p-ISSN 2355-5343
e-ISSN 2502-4795
http://ejournal.upi.edu/index.php/mimbar

Article Received: 11/09/2024; Accepted: 07/11/2024
Mimbar Sekolah Dasar, Vol.11(4), 659-676
DOI: 10.53400/mimbar-sd.v11i4.78657

The SIAR Book (Interactive Science with Augmented Reality) for Enhancing Science Process Skills of Students in Indonesia

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Abstract: The science process skills of elementary school students in Langsa city are still relatively low, despite these skills being a crucial element in science education based on the Merdeka curriculum. Additionally, teachers have reported several challenges, including the presence of abstract science material, textbooks that use two-dimensional visualizations, and the inability to practice all science concepts. This research developed the SIAR book (Interactive Science with Augmented Reality) to enhance science process skills. The study produced an elementary school science book that includes observational activities and integrates augmented reality (AR) to present more concrete three-dimensional visualizations. The objectives of this study were to create a valid and effective SIAR book product for improving science process skills. This research employed the ADDIE model (Analysis, Design, Development, Implementation, Evaluation) for development. Participants included three expert validators and 100 elementary school students. The results indicated that: (1) the SIAR book is highly valid for improving science process skills, with a validity score of 96.11%; (2) the SIAR book is effective in enhancing science process skills, achieving a gain score of 0.76, which falls within the high criteria. Based on these findings, it can be concluded that a book integrated with AR can assist students in improving their science process skills. As science process skills improve, students' understanding of science also increases. Therefore, science education in schools should leverage digital technology, as it meets students' needs and facilitates the learning process in science.

Keywords: Natural Science; Digital Learning Innovation; Interactive; Science Process Skills; Augmented Reality Technology.

1. Introduction

According to the Minister of Education, Culture, Research, and Technology Regulation Number 7 of 2022, science education at the elementary school level must be implemented through investigative activities related to scientific content, alongside the analysis of data and information in addressing everyday problems (Permendikbudristek, 2022). Such investigative activities, analysis, and communication are designed to facilitate students' achievement of two fundamental components in science education: process skills and scientific understanding. Science process skills encompass the ability to conduct scientific inquiries within the natural environment and are characterized by several key indicators, including: the formulation of scientific questions, the development of hypotheses, the identification of variables and control factors, the planning of experiments, the recording of data, the interpretation of results, and the drawing of conclusions (Beichumila et al., 2022).

Science process skills do not always follow a linear sequence; rather, they represent a dynamic cycle that must be adapted to the development and capabilities of students. These skills serve as tools for further exploration of the natural world through scientific inquiry (Alatas & Fachrunisa, 2018; Kruea-In & Thongperm, 2014; Shahali & Halim, 2010). According to the Decision of the Head of the Education Standards, Curriculum, and Assessment Agency Number 032/H/KR/2024, six indicators of science process skills for elementary school students are outlined: observing; questioning and predicting; planning and conducting investigations;

processing and analyzing data and information; evaluating and reflecting; and communicating results (Keputusan Kepala Badan Standar, 2024). Thus, science process skills are crucial for elementary students, considering both the meaningfulness of learning for the students and the necessity of adhering to governmental regulations. The issue of science process skills among elementary school students is not only significant in Indonesia but also worldwide. Various studies indicate that these skills remain underdeveloped among elementary students, prompting the implementation of solutions aimed at enhancement. These solutions include the adoption of inquiry-based approaches in science education (Mulyeni et al., 2019), the use of student-centered methodologies (Balanay & Roa, 2013), the incorporation of instructional materials that integrate indicators of science process skills within the content and practical steps (Ma et al., 2021; Yang et al., 2019), and the employment of assessments specifically designed to measure students' science process skills in accordance with their learning achievements (Gizaw & Sorsa, 2023).

1.1. Problem Statement

Preliminary findings of the research indicate that the science process skills of elementary school students in Langsa City are still relatively low, despite these skills being a crucial element in science education according to the Merdeka curriculum. Globally, science education emphasizes three important aspects: scientific content knowledge, science process skills, and scientific literacy (Aiman et al., 2020). Similarly, the Merdeka curriculum in Indonesia establishes two key elements that must be achieved: understanding of science and science process skills. Understanding of science is defined as students' ability to master scientific concepts or meet learning achievements in the cognitive domain. In contrast, science process skills refer to students' abilities to apply and validate scientific concepts in real-life contexts, thereby making science not only theoretical but also practical. However, initial observations in three public elementary schools in Langsa indicate that over 50% of students possess low science process skills. Consequently, there is a pressing need for solutions to enhance these skills among elementary school students.

