do not fully engage students actively (Masbukhin & Sausan, 2023; Nurdiyanti et al., 2024). Learning strategies that encourage active participation are essential to improve motivation and improve learning outcomes, which are still suboptimal, particularly given the limited availability of learning resources in various educational institutions. A clear gap is found in the field, where the use of learning media is still conventional, dominated by text without adequate visualization, making it less effective in fostering in-depth conceptual understanding (Imron et al., 2024). Research by Masruroh et al. (2020) shows a lack of teacher innovation and minimal integration of local knowledge in science and science, even though these aspects have the potential to create meaningful learning (Widayati et al., 2023). This condition is reflected in the results of the 2022 PISA (PISA) which showed a low scientific literacy score of 383 for Indonesian students, indicating that learning is still oriented towards memorization.

However, the integration of ethnoscience has been proven effective in bridging the gap between school science and everyday knowledge (Wahyuningtyas et al., 2023) and strengthening students' critical thinking skills. Specific problems were identified in grades IVA and IVB at Muhammadiyah Elementary School in Kebumen, where a preliminary study showed that only 7% of students enjoyed science. Ninety-five percent of students disliked the topic of states of matter and their changes because the material was difficult to understand (61%) and the presentation was uninteresting (11%). Furthermore, teachers still rely entirely on government-printed textbooks without contextual modification, even though 57% of students stated that learning resources were limited to text. Although 85% of students own smartphones, their use is not optimal for learning, as they are primarily used for entertainment, spending more than four hours a day. However, 95% of students expressed a strong interest in using smartphones as learning aids. This situation resulted in low learning outcomes, with 76% of grade IVA students and 71% of grade IVB students failing to achieve the minimum grade point average (KKTP) (75) on the state of matter topic. In response to these issues, innovation is needed in the form of integrated ethnoscience-assisted science e-teaching materials using augmented reality (AR).

The use of digital learning materials provides a more immersive and enjoyable learning experience (Malahayati & Zunaidah, 2021). E-learning materials are systematically designed to facilitate competency achievement in the digital era. Ethnoscience plays a role in integrating local culture as a contextual approach (Zidny & Eilks, 2022), while AR technology extracts intuitive and abstract learning content for easy understanding (Sri Asmini et al., 2025). AR-based media has been shown to significantly increase learning outcome completion from 33% to 100% (Faiza et al., 2022). This technology offers flexibility for students to set their own learning rhythm (Aina Almardiyah et al., 2022; Ginanjar et al., 2024; Prabowo et al., 2024). The novelty of this research lies in the development of an E-Science Teaching Material that synergizes local ethnoscience elements from Kebumen with AR technology in the form of an interactive digital book. Through an ethnoscience approach, students are invited to connect real-world phenomena, such as the transformation of liquid sap into solid sugar, with the scientific concept of states of matter.

AR technology is implemented through QR codes that enable real-time visualization of 3D objects that can be rotated 360 degrees using a smartphone. The aim of this research is to produce valid, practical, and effective learning media to optimally improve learning outcomes, interest, and conceptual understanding of fourth-grade students at Muhammadiyah Elementary School in Kebumen. Thus, it is hoped that there will be a balance between mastery of science, scientific attitudes, and preservation of local wisdom in responding to the challenges of 21st-century education (Hikmawati et al., 2022; Völkel & Nassenstein, 2022).

Method

This research is a Research and Development (R&D) study aimed at developing learning products and testing their effectiveness. The focus of this research is the development of integrated ethnoscience e-teaching materials using Augmented Reality for the Natural Sciences (IPAS) subject, focusing on the state of matter and its changes, for fourth-grade elementary school students. According to Lee et al. (2017), the Research and Development (R&D) method is a research method used to develop, test, and produce a specific product. The R&D process begins with the research phase, followed by the development phase. This method encompasses a series of steps, starting with the analysis of previous findings or research relevant to the product to be developed, followed by the design, development, testing, and revision processes to perfect the resulting product. This research uses the ADDIE development model, which consists of five main stages: Analysis, Design, Development, Implementation, and Evaluation. The ADDIE model was chosen because it has a continuous evaluative approach at each stage, so that the

development process not only runs systematically but also allows for continuous improvement (Branch, 2009). Furthermore, this model allows for evaluation of the integration between stages to ensure consistency and coherence in product development. The stages in the ADDIE model are presented in more detail in the illustration in Figure 1.

Figure 1. ADDIE development stages

The development of the ADDIE model consists of five main stages, implemented systematically and in stages. The first stage is analysis, which identifies potential and problems at the research site. This activity was conducted through observation, interviews, and documentation, including the collection of learning outcomes data from fourth-grade students. In addition, a questionnaire was distributed to assess student needs as a basis for planning the product to be developed. The analysis stage included problem identification, student characteristics, teacher needs for learning media, and a review of the teaching materials used. The analysis revealed obstacles in developing interactive teaching materials and utilizing digital media, resulting in poor student conceptual understanding of science (IPA) material, particularly regarding the states of matter and their changes. This situation was also influenced by learning that was still oriented towards memorization. Therefore, e-learning materials were developed using Augmented Reality based on concrete examples to support more contextual learning. The second stage was design, which aimed to develop learning media in the form of e-learning materials integrated with ethnoscience using Augmented Reality.