Science process skills are recognized as 21st-century skills within science education (Virtič, 2022). Several compelling reasons underscore the necessity for elementary students to develop these skills. Proficient science process skills enable students to engage in critical and analytical thinking through scientific activities (Ahmed et al., 2023). Learning activities that focus on science process skills also foster innovation and creative thinking, as they involve all students in the resolution of scientific projects (Fredagsvik, 2022). Improving students' science process skills is tantamount to preparing them for higher levels of education, as advancing through educational stages typically results in increased material difficulty, greater depth of subject matter discussion, and a heightened awareness of the relevance of science concepts in everyday life. If educators and education stakeholders do not cultivate students' science process skills, these students may struggle to grasp scientific material both theoretically and practically. Moreover, students with low levels of science process skills are more likely to forget the scientific content they have learned and may not consciously recognize the connections between scientific concepts and their daily lives.

Preliminary observations also revealed various challenges expressed by classroom teachers, including the presence of abstract science content, the use of two-dimensional visualizations in textbooks, and the inability to practice all science concepts. In response to these challenges, a solution was proposed involving the integration of technology in elementary science education through the development of the SIAR book. The use of technology serves as an effective solution to enhance student engagement in science learning (Yun & Crippen, 2024), enabling students to study scientific material that cannot be practically applied through scientific activities such as visualizing three-dimensional representations or demonstrating concrete forms. Technology acts as a transformative force in education, reshaping the ways in which students actively engage with and understand science content (Yılmaz, 2923). Consequently, the integration of technology can help mitigate the negative stigma associated with abstract science concepts for students.

1.2. Related Research

Previous research indicates that the majority of public elementary schools in Indonesia are equipped with technological resources, such as Chromebooks. However, these devices are not being utilized to their full potential due to the absence of science-related content. According to Baysal et al. (2022) the enhancement of science process skills and innovative thinking can be achieved through the integration of digital resources within educational activities. Therefore, a proposed solution to address the challenges faced by these schools is the development of technological content in the form of augmented reality (AR), which will be embedded in an interactive science book aimed at improving students' science process skills.

Augmented reality (AR) represents a significant digital advancement currently gaining traction in the educational sector. The increasing application of AR as a resource for knowledge and research is largely due to its capacity to present information through a combination of real and digital imagery (Borgohain et al., 2022), effectively bridging the gap between the virtual and physical realms (Carolina, 2023). In the realm of science education, students engage not only in scientific inquiry but also in recognizing the beneficial impacts of digital technologies on their learning experiences. A bibliometric analysis conducted by Cecilia found that over a 25-year (1995-2020), a total of 3,475 studies addressed the integration of AR technology in educational contexts (Avila-Garzon et al., 2021). Notably, the bibliometric analysis for AR research in 2020 recorded the highest Scopus index, with 1,381 publications (Dewi et al., 2021). While prior investigations have outlined various advantages of AR technology in science education, none have incorporated AR into an interactive science book format.

Consequently, the objective of this research is to create an innovative product titled SIAR, which stands for Interactive Science with Augmented Reality. The designation "interactive science" signifies that the SIAR book is methodologically designed to engage students actively in the learning process, with a strong focus on developing science process skills. As a result, students will participate directly in activities such as observation, information analysis, evidence collection, documentation of findings, formulation of conclusions, and communication of results, all of which correspond to the indicators of science process skills. Additionally, the SIAR book utilizes AR technology to present three-dimensional visualizations, thereby making scientific concepts more engaging and concrete for students. The incorporation of tangible three-dimensional visualizations alongside participatory and interactive learning activities is expected to enhance students' theoretical and practical understanding of science. This approach aligns with Piaget's theory, which posits that children aged 7-11 develop cognitively through logical reasoning concerning concrete objects they encounter (Miller, 2010; Rabindran & Madanagopal, 2020), and through the comprehension of concepts via conservation and exploration as well as foundational literacy skills and scientific reasoning (Malik & Marwaha, 2024).

1.3. Research Objectives

Thus, this research focuses on the development of the SIAR book (Interactive Science Assisted by Augmented Reality) to enhance the science process skills of elementary school students. In addition to incorporating augmented reality, the SIAR book provides instructions for students to engage in interactive practical activities, thereby facilitating the improvement of their science process skills. The research will address the following research questions:

1. How can the SIAR book (Interactive Science Assisted by Augmented Reality) be developed to effectively enhance the science process skills of students?
2. Is the SIAR book (Interactive Science Assisted by Augmented Reality) effective in enhancing the science process skills of elementary school students?

2. Theoretical Framework

2.1. Science Education in Elementary Schools

Science is a discipline that studies phenomena and events in the universe through scientific inquiry. It encompasses various fields, including biology, physics, chemistry, and astronomy (Strat et al., 2024). In the Merdeka curriculum, the subject of science is integrated with Social Studies, resulting in the combined subject known as Natural and Social Sciences (IPAS). This integration aims to encourage students to manage their natural and social environments as a cohesive whole (Nurani et al., 2022). Furthermore, IPAS is introduced in the third grade during phase B of the Merdeka curriculum, with the goal of strengthening students' awareness of their surroundings.