The design process was based on the results of an analysis of teacher and student needs through interviews and questionnaires. The e-learning material design was developed using the Canva platform, while the Augmented Reality objects were created using the Assemblr Edu application. Next, the e-learning material was integrated with the Augmented Reality feature via a QR code. The designed product was then validated by lecturers from Semarang State University, who served as validators, consisting of subject matter, language, and media experts. The validation process used an assessment instrument with a Likert scale of 1–4. The third stage was development, which involved creating a product in the form of an e-learning material integrated with ethnoscience and augmented reality that can be accessed via smartphone devices. Product development was based on the results of the needs analysis and input from validators and practitioners. The product was designed with attention to language, content, and media design aspects aligned with the Learning Outcomes (CP) and Learning Objectives (TP) for the topic "States of Matter and Their Changes" for fourth-grade elementary school Phase B. The final product is a digital book in flipbook format that can be accessed online and scanned using the Assemblr Edu application, Google Lens, or a smartphone's built-in scanner. After the development stage, design validation was conducted to ensure product feasibility before implementation. The fourth stage was implementation, which involved product trials with students.

The study population consisted of 36 fourth-grade students from Kemijen 02 and Kemijen 03 Public Elementary Schools. The trials were conducted in two stages: a small group of 15 students (grade IVA) and a large group of 21 students (grade IVB) using a purposive sampling technique. Data collection was conducted through pretests and posttests to measure the product's effectiveness on student learning outcomes. The learning process utilized a Problem-Based Learning (PBL) model to encourage active student engagement through contextual problem-solving. The data types in this study consisted of qualitative and quantitative data. Qualitative data were obtained through observations, teacher interviews, and student response questionnaires. Meanwhile, quantitative data were obtained from the results of pretests and posttests on the topic of states of matter and their changes. The research design used was a pre-experimental one-group pretest-posttest design, comparing conditions before and after treatment to determine the effect of product use. Data collection techniques included both test and non-test methods. The test consisted of 30 multiple-choice questions used in the pretest and posttest to measure student understanding. The questions were structured with the same indicators, but the narratives were differentiated to avoid memorization effects. All items underwent content validity and empirical validity testing using SPSS software. A summary of the item analysis results is presented in Table 1.

Non-test techniques included interviews, questionnaires, observation, documentation, and scorecards. Product feasibility was assessed through validation by subject matter, language, and media experts using a Likert scale of 1–4. Practicality was assessed through questionnaires comprising teacher and

student responses to the use of e-learning materials in learning. Effectiveness was assessed through analysis of pretest and posttest results. Data analysis began with a normality test using the Shapiro-Wilk method, followed by a paired samples t-test to identify significant differences, and an N-Gain test to measure improvements in student learning outcomes. The final stage was evaluation, which focused on assessing the effectiveness of the e-learning materials integrated with ethnoscience and augmented reality in enhancing student understanding. Evaluation was conducted through analysis of learning outcomes and teacher and student responses to product use. This stage aimed to provide feedback for product improvement and ensure its usefulness in elementary school learning.

Table 1. Detailed Analysis Results of Validity, Reliability, Difficulty Level, and Distinctive Power of the Items

Analysis Aspects	Results
Question Validity	All 30 questions were declared valid with a correlation coefficient > 0.51
Question Reliability	The Cronbach's Alpha coefficient was 1.07 (very high)
Question Difficulty Level	
Question Distinction Power	- 27 questions: Moderate category
Conclusion	- 3 questions: Difficult category

Result and Discussion

Analysis Phase

Based on the results of a preliminary study conducted at Muhammadiyah Elementary School in Kebumen, several problems were identified in science learning. Students tended to be less interested in science, particularly in the topic of states of matter and their changes, which they considered difficult to understand. This was due to the lack of concrete presentation of the material and the suboptimal connection of the material to the context of students' daily lives. Furthermore, the learning resources used were not fully aligned with students' needs. Teachers still tended to rely on government-published textbooks, such as teacher's and student's textbooks, as the primary learning resource. The use of supplementary media, such as YouTube videos, was not accompanied by an adaptation or modification process that took into account students' characteristics and needs. Although technological facilities, such as Wi-Fi, were available in every classroom, they were not optimally utilized to support interactive learning.

In terms of learning implementation, students tended to be passive. This was evident in the dominant use of lecture methods by teachers and the low participation of students in question-and-answer sessions. These conditions resulted in low student engagement in the learning process, which ultimately impacted conceptual understanding. Learning outcome data shows that the level of student mastery is still low. In class IV A, as many as 16 out of 21 students (76%) have not achieved the Learning Objective Achievement Criteria (KKTP), while only 5 students (24%) have achieved mastery. Meanwhile, in class IV B, as many as 15 out of 21 students (71%) have not achieved KKTP, and only 6 students (29%) have completed it, with a minimum mastery standard of 75. These findings indicate that the low level of student learning outcomes is inseparable from the lack of variety in learning media, presentation of material that is not yet linked to everyday life, minimal use of technology, and a learning approach that is still teacher-centered.

Design and Development Stage

After identifying the potential and existing problems, the next stage is designing and developing a solution. The solution developed in this research is an e-learning material integrated with ethnoscience, aided by Augmented Reality, on the topic of states of matter and their changes, considering that student learning outcomes in this material still do not meet the Learning Objective Achievement Criteria (KKTP). The development of this e-learning material takes into account several important aspects, including ease of access, ease of use, attractive design, and suitability to student needs. The learning media is designed in the form of a digital book with an aesthetic and interactive display to increase student interest in learning. The developed product integrates three main components. First, digital e-learning material that can be accessed anytime and anywhere, and is equipped with learning materials and videos tailored to student characteristics. Second, ethnoscience integration, which links learning materials to local culture to make learning more contextual and meaningful. Through this approach, students are expected to more easily grasp concepts because they are linked to real-life experiences in their surroundings. Third, the use of Augmented Reality (AR) technology to visualize abstract concepts makes them easier for students to understand. AR technology enables the integration of digital information, such as images, video, audio, text, and three-dimensional (3D) objects, into a real-time environment.

The AR content presented in this e-learning material highlights phenomena close to students' lives,

such as the process of making ice cream and making sugar from palm sap, which relate to the concept of changes in the state of matter. The AR feature is accessed through a QR code integrated into the e-learning material in flipbook format, so students can easily access it via their smartphones. This learning media is designed in accordance with the Learning Outcomes (CP) and Learning Objectives (TP) for the material on states of matter and their changes. Furthermore, the product design is also tailored to the characteristics of elementary school students, incorporating a combination of visual elements such as images, animations, videos, text, and 3D objects to enhance learning motivation and understanding. The development process begins with the preparation of materials, design, and layout. Next, the product was created using several applications, namely Canva for e-learning material design and Assemblr Edu for Augmented Reality object creation. The integration of ethnoscience into this product was realized through the selection of local culture-based examples, particularly traditional foods relevant to the learning material. The final product of this learning media is a digital book in flipbook format that can be accessed online. This e-learning material can be accessed by scanning a QR code using the Assemblr Edu app, Google Lens, or a smartphone's built-in scanner. The components of this Augmented Reality-assisted e-learning material consist of several parts, as follows.

Figure 2. Cover page

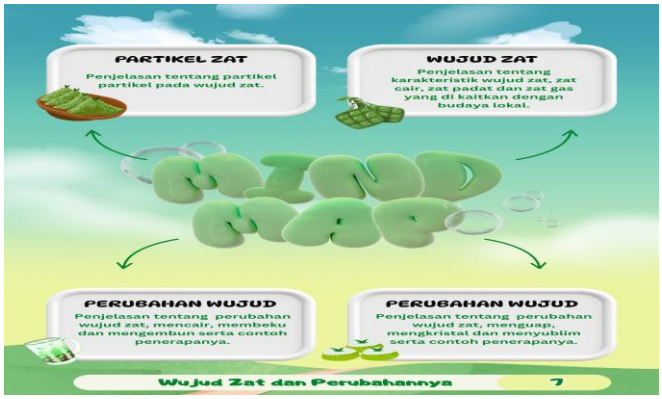

Figure 3. Cover page

Figure 4. Material concept map

Figure 5. CP and TP

Figure 6. Integrated ethnoscience material page

Figure 7. AR-assisted ethnoscience integrated material page

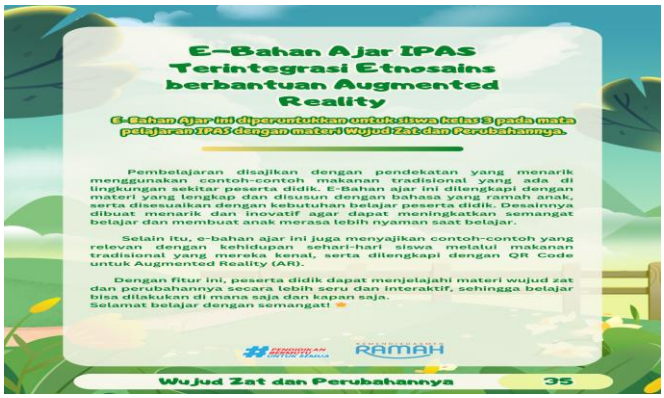

Figure 8. Back cover page

Figure 9. Display of e-teaching materials using flipbook

Figure 10. AR media with a process of changing the state of matter integrated with ethnoscience

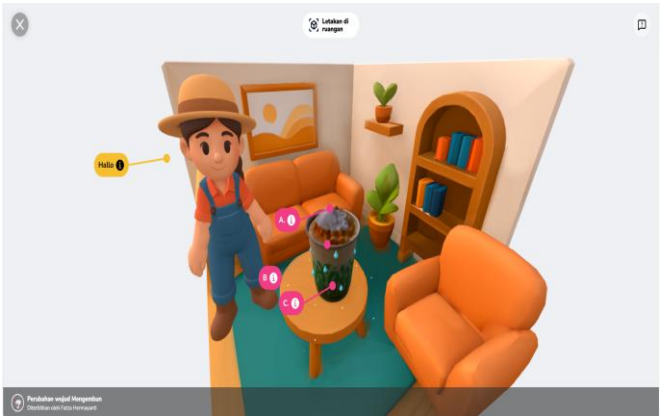

Figure 11. AR media with a process of changing the state of matter integrated with ethnoscience

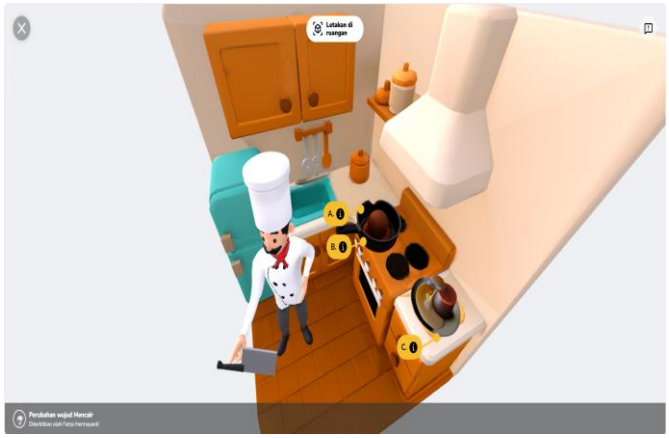

Figure 12. AR media with a process of changing the state of matter integrated with ethnoscience

Implementation and Evaluation Phase

The implementation phase was conducted through a product trial on a small group of 15 grade IV A students, conducted on April 18–19, 2026. During this phase, students were first given a pretest to determine their initial abilities. Next, the researcher explained the use of the integrated ethnoscience e-learning materials with Augmented Reality. Students then operated the e-learning materials independently, including utilizing the Augmented Reality feature by scanning the QR codes provided in each section of the material. The results of the small group trial showed that students were able to use the media effectively and achieved high posttest scores. Furthermore, no significant obstacles were encountered in the use of the media, so the product did not require revision and was deemed suitable for further large-group trials. The large-group trial was conducted on 21 grade IV B students of Muhammadiyah Elementary School, Kebumen, on April 22–28, 2026. This phase aimed to test the product's effectiveness in improving student learning outcomes on a broader scale. The next stage was evaluation, which aimed to determine the effectiveness of the use of e-learning materials integrated with Augmented Reality-assisted ethnoscience. Data collection was conducted by distributing questionnaires to fourth-grade students and teachers. The student questionnaire consisted of 10 items, while the teacher questionnaire consisted of 24 items. Respondents were asked to provide answers by placing a checkmark (√) on the available options based on their experience using the learning media. The results of this evaluation were used to determine the level of practicality and acceptability of the product, as well as to provide a basis for improving the developed learning media.