The characteristics of science include: scientific processes, scientific attitudes, scientific products, and applications (Elisa et al., 2023). The scientific process involves investigative activities aimed at discovering scientific concepts or describing existing scientific materials. Within the IPAS framework of the Merdeka curriculum, one specific scientific process has been identified as science process skills. These skills are defined as the competencies required to conduct investigations, enabling students to generate concepts, theories, principles, and scientific facts. Science process skills are closely related to scientific literacy, as outlined by PISA 2018, which includes the ability to explain phenomena scientifically, evaluate and design scientific investigations, and interpret data and evidence in a scientific manner. Therefore, science process skills are essential for elementary students, serving as a foundational element of their scientific knowledge.

2.2. 21st Century Education

21st-century education emphasizes advancements in technology, globalization, and the changing demographics of students (Rahiman & Kodikal, 2024). Consequently, this educational approach impacts the skills relevant to current needs. In elementary science education, several key skills must be developed: critical thinking, creativity, communication, problem-solving abilities, and environmental awareness (Darling-Hammond et al., 2020). All of these skills are interconnected with science process skills, which encompass three indicators related to critical and creative thinking: (1) observing; (2) planning and conducting investigations; and (3) processing and analyzing data and information. One indicator associated with problem-solving skills is questioning and predicting. An indicator related to environmental awareness involves evaluating outcomes and impacts, as well as reflecting on them. Finally, the communication indicator pertains to sharing results. Digital literacy can be achieved through the integration of augmented reality in the SIAR book developed in this study. Thus, one of the essential 21st-century skills needed by students in science education is science process skills.

2.3. Augmented Reality in Education

Augmented Reality (AR) in elementary science education represents an innovative and interactive approach. AR integrates digital elements with the real world, creating an immersive learning experience (Wang et al., 2024). Several methods for implementing AR in elementary science education include visualizing scientific concepts, contextual learning, and enhancing student engagement.

AR enables students to comprehend complex scientific concepts in a more accessible manner. For example, students can utilize AR to visualize the human body's movement system, including bones, muscles, and joints, in three-dimensional form. This three-dimensional visualization aids students in better understanding science concepts by connecting all components of the human skeletal system. Furthermore, this understanding fosters an increased awareness of the importance of maintaining their health. Additionally, AR has the potential to bridge curricular content with real-world applications. For instance, when students direct their devices at a barcode or an image of human bones, AR can provide detailed information, including the overall structure of bones viewable from multiple angles, the various types of bones in the human body, and the functions of each bone. AR also significantly

enhances student engagement in the learning process. This engagement can be achieved when AR is designed as gamified experiences, interactive quizzes, or guided investigations. Consequently, students are encouraged to interact with the AR content out of curiosity about the outcomes they might achieve. This sense of curiosity is a fundamental starting point for fostering interest in learning.

3. Method

3.1. Research Design

This study employs a research and development (R&D) design aimed at creating innovative products and evaluating their feasibility and effectiveness. The chosen R&D framework for product development is the ADDIE model, which stands for Analysis, Design, Development, Implementation, and Evaluation (Niekrenz & Spreckelsen, 2024). The innovation resulting from this research is the SIAR book (Interactive Science Based on Augmented Reality), which is specifically designed to enhance the science process skills of elementary school students.

The selection of the ADDIE model is predicated on its structured approach to development, which includes a dedicated implementation phase intended to gather data regarding the product's effectiveness through trial applications. The effectiveness of the SIAR book will be assessed in relation to the improvement observed in students' science process skills. Consequently, the objectives of this research will be addressed through the systematic application of the ADDIE model within the R&D framework.

3.2. Participant

The respondents in this study are divided into two groups: those involved in the expert validation phase and those participating in the product trial implementation phase. The expert validation phase included three respondents. The first validator is the Vice Director for Academic Affairs and Student Affairs at the Graduate School of Universitas Negeri Medan and is recognized as an expert in elementary school curriculum content. The second validator is a professor at UIN Sumatera Utara Medan and specializes in digital teaching materials. The third validator is the head of the Indonesian Language Education Program at UIN Sumatera Utara Medan and a member of ADOBSI (the Association of Indonesian Language and Literature Lecturers), serving as a language expert.

In the implementation phase of the product trial, a total of 100 sixth-grade students participated, distributed across three schools: SD Negeri 1 Langsa, SD Negeri 3 Langsa, and SD Negeri 5 Langsa. Among the respondents, there were 58 male students and 42 female students. The selection of schools was based on collaboration with the researcher's academic program and the proximity of the schools to Universitas Samudra. The determination of the number of participants was informed by the total enrollment of sixth-grade students across these three schools.

3.3. Data Collection

The data collection techniques employed in this study include questionnaires and tests. The research instruments consist of an expert validation questionnaire and a test assessing science process skills. The expert validation questionnaire was developed based on the grid presented in Table 1.