Feasibility of E-learning Materials Assisted with Augmented Reality

The feasibility of the developed product was determined based on validation results by linguists, material experts, and media experts, supported by feedback from students and teachers. The validation process was conducted by lecturers at Semarang State University to obtain assessments and input for product improvements. Aspects assessed in the development of e-learning materials integrated with Augmented Reality-assisted ethnoscience included language, material, and media components to ensure product quality and effectiveness. From a linguistic perspective, the sentences are structured simply, communicatively, and appropriately to the characteristics of elementary school students, facilitating understanding of the material. From a media perspective, the product is designed to be easily accessible, practical, and support flexible learning in various situations.

Assessment by subject matter experts includes the appropriateness of the content to learning outcomes, clarity of learning steps, and the accuracy of the learning outcome assessment instruments. At this stage, the Augmented Reality-assisted e-learning materials received several suggestions for improvement, including adjusting the question grid to align with students' cognitive domains, aligning the learning syntax with the material presented, and summarizing the conclusion section to make it more effective and informative. Meanwhile, assessment by media experts covers aspects of visual appearance, media communication, interactive and engaging design, benefits of media use, and technical aspects of the software. This assessment aims to ensure that the e-learning materials are not only effective in conveying material, but also engaging, easy to operate, and appropriate to students' needs. The validation results from subject matter and media experts are presented in Table 2.

Table 2. Results of the Feasibility Validation of Augmented Reality (AR)-Assisted E-Learning Materials

Validator	Category Indicators	Percentage (%)	Eligibility criteria
Linguist	Language used is appropriate to the students' thinking level	96	Very Worthy
	Language used complies with Indonesian grammar rules		
	Display and visual communication of learning media		
Materials Expert	Learning media design		
	Benefits of learning media	94	Very Worthy
	Smooth presentation		
	Suitability of materials		
Media Members	Learning steps	100	Very Worthy
	Assessment		

Based on the validation results presented in Table 2, the development of integrated ethnoscience e-teaching materials using Augmented Reality was declared "very feasible" by three validators: a material expert, a language expert, and a media expert, for implementation with fourth-grade students at Muhammadiyah Elementary School in Kebumen. This assessment was obtained after the author made improvements based on the suggestions and input provided by the validators. The product revision process was carried out based on input from each validator. The material expert validator provided suggestions regarding adjusting learning objectives, rearranging the order of material presentation, and refining the discussion on states of matter and their changes to make it more systematic and aligned with learning outcomes. The language expert validator provided input on simplifying sentence usage for easier understanding by students, and improving the structure and language rules in the material explanations. Meanwhile, the media expert validator provided suggestions regarding the display aspect, specifically the selection of a more readable font, by replacing the previously comic-style font with a more formal, learning-appropriate font. After going through the revision stage, the developed product was then tested to determine the response of fourth grade students and teachers to the use of integrated ethnoscience e-teaching materials assisted by Augmented Reality on the material of states of matter and their changes. The responses were obtained through student and teacher response questionnaires used to assess the practicality and acceptance of the product in the science learning process. The following are the results of AR-assisted ethnoscience integrated e-teaching materials before and after revision by the author:

Figure 13. Front cover before revision

Figure 14. Front cover after revision

Figure 15. Introduction before revision

Figure 16. Introduction after revision

Figure 17. Foreword before revision

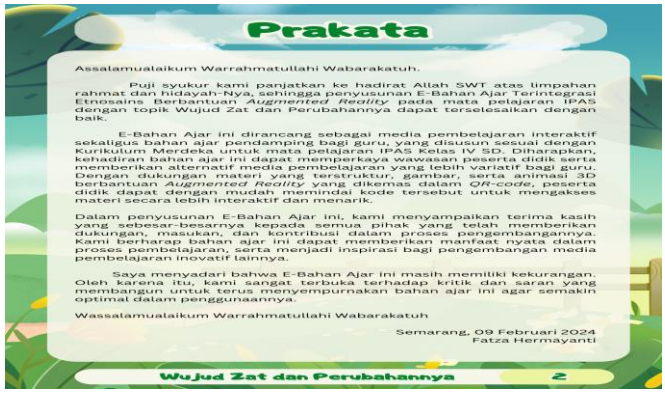

Figure 16. Foreword after revision

Practicality of Augmented Reality-assisted E-learning Materials (Product Trial)

Based on Table 3, the next stage was a small-scale product trial involving 15 fourth-grade students at Muhammadiyah Elementary School in the 2024/2025 academic year. The students were selected heterogeneously based on their ability level, consisting of 5 students with a high level of understanding, 5 students with a medium level of understanding, and 5 students with a low level of understanding. This grouping aimed to determine the product's acceptability across various levels of student ability. After the learning process using the e-learning materials integrated with ethnoscience and augmented reality was completed, teachers and students were asked to complete a response questionnaire regarding the use of the learning media. The questionnaires given to teachers and students each consisted of 20 items covering three assessment aspects: material quality, language quality, and media quality.