Table 1. Outline of the Expert Validation Questionnaire

Expert	Aspect
Content	Quality if Content
	Presentation of Content
	Benefits
Digital Teaching Materials	Relevance of the SIAR Book
	Durability of the SIAR Book
	Physical Attributes of the SIAR Book
Languange	Clarity
	Communicative Quality
	Language Conventions

Table 1 contains three aspects of expert assessment, namely material suitability, digital teaching materials suitability, and language accuracy. From this grid, a questionnaire instrument was then developed and distributed to three validator experts to assess and provide suggestions for improvements the SIAR book. Apart from the questionnaire instrument, this research also used a science process skills test instrument. The science process skills test grid is presented in table 2.

Tabel 2. Indicator Science Process Skills

Indicator	Sub-Indicator
Observing	1. Carefully observe the human body's movement system through images in the interactive science book enhanced by Augmented Reality.
	2. Accurately record observation results on the observation sheet.
Questioning and Predicting	3. Formulate additional questions related to the observation results accurately.
	4. Make predictions based on logical reasoning.
Planning and Conducting Investigation	5. Meticulously plan scientific investigation activities to address the proposed questions.
	6. Accurately conduct scientific investigations using appropriate tools and materials.
Processing, Analyzing Data, and Information	7. Present data from the scientific investigation in the form of tables or graphs with precision.
	8. Compare the results of the scientific investigation with prior predictions, utilizing concrete evidence and logical reasoning.
Evaluating and Reflecting	9. Document conclusions based on comparative results and the content provided in the textbook.
	10. Accurately respond to questions related to the material that has been investigated.
	11. Provide feedback, impressions, and suggestions regarding the use of Augmented Reality and scientific investigation in the response questionnaire.
Communicating Results	12. Effectively communicate the results of activities using scientific language and a respectful tone.
	13. Graciously accept criticism and suggestions from peers and educators.

3.4. Data Analysis

The data obtained from the instruments were subsequently analyzed using quantitative analysis to assess validity and effectiveness. Validity is crucial in research as it establishes the legitimacy, accuracy, and relevance of an object The validity data in this study were derived from content

validation activities, specifically the validity estimated through expert assessments regarding the appropriateness or relevance of the content (Hendryadi, 2017). The experts providing evaluations of the suitability of the SIAR book included specialists in subject matter, digital instructional materials, and linguistics. The assessment questionnaire employed a Likert scale with four response alternatives: strongly agree, agree, disagree, and strongly disagree. The validity data were analyzed using the formula for average percentage scores as follows:

$$\boldsymbol{Percentage\ of\ validity} = \frac{\boldsymbol{Score\ obtained}}{\boldsymbol{Ideal\ MAximum\ Score}}\ \boldsymbol{x}\ \mathbf{100}\%$$ (Jannah & Putra, 2024)

Next, the level of validity was determined through an analysis of the product validity criteria table based on the Product Rating Scale (PRS), as presented in Table 3:

Table 3. Product Validity Criteria Based on the Product Rating Scale (PRS)

PRS Score Range	Validity Criteria
PRS > 81,25 %	Highly valid
62,50 % < PRS ≤ 81,25 %	Valid
43,75 % < PRS ≤ 62,50 %	Moderately valid
PRS ≤ 43,75 %	Not valid

Note. (Khadijah et al., 2022)

If a validation score greater than 65 is achieved, the SIAR book can be implemented with students to obtain effectiveness data. The effectiveness data were collected from the implementation of the SIAR book with fourth-grade elementary school students. The trial was conducted in three public elementary schools in Indonesia, with the number of respondents limited to 100 individuals. The data on science process skills were analyzed using the N-gain score formula as follows:

$\boldsymbol{g} = \frac{\boldsymbol{Skor\ Postest - Skor\ Pretest}}{\boldsymbol{Skor\ Ideal - Skor\ Pretest}}$ (Meltzer, 2002)

Notation:

g : N-gain score obtained
Posttest Score : Science process skills score after using the SIAR book
Pretest Score : Science process skills score before using the SIAR book
Ideal Score : Maximum score for science process skills

Next, the level of effectiveness will be determined through an analysis of the product effectiveness criteria based on the gain score, as presented in Table 4:

Table 4. Product Effectiveness Criteria Based on N-Gain Value

Nilai N-Gain	N-Gain Criteria	Effectiveness Criteria
g > 0,7	High	Effective
0,3 ≤ g ≤ 0,7	Medium	Quite effective
G < 0,3	Low	Not effective

Note. (Meltzer, 2002)

3.5. Validity and Reliability

Validity is the valid nature of the object being proven, and validity testing is the activity of testing or proving the validity of an object (Jatiyasa et al., 2024). The validity referred to in this subsection is the test of the validity and reliability of the science process skills test instrument used. Validity testing is carried out through criterion validity by testing the test on respondents

who are not research participants. The number of test trial respondents was 30 people. Validity data analysis uses the product moment correlation formula as follows:

$$r_{xy} = \frac{N\sum XY - (\sum X).(\sum Y)}{\sqrt{(N\sum X^2 - (\sum X)^2).(N\sum Y^2 - (\sum Y)^2)}}$$ (Gandung, 2022)

Description:
r_{xy} : product moment correlation score
x : item X score minus the average of item X scores
y : item Y score minus the average of item Y scores
Σ : summary coefficient

From the test validity results, it was found that 18 questions out of 26 questions were in the valid category with an average rcount greater than r_{table} (0.349). However, this study only used 13 questions out of 18 valid test questions. The selection of questions is based on the fulfillment of sub-indicators of science process skills and higher cognitive levels.