Table 3. Results of a Small-Scale Student and Teacher Questionnaire

Validator	Percentage (%)	Eligibility Criteria
Fourth Grade Teacher	96	Very Positive
Student	94.20	Very Positive

The questionnaire instrument used a Likert scale of 1–4, in which respondents provided ratings based on their experiences using the developed product. The questionnaire results were then analyzed to determine the product's suitability based on predetermined criteria. These criteria include: very feasible (82%–100%), feasible (63%–81%), fairly feasible (44%–62%), less feasible (25%–43%), and very inadequate (<25%). Through this small-scale trial, it is hoped that an initial overview of the practicality, acceptability, and quality of the product can be obtained before proceeding to a larger-scale trial. The following table presents the student and teacher questionnaire responses.

Table 4. Results of the Large-Scale Student and Teacher Questionnaire Responses

Validator	Percentage (%)	Eligibility Criteria
Fourth Grade Teacher	98	Very Positive
Student	98	Very Positive

Based on the data presented in Table 4, teacher and student responses in the small-scale trial indicated a very positive response to the use of the integrated ethnoscience e-learning materials supported by Augmented Reality. This is demonstrated by a score of 98.00%, which falls into the "very positive" category. This result indicates that the developed product has a very high level of acceptance and is easy for students to use in the learning process. Furthermore, responses from the large-scale trial also showed a similar trend. The Augmented Reality e-learning materials achieved a score of 98.02%, also in the "very positive" category. This assessment was based on 20 questionnaire items using a Likert scale of 1–4, covering aspects of material quality, language, and media. The high percentages in both trial stages indicate that the developed e-learning materials are not only engaging and easy to use, but also effectively support the learning process. Thus, the e-learning materials integrated with ethnoscience and Augmented Reality can be declared practical and feasible for use in science learning activities in elementary schools.

Effectiveness of E-learning Materials Assisted with Augmented Reality in Improving Student Learning Outcomes

Product evaluation was conducted through a trial on all fourth-grade students of Muhammadiyah Elementary School as research subjects. This stage aimed to assess the suitability, feasibility, and effectiveness of the e-learning materials integrated with ethnoscience and Augmented Reality in science learning. Effectiveness was assessed by comparing student learning outcomes before and after using the media through a pretest and posttest. In addition, to determine user responses, the researchers also distributed a questionnaire to fourth-grade teachers. The results showed that 98.00% of teacher responses were in the very positive category, indicating that the e-learning materials integrated with ethnoscience and Augmented Reality were deemed capable of supporting the learning process and had the potential to improve student learning outcomes.

Quantitative data analysis was conducted using a paired sample t-test to determine differences in student learning outcomes before and after using the media. Before conducting the hypothesis test, a normality test was first performed to ensure that the data were normally distributed, as a prerequisite for parametric analysis. Decisions regarding the normality test were based on the significance value: if the significance value is >0.05, the data are normally distributed, whereas if the significance value is <0.05, the data are not normally distributed. The results of the normality test are presented in Table 5 as a basis for determining the appropriateness of using the paired sample t-test in subsequent data analysis.

Table 5. Data Normality Test Results

Normality test			
			Shapiro-Wilk
	Statistics	Df	Sig.
Pretest Score	.945	21	.120
Posttest Score	.962	21	.310

Based on the analysis results in Table 5, it is known that the data are normally distributed, as indicated by a significance value greater than 0.05. Therefore, the data meet the assumptions for parametric statistical testing. Next, a paired sample t-test was conducted to determine whether there was a significant difference between student learning outcomes before and after using the integrated ethnoscience e-learning materials assisted by Augmented Reality. Decision-making in this test was based on the significance value (Sig. 2-tailed), with the following criteria: if the significance value is <0.05, there is a significant difference between the pretest and posttest scores; conversely, if the significance value is >0.05, there is no significant difference. This test aims to measure the effectiveness of the developed learning media in improving student learning outcomes in the science subject, specifically regarding the state of matter and its changes. The results of the paired sample t-test analysis are presented in Table 6.

Table 6. Paired Sample T-test Results

Paired Sample Test			
Pretest Score	T-statistic	Degree of freedom	Sig. (2-tails)
Posttest Score	11.99	21	.000

The data in the table above shows a 2-tailed significance value of 0.000 < 0.05, thus concluding that there is a significant difference between the pretest and posttest using the Etnoscience-integrated e-learning materials with Augmented Reality. Furthermore, this is further confirmed by the average increase (N-gain) test, which compares the increase in pretest and posttest scores, calculated using the n-gain index analysis in Table 7. The data in the table above shows a 2-tailed significance value (Sig.) of 0.000 < 0.05, thus concluding that there is a significant difference between the pretest and posttest scores after using the Etnoscience-integrated e-learning materials with Augmented Reality. These results indicate that the developed learning media significantly improved student learning outcomes in the science subject. Furthermore, the improvement in learning outcomes was further strengthened by the N-Gain index analysis, which compares pretest and posttest scores to determine the level of improvement. The results of the N-Gain calculation are presented in Table 7, which shows that the use of e-learning materials integrated with ethnoscience and augmented reality effectively improves student learning outcomes. Based on the results of the paired sample t-test and N-Gain analysis, it can be concluded that the developed learning media not only provides a significant difference but also provides improvements in learning outcomes that are in the good category. The following N-Gain test results are presented in Table 7.