4. Findings

This study resulted in the SIAR book (Interactive Science Assisted by Augmented Reality) aimed at enhancing students' science process skills. The resulting SIAR book is available in both print and digital formats and includes 3D content utilizing Augmented Reality technology. The development of the SIAR book for science process skills was carried out through five stages of the ADDIE model: Analysis, Design, Development, Implementation, and Evaluation.

4.1. Analysis

In the analysis phase, it revealed that teachers and students needed an interactive science book featuring 3D images related to the human skeletal system for sixth-grade elementary school students. Specifically for sixth-grade elementary school students. This conclusion is based on four stages of analysis: learner analysis, task analysis, concept analysis, and specifying instructional objectives.

Figure 1. Stages of Learner Analysis

Figure 1 indicates that elementary school students demonstrate characteristics of being active, energetic learners who follow teacher instructions effectively. However, students appear disinterested in learning when the teacher relies solely on lectures without incorporating activities that stimulate their curiosity.

Figure 2 illustrates the tasks related to the science curriculum based on the textbook, along with the processes involved in completing these tasks. Generally, elementary school students prefer to engage in discussions and collaborative group work. However, the textbook primarily presents two-dimensional images and promotes independent reading without facilitating discussions, thereby hindering students' abilities to observe details effectively. This limitation adversely affects the development of students' science process skills. To enhance these skills, it is essential to provide a book that integrates three-dimensional digital features and encourages group-based practical activities. During the Concept Analysis stage, the specific science

content to be developed and the intended learning objectives are determined. In the Specifying Instructional Objectives stage, a research design was developed along with the targeted outcomes.

Figure 2. Stages of Task Analysis

4.2. Design

In the design phase, the writing team initiated the development of the SIAR book aimed at enhancing students' science process skills. This phase involved three key activities: media selection, format selection, and initial design. During the media selection step, the team identified suitable digital platforms and applications for creating the SIAR (Interactive Science book assisted by Augmented Reality). After discussions, it was decided that Microsoft Word, Canva, and Assemblr Edu would be utilized for this research. Each of these platforms serves distinct functions: Microsoft Word is employed for drafting the content of the SIAR book; Canva is used to design the book's background and layout, ensuring a more attractive and interactive appearance; and Assemblr Edu is utilized for creating augmented reality content and barcodes, enabling students to visualize material in a more concrete and three-dimensional manner. The design phase proceeded with the format selection step, which involved choosing font styles, text layout, and images. The subsequent step, initial design, encompassed drafting the text, creating augmented reality content, generating barcodes, and completing the preliminary design of the SIAR book. Scanned image of one of the augmented reality barcodes included in the SIAR book as illustrated in the Figure 3.

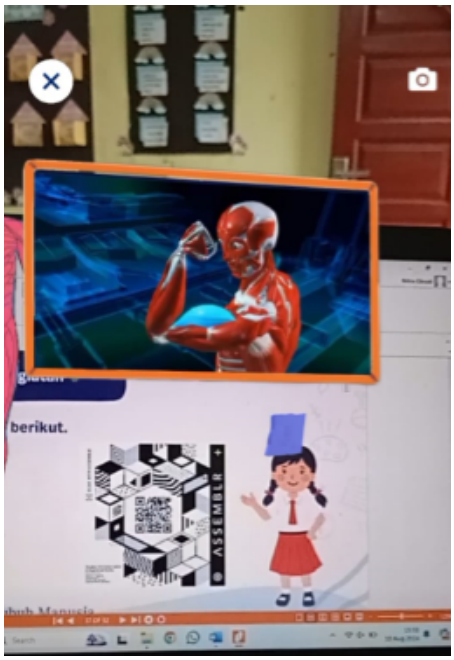

Figure 3: Scan Result of an Augmented Reality Barcode in the SIAR Book

4.3. Development

During the development phase, a validity test was conducted to obtain feasibility data from expert judgment and to produce a SIAR book that is suitable for enhancing students' science process skills. The results of expert validation are presented in Table 5.

Table 5. Expert Validation Result

judgement expert	First validation stage		Second validation stage	
	PRS (%)	Criteria	PRS (%)	Criteria
Material	80,56	Valid with revision notes	97,22	Very valid
Digital teaching material	81,67	Valid with revision notes	96,67	Very valid
Language	77,78	Valid with revision notes	94,44	Very valid
Average	80,00	Valid with revision notes	96,11	Very valid

From the expert validation results, it is proven that the SIAR book is categorized as very valid for use by elementary school students and is considered to be able to improve students' science process skills.