Table 7. N-Gain Test Results

Difference	Middle	N-Profit	Group
Pretest	50.25	0.80	High
Posttest	90.10		

Based on the N-Gain test results, a value of 0.80 was obtained, which is in the high category (g > 0.7). This result indicates a significant increase in student learning outcomes between the pretest and posttest scores after using the e-learning materials integrated with ethnoscience and augmented reality. Furthermore, the feasibility and practicality tests showed that the developed e-learning materials received very positive responses from both students and teachers. This indicates that the learning media is not only effective in improving learning outcomes but also easy to use and well-received in the learning process. Overall, the data analysis results indicate that the e-learning materials integrated with ethnoscience and augmented reality meet the criteria of feasibility, practicality, and effectiveness in improving the learning outcomes of fourth-grade elementary school students in science, particularly on the topic of states of matter and their changes in Phase B. This success is supported by several factors. First, the integration of ethnoscience into e-learning materials contributes to increasing student learning motivation by linking the material to local culture, particularly traditional foods closely related to everyday life. This approach makes learning more contextual and meaningful, enabling students to more easily grasp the concept of states of matter and their changes (Sariwedani et al., 2025).

Furthermore, simple practical activities, such as making ice cream, actively engage students in observing the states of matter and the changes that occur. This supports meaningful learning and centers on students' direct experiences (Morris et al., 2025). Second, e-learning materials integrated with ethnoscience, supported by Augmented Reality, are an innovative and practical learning medium (Rizki et al., 2025; Putri et al., 2025). This medium not only supports classroom learning but also enables students to learn independently outside of class. Thus, it can assist students with varying levels of understanding, including those who require more time to grasp the material. The Augmented Reality feature also provides interactive visualizations that help explain abstract concepts in a more concrete and understandable way (Gjoka & Pireva Nuci, 2025; Haryadi et al., 2026). Third, the attractive design of e-learning materials, complemented by images, videos, and three-dimensional (3D) objects, can increase student interest and engagement in learning. This media not only helps students understand concepts but also stimulates curiosity and active participation in the learning process. Thus, the use of this media directly contributes to improving student learning outcomes (Ritonga et al., 2024; Hasanah Lubis et al., 2023). Fourth, the use of Augmented Reality technology as an innovation in learning provides an interactive learning experience and supports active student engagement (Tanjung & Louise, 2024; Prananta et al., 2024).

This technology not only facilitates conceptual understanding but also has the potential to develop critical thinking skills and visual-spatial skills. Furthermore, the developed e-learning materials have the advantage of flexibility, as they can be accessed anytime and anywhere via smartphones (Khairani & Prodjosantoso, 2023; Aththibby et al., 2024). This makes it easy for students and teachers to utilize the media as a practical and efficient learning resource (Ramakrishnappa et al., 2025; Amirahma & Setyasto, 2024). Therefore, based on the overall research findings, it can be concluded that the e-learning materials integrated with ethnoscience using Augmented Reality are a suitable, practical, and effective learning medium for use in science teaching for fourth-grade elementary school students (Niman, 2025; Salmiyanti et al., 2023). This media is able to support more meaningful,

contextual, and engaging learning through the integration of local culture and technology (Perales & Bedoya Ulla, 2025; Ratri et al., 2025).

Conclusion

This study concludes that the design for developing e-learning materials integrated with Augmented Reality for ethnoscience, which includes a cover, user manual, concept maps, learning outcomes and objectives, materials integrated with local cultures, learning videos, Augmented Reality features, and student worksheets, is feasible, practical, and effective for use in learning. The product's feasibility was demonstrated through validation by linguists, media experts, and material experts, which categorized it as "very feasible" after revisions were made based on the recommendations provided. The product's practicality was demonstrated by the very positive responses from teachers and students, with a percentage of 98.00% in the small-scale trial and 98.02% in the large-scale trial, which falls within the "very positive" criteria. The effectiveness of the e-learning materials integrated with Augmented Reality for science learning was also confirmed based on pretest and posttest results, which showed significant improvements. The results of the paired sample t-test showed a significance value of 0.000 (<0.05), which means there is a significant difference between learning outcomes before and after the use of media. In addition, the N-Gain test result of 0.80 is included in the high category, which indicates a significant increase in student learning outcomes. Thus, the development of integrated ethnoscience e-teaching materials assisted by Augmented Reality is declared feasible, practical, and effective in improving student learning outcomes on the material of states of matter and their changes. This research provides a positive contribution to science learning in elementary schools, especially in presenting more contextual, interactive, and meaningful learning through the integration of local culture and technology. Therefore, this e-teaching material can be an alternative innovative solution in supporting enjoyable learning through the synergy of tradition and technology in elementary schools.

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Conflicts of Interest
The author declares no conflict of interest.

References

Almardiyah, A., Syaputra, W. Z., Yulistina, N., Rozi, M. F., Mardiansyah, R., & Maiziani, F. (2023). Garhana: Development Of Applications For Elementary School Students To Learn About Solar And Lunar Eclipses Based On Augmented Reality. *International Journal of Ethnoscience, Bio-Informatic, Innovation, Invention and Techno-Science*, *2*(01), 1–5. https://doi.org/10.54482/ijebiiits.v2i01.183

Amirahma, S., & Setyasto, N. (2024). Development of Augmented Reality-Assisted Teaching Materials in Science Subjects: Solar System Topic. *Jurnal Penelitian Pendidikan IPA*, *10*(5), 2346–2355. https://doi.org/10.29303/jppipa.v10i5.7027

Aththibby, A. R., Rosa, F. O., Farida, N., & Prihandono, E. (2024). Development of Astronomy Learning Modules on the Subject of the Solar System Integrated with Augmented Reality Videos. *Jurnal Penelitian Pendidikan IPA*, *10*(5), 2760–2767. https://doi.org/10.29303/jppipa.v10i5.4873

Branch, R. M. (2009). *Instructional Design: The ADDIE Approach*. Springer US. https://doi.org/10.1007/978-0-387-09506-6