4.4. Implementation

Furthermore, the SIAR book was implemented in three elementary schools with a total of 100 respondents. The implementation process can be seen in Figure 4-9. From the implementation stage, the pretest and posttest scores for the science process skills of students who used the SIAR book were obtained. Data on students' science process skills are presented in Table 6.

Table 6. Science Process Skill Data

Data	N	Minimum	Maksimum	Average	Summary	Std.Deviation
Pretest	100	53,85	76,92	68,00	68000	8,80
Postest	100	69,23	100,00	91,77	9176,92	8,42
N-Gain	0,76					
N-Gain Criteria	High					
Effectiveness Criteria	Effective					

The use of the SIAR book significantly enhances students' science process skills. This improvement is evident in the average pre-test score of 68.00, which increased to 91.77 in the post-test. The analysis of the pre-test and post-test data yielded an N-gain score of 0.76, categorizing it as high. Therefore, it can be concluded that the implementation of the SIAR book is effective in improving students' science process skills.

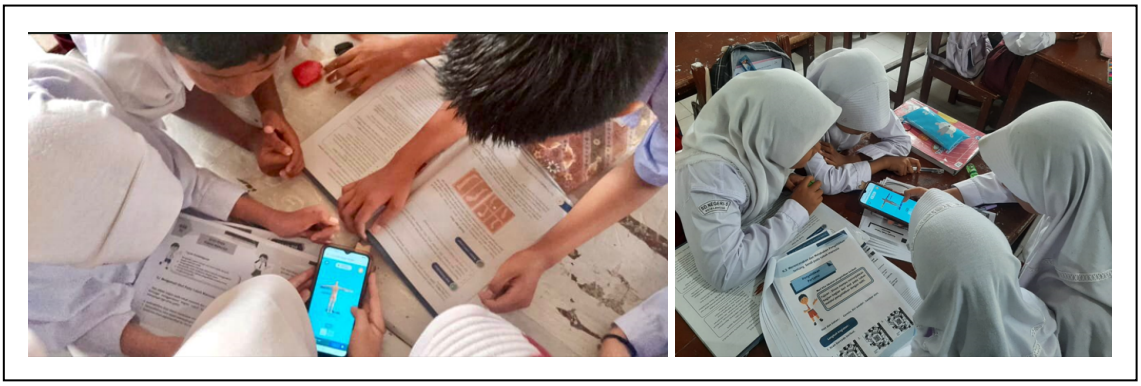

Figure 4. Students Observe Images Produced by Augmented Reality with Textbooks

Figure 5. Students Question and Predict Answers

Figure 6. Students Plan and Carry Out Investigations

Figure 7. Students Process, Analyze Data and Information

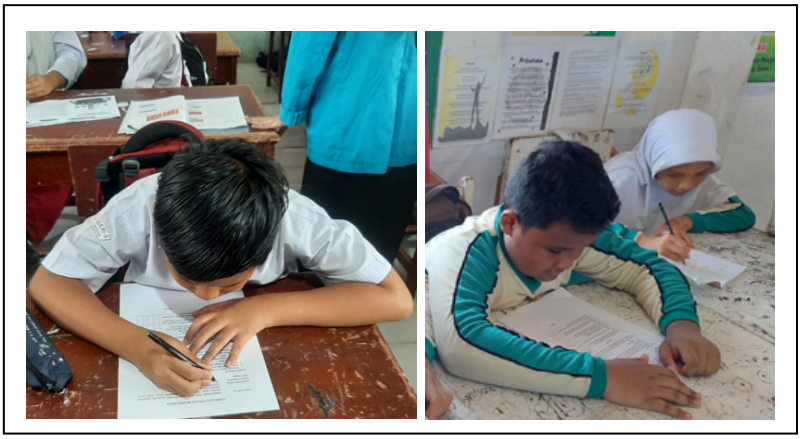

Figure 8. Students Evaluate and Reflect

Figure 9. Students Communicate Results

The score improvement was also observed across all sub-indicators of science process skills after students used the SIAR book. However, the increases were somewhat variable, as illustrated in the Figure 10.

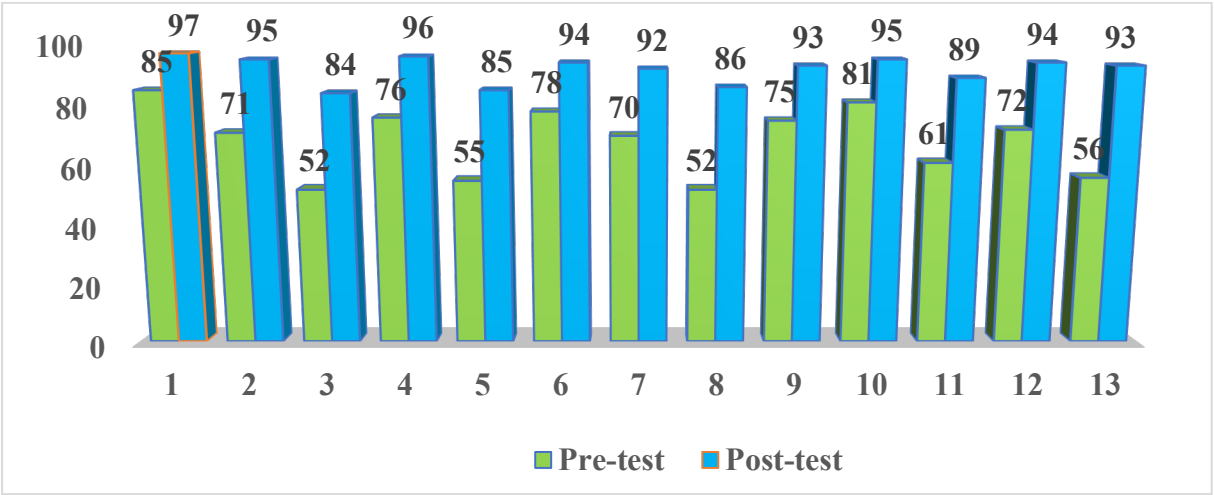

Figure 10. Increase in the Number of Students Based on Science Process Skills Sub-Indicators

Based on Figure 10, it is evident that after using the SIAR book:

1. There was an increase of 12 students, resulting in a total of 97 students who demonstrated the ability to observe the human body's movement system through images attentively.
2. An increase of 24 students was noted, bringing the total to 95 students who could accurately record their observations on the observation sheet.

3. There was an addition of 32 students, resulting in 84 students who were able to pose further questions related to their observations correctly.
4. An increase of 20 students occurred, culminating in a total of 96 students who could make predictions based on logical reasoning.
5. An additional 30 students were added, leading to a total of 85 students who could plan scientific investigations to answer the posed questions accurately.
6. There was an increase of 16 students, with a total of 94 students successfully conducting scientific investigations using tools and materials accurately.
7. An increase of 22 students was observed, resulting in 92 students who could present their scientific investigation data in the form of tables or graphs with precision.
8. An increase of 34 students occurred, bringing the total to 86 students who could compare their scientific investigation data with previous predictions using concrete evidence and logical reasoning.
9. An addition of 18 students was recorded, resulting in 93 students who could summarize conclusions based on comparison results and the material presented in the textbook.
10. An increase of 14 students was noted, leading to a total of 95 students who could accurately answer questions related to the material they had investigated.
11. There was an increase of 28 students, resulting in 89 students who could effectively communicate feedback, impressions, and suggestions regarding the use of Augmented Reality and scientific investigations on the response questionnaire.
12. An increase of 22 students occurred, culminating in a total of 94 students who could communicate their findings using scientific and respectful language.
13. An increase of 37 students was noted, bringing the total to 93 students who were able to accept feedback and suggestions from peers and teachers graciously.

5. Discussion

The SIAR book produced has proven to be highly suitable for use by elementary school students and effective in enhancing students' science process skills. The validity of the product was assessed through expert judgment from specialists in elementary school science content, digital instructional materials, and linguistics. The elementary school science expert rated the book at 97.22%, categorizing it as highly valid. The validity of educational products is crucial to ensure the quality of teaching materials. Research by Reiser & Dempsey (Reiser et al., 2024) indicates that assessments by educational experts provide high validity regarding the quality of educational materials. The achieved validity level of 97.22% demonstrates that the book aligns well with expected standards in the context of the curriculum and educational needs.

According to the elementary school science expert, the developed SIAR book contains content that aligns with the Independent Curriculum and learning objectives. Research by Tekir & Akar (2019) shows that policies, education, and content in teaching materials must be aligned for effective learning. Meij & Merx (2018) confirm that curriculum alignment is essential for achieving educational goals. Thus, the consistency between teaching material and curriculum serves as a crucial indicator for ensuring educational objectives are met.

The SIAR book includes the Pancasila learner profile, particularly the critical thinking element. This element is closely related to students' science process skills, as both critical thinking and science process skills share several indicators, such as investigation activities, processing investigation results, and drawing conclusions. Numerous studies have explored the connection between the two; for instance Tanti et al. (2020) found that science process skills positively impact students' critical thinking, while Özgelen (2012) concluded that science process skills should be integrated with advanced knowledge, such as critical reasoning. Therefore, the

development of the SIAR book, which incorporates the critical thinking element of the Pancasila learner profile, adds significant value and novelty to the product.

The SIAR book avoids ambiguous language or content. Several studies indicate that ambiguous language can lead to misconceptions or failure to achieve learning objectives. Fiset et al. (2023) noted that improper use of language can result in communication misunderstandings and affect performance. Clear communication and appropriate language usage can assist students in understanding the topics discussed, including the comprehension of the material covered (Janicki, 2024). Furthermore, the delivery of content using ambiguous language can hinder students' understanding. The teaching style and communication methods employed by teachers are critical aspects of material delivery, and teachers are encouraged to use unambiguous language (Khairinnisa et al., 2024).