De Sarkar, T. (2023). Augmented reality applications and the future library. *Library Hi Tech News*, *40*(9), 7–11. https://doi.org/10.1108/LHTN-07-2023-0129

Faiza, M. N., Yani, M. T., & Suprijono, A. (2022). Efektivitas Penggunaan Media Pembelajaran IPS Berbasis Augmented Reality untuk Meningkatkan Kompetensi Pengetahuan Siswa. *Jurnal Basicedu*, *6*(5), 8686–8694. https://doi.org/10.31004/basicedu.v6i5.3901

Ginanjar, A. E., Anggraeni, A. D., Surjanti, J., Dewi, R. M., & Ghofur, M. A. (2024). Pengembangan bahan ajar majalah interaktif berbantuan augmented reality untuk meningkatkan hasil belajar dan keterampilan kolaborasi siswa. *EQUILIBRIUM : Jurnal Ilmiah Ekonomi Dan Pembelajarannya*, *12*(2),

106. https://doi.org/10.25273/equilibrium.v12i2.19545

Gjoka, A., & Pireva Nuci, K. (2025). Exploring the Role of Augmented Reality in STEAM Learning Environments: Evidence from Geometry Education. *Information*, *16*(12), 1113. https://doi.org/10.3390/info16121113

Haryadi, R., Pujiastuti, H., & Utomo, D. W. (2026). Interactive visualization of thermodynamic concepts through augmented reality to improve critical thinking. *Computers & Education: X Reality*, *8*, 100137. https://doi.org/10.1016/j.cexr.2026.100137

Hasanah Lubis, L., Febriani, B., Fitra Yana, R., Azhar, A., & Darajat, M. (2023). The Use of Learning Media and its Effect on Improving the Quality of Student Learning Outcomes. *International Journal Of Education, Social Studies, And Management (IJESSM)*, *3*(2), 7–14. https://doi.org/10.52121/ijessm.v3i2.148

Hikmawati, H., Sutrio, Wahyudi, & Syahidi, K. (2022). Effects of Learning with Ethnoscience Context on Learning Outcomes in Cognitive Aspects of Prospective Physics Teacher Students. *Jurnal Penelitian Pendidikan IPA*, *8*(6), 2793–2801. https://doi.org/10.29303/jppipa.v8i6.2388

Imron, I., Pramono, S. E., Rusilowati, A., Sulhadi, S., & Samsudin, A. (2024). Analysis of the Use of Polypad-Based Educational Media on Mathematics Teacher Competencies in Indonesia: A Structural Equation Modelling (SEM) Approach. *Journal of Advanced Research in Applied Sciences and Engineering Technology*, 16–31. https://doi.org/10.37934/araset.53.1.1631

Khairani, R. N., & Prodjosantoso, A. K. (2023). Application of Augmented Reality on Chemistry Learning: A Systematic Review. *Jurnal Penelitian Pendidikan IPA*, *9*(11), 1221–1228. https://doi.org/10.29303/jppipa.v9i11.4412

Lee, K., Jeong, Y., & Yoon, B. (2017). Developing an research and development (R&D) process improvement system to simulate the performance of R&D activities. *Computers in Industry*, *92–93*, 178–193. https://doi.org/10.1016/j.compind.2017.08.001

Lei Pan, & Songco, E. A. (2023). Exploration leadership that advancing creative collaboration for teachers: A thematic analysis of a case study in a college of fine arts in China. *International Journal of Research in Business and Social Science (2147- 4478)*, *12*(7), 208–223. https://doi.org/10.20525/ijrbs.v12i7.2911

Malahayati, E. N., & Zunaidah, F. N. (2021). Analisis Kebutuhan Bahan Ajar Mata Kuliah Kurikulum. *Jurnal Basicedu*, *5*(6), 6218–6226. https://doi.org/10.31004/basicedu.v5i6.1802

Masbukhin, F. A. A., & Sausan, I. (2023). Analyzing the Implementation of Kurikulum Merdeka: Insights from Chemistry Educators in Gunung Kidul Vocational Schools. *Jurnal Penelitian Pendidikan IPA*, *9*(12), 11250–11260. https://doi.org/10.29303/jppipa.v9i12.5991

Masruroh, L., Dafik, & Suprapti. (2020). The analysis of the implementation of multi techniques based learning media in improving the elementary school students' higher order thinking skill in solving exponential problem. *Journal of Physics: Conference Series*, *1563*(1), 012063. https://doi.org/10.1088/1742-6596/1563/1/012063

Morris, T. H., Bremner, N., & Sakata, N. (2025). Self-directed learning and student-centred learning: A conceptual comparison. *Pedagogy, Culture & Society*, *33*(3), 847–866. https://doi.org/10.1080/14681366.2023.2282439

Mystakidis, S. (2021). Deep Meaningful Learning. *Encyclopedia*, *1*(3), 988–997. https://doi.org/10.3390/encyclopedia1030075

Niman, E. M. (2025). Embedding local culture in social studies: Pathways to strengthen social-emotional learning in primary education. *Frontiers in Education*, *10*, 1655528. https://doi.org/10.3389/feduc.2025.1655528

Nurdiyanti, N., Wajdi, M., & Magfirah, N. (2024). Impelementation of Kurikulum Merdeka (Freedom curriculum) in science learning: A case study in Sekolah Indonesia Kuala Lumpur, Malaysia. *Edelweiss Applied Science and Technology*, *8*(6), 184–196. https://doi.org/10.55214/25768484.v8i6.2035

Perales, W., & Bedoya Ulla, M. (2025). Technology in EFL contextual teaching and learning: Teachers' practices and perspectives in a Thai university. *Heliyon*, *11*(17), e44169. https://doi.org/10.1016/j.heliyon.2025.e44169