According to the digital instructional materials expert, the developed SIAR book exhibits excellent characteristics of digital teaching materials by meeting various criteria, including alignment with learning outcomes, incorporation of science content, fostering student curiosity, promoting reading interest, being safe and easy for students to use repeatedly, having straightforward application installation across various devices, appropriate size and display, user-friendly symbols, appealing background selection, and layout and typography suited to user characteristics, as well as utilizing animations that support material delivery or student activity instructions. The linguistics expert confirmed that the developed SIAR book meets the criteria of sentence structure accuracy, selection of simple and user-appropriate vocabulary, inclusion of essential information relevant to the material, use of polite language consistent with the prevailing linguistic standards in Indonesia (PUEBI), and consistency in the use of terminology and specific navigation icons.

This study resulted in the SIAR book (Interactive Science Assisted by Augmented Reality) aimed at enhancing students' science process skills. During the analysis phase, issues were identified related to the low levels of students' science process skills, the difficulty of implementing science material, the abstract nature of science topics due to reliance on two-dimensional visualizations, and the suboptimal use of Chromebooks, which lacked science content. In the design phase, the SIAR book was developed using Canva for the book's background and Assembler platform for creating augmented reality content along with QR codes. The science content organized in the SIAR book aligns with the indicators of science process skills concerning the human body's movement system for elementary education. During the validation phase, the SIAR book underwent revisions based on expert feedback, achieving a score of 96.11, indicating a "very valid" criterion. In the implementation phase, the N-Gain score for elementary students' science process skills was recorded at 0.76, categorized as high, thus confirming that the SIAR book is effective in improving these skills.

This research has implications for both teachers and students regarding the use of Augmented Reality technology, demonstrating that it can yield positive outcomes when specifically designed to meet learning objectives. Furthermore, teachers are encouraged to be creative and innovative to make learning engaging for students and to achieve educational goals. However, various challenges remain in the utilization of Augmented Reality technology, including teachers' unfamiliarity with technological tools, limited internet access in certain areas, and insufficient English proficiency, as most digital platforms predominantly use English.

The limitations of this study include the lack of detailed breakdown for each sub-indicator of science process skills. This weakness arises from the time constraints of the research, which was conducted within a period of two months, and the specific focus on developing the SIAR book to enhance science process skills. Consequently, this initial study concludes with a discussion of data related to the development process of the SIAR book based on the ADDIE model phases, the findings, and its effectiveness in improving the science process skills of elementary students in Langsa city.

In light of the identified limitations, there is an opportunity for further research, especially concerning the effects of Augmented Reality (AR) technology on various sub-indicators of students' science process skills. This subsequent research is anticipated to yield comprehensive data regarding which specific sub-indicators can be affected by AR technology, as well as to uncover the reasons why certain sub-indicators may remain unchanged. Consequently, the findings from future investigations could be valuable resources for educators in their teaching practices, thereby significantly contributing to the improvement of students' science process skills.

6. Conclusion

The research findings indicate that the SIAR book is highly valid for enhancing students' science process skills, achieving a score of 96.11%. This effectiveness is attributed to the use of the Assembler platform for creating augmented reality content and QR codes, with the science content structured according to the indicators of science process skills. Additionally, the SIAR book is shown to be effective in improving science process skills, evidenced by a gain score of 0.76, classified as high. The study concludes that integrating books with augmented reality can assist students in enhancing their science process skills. This research aligns with the goals of the Fourth Industrial Revolution by combining physical technology (in the form of the SIAR book), digital utilization (through augmented reality content embedded in the book), and biological elements (involving human activities such as reading and conducting observations based on the instructions within the SIAR book). Furthermore, the study supports the objectives of Society 5.0 by integrating advanced technology (augmented reality) to address research challenges, specifically the low levels of science process skills and the abstract nature of science material. By enhancing students' science process skills, it is anticipated that the quality of future generations will improve. The study also offers implications for both teachers and students regarding the positive impact of utilizing augmented reality technology when specifically designed to achieve educational objectives. Additionally, it motivates teachers to be creative and innovative in making learning engaging for students and meeting learning goals.

Limitation

Challenges in utilizing Augmented Reality technology include teachers who are not accustomed to using technological tools and a lack of proficiency in English, as most digital platforms are typically in English.

Recommendation

This study recommends that teachers actively participate in training on the use of educational technology and pursue guidance to improve their English language skills. Additionally, it encourages researchers and education stakeholders to continuously advance research in the field of educational technology, providing training for teachers on the use of various learning technologies and enhancing their English language competencies. By doing so, the challenges related to limited technological skills and insufficient English proficiency among teachers can be minimized.

Acknowledgments

The authors express their gratitude to the Rector of Samudra University and the LPPM team for entrusting the research team with this study. They also extend their thanks to all parties involved in the research, particularly the principals and teachers at SD Negeri 1 Langsa, SD Negeri 3 Langsa, and SD Negeri 5 Langsa.

Conflict of Interest

The Author(s) declare(s) that there is no conflict of interest.

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