Prabowo, D. W., Bramastia, B., Sarwanto, S., & Cohen, J. (2024). Connecting Indigenous Knowledge of Keris with Science Through an Ethnoscience E-module: A Case Study in Surakarta, Indonesia. *Jurnal Pendidikan Sains Indonesia*, *12*(3), 693–704. https://doi.org/10.24815/jpsi.v12i3.38652

Prananta, A. W., Rohman, A., Agustin, R., & Pranoto, N. W. (2024). Augmented Reality for Interactive, Innovative and Fun Science Learning: Systematic Literature Review. *Jurnal Penelitian Pendidikan IPA*, *10*(SpecialIssue), 45–51. https://doi.org/10.29303/jppipa.v10iSpecialIssue.7519

Putri, R. M., Asrizal, & Fitri, M. N. (2025). Development of E-Physics Teaching Material Integrated with Augmented Reality and Ethno-Meaningful Learning to Promote Students' 21st Century Skills.

Jurnal Penelitian Pendidikan IPA, *11*(7), 1172–1185. https://doi.org/10.29303/jppipa.v11i7.12214

Ramakrishnappa, M., Manjegowda, A., Kulkarni, M., S., & Rajgopal, V. T. (2025). An Analytical Study of Augmented and Virtual Reality in Online Learning: Exploring Technological Advancements and Pedagogical Impacts. *Journal of Digital Learning And Distance Education*, *4*(7), 1791–1800. https://doi.org/10.56778/jdlde.v4i7.677

Ratri, D. P., Rachmajanti, S., Anugerahwati, M., Laksmi, E. D., & Gozali, A. (2025). Fostering cultural competence: Developing an English syllabus for young learners in the Indonesian EFL context with emphasis on local culture to maintain students' identity. *Cogent Education*, *12*(1), 2440177. https://doi.org/10.1080/2331186X.2024.2440177

Ritonga, A. R., Dalimunthe, M. A., Nur'aini, & Januarini, E. (2024). Utilization Of Digital Media in Improving Student Literacy (Case Study at SDN 10 Rantau Selatan). *CONTENT: Journal of Communication Studies*, *2*(02), 01–08. https://doi.org/10.32734/cjcs.v2i02.18117

Rizki, I. A., Mirsa, F. R., Islamiyah, A. N., Saputri, A. D., Ramadani, R., & Habibbulloh, M. (2025). Ethnoscience-enhanced physics virtual simulation and augmented reality with inquiry learning: Impact on students' creativity and motivation. *Thinking Skills and Creativity*, *57*, 101846. https://doi.org/10.1016/j.tsc.2025.101846

Salmiyanti, S., Erita, Y., Putri, R. S., & Nivetiken, N. (2023). Augmented Reality (Ar) In Learning Social Science (Ips) In Elementary Schools. *Journal Of Digital Learning And Distance Education*, *1*(10). https://doi.org/10.56778/jdlde.v1i10.51

Sariwedani, N. M. G., Werang, B. R., & Sudarma, I. K. (2025). Contextual-Based Interactive Learning Video Media to Improve Science Learning Outcomes of Grade VI Elementary School Students. *MIMBAR PGSD Undiksha*, *13*(2), 218–228. https://doi.org/10.23887/jjpgsd.v13i2.93717

Sri Asmini, N. K., Rati, N. W., & Paramartha, W. E. (2025). Interactive Multimedia Based on Augmented Reality for Photosynthesis Material to Improve Science Learning Outcomes of Fourth Grade Elementary School Students. *MIMBAR PGSD Undiksha*, *13*(2), 297–307. https://doi.org/10.23887/jjpgsd.v13i2.93922

Tanjung, A. K. P., & Louise, I. S. Y. (2024). Development of Student Worksheets with Discovery Learning Models Based on Augmented Reality in Chemical Bonding Materials to Increase Learning Motivation and Learning Outcomes. *Jurnal Penelitian Pendidikan IPA*, *10*(3), 1063–1074. https://doi.org/10.29303/jppipa.v10i3.6684

Völkel, S., & Nassenstein, N. (Eds.). (2022). *Approaches to Language and Culture*. De Gruyter. https://doi.org/10.1515/9783110726626

Wahyuningtyas, D. A., Rohmanurmeta, F. M., & Widyastuti, S. (2023). Improving the Critical Thinking Ability Science through Problem-Based Learning Model Assisted Student Worksheet Ethnoscience. *Jurnal PTK Dan Pendidikan*, *9*(1). https://doi.org/10.18592/ptk.v9i1.9002

Weng, C., Chen, C., & Ai, X. (2023). A pedagogical study on promoting students' deep learning through design-based learning. *International Journal of Technology and Design Education*, *33*(4), 1653–1674. https://doi.org/10.1007/s10798-022-09789-4

Widayati, W., Imron, I. A., Standsyah, R. E., & Putri, N. C. (2023). Systematic Literature Review: Penggunaan Komik Pada Pembelajaran Bahasa Indonesia. *Imajeri: Jurnal Pendidikan Bahasa Dan Sastra Indonesia*, *5*(2), 116–124. https://doi.org/10.22236/imajeri.v5i2.10604

Zidny, R., & Eilks, I. (2022). Learning about Pesticide Use Adapted from Ethnoscience as a Contribution to Green and Sustainable Chemistry Education. *Education Sciences*, *12*(4), 227. https://doi.org/10.3390/educsci12040227

Zuschaiya, D., Marni, & Valentina, A. D. (2024). Optimalisasi Hasil Belajar IPAS melalui Metode Talking Stick Berbantuan Media Audio Visual di Madrasah Ibtidaiyah. *JUDIKDAS: Jurnal Ilmu Pendidikan Dasar Indonesia*, *3*(3), 111–122. https://doi.org/10.51574/judikdas.v3i3.1490