AR-Book and Its Role as a Learning Media in Enhancing Literacy and Numeracy Skills

Tetep[1,*], Ali Ismail[2], Iman Nasrulloh[3], and Sela Oktariza[1]

[1]Department of Social Studies Education, Faculty of Social Science and Language Education, Indonesia Institute of Education Garut, Indonesia
[2]Department of Primary Education, Indonesia University of Education, Sumedang, Indonesia
[3]Department of Information Technology of Education, Faculty of Applied and Science Education, Indonesia Institute of Education Garut, Indonesia
E-mail: tetep@institutpendidikan.ac.id (T.); ali_ismail@upi.edu (A.I.); imannasrulloh@institutpendidikan.ac.id (I.N.); sellaoktariz48@gmail.com (S.O.)
[*]Corresponding author
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***Abstract*—This study examines using Augmented Reality (AR) books as learning media to improve literacy and numeracy skills in elementary school students' students' Integrated Science and Social Studies (IPAS) Education. The study follows the ADDIE model stages: Analysis, Design, Develop, Implement, and Evaluate. In implementing the AR book, the groups involved are 4th and 5th-grade students, and they are aligned with the study's goals and the current curriculum. We also involved professional teachers, technology experts, and 120 elementary school students from 10 schools. All participants contributed generously to the application of the AR book. The implementation uses the Android OS platform, making it easy to use. After the implementation, a post-test and a questionnaire were conducted. The research data were analyzed using VOSviewer analysis, Rasch model, and statistics analysis application to test the significance level. The research results show that AR books can improve students' literacy and numeracy skills in elementary school IPAS learning with a significance margin of 0.58 and a student response percentage of 91.8%. Thus, the use of AR books can make a significant contribution to improving literacy and numeracy skills in elementary school IPAS learning.**

***Keywords*—Augmented Reality (AR) book, learning media, literacy and numeracy skills**

I. Introduction

Research by the Organisation for Economic Cooperation and Development (OECD) indicates a concerning trend in Indonesia's Programme for International Student Assessment (PISA) rankings, placing the country at 71st [1]. This ranking highlights the low levels of literacy and numeracy skills among Indonesian students. Enhancing these skills through strategic policy-making and developing creative and innovative educational practices is imperative in response to this phenomenon. Such initiatives aim to equip students to become a creative and innovative generation with solid literacy and numeracy skills that support the targets for fostering creative thinking abilities [1]. Literacy and numeracy skills are crucial for enhancing students' capabilities and creativity, particularly in Integrated Science and Social Studies (IPAS) education at the elementary school level.

The IPAS textbook integrates subjects from both Natural Sciences (IPA) and Social Sciences (IPS) [2]. Natural Sciences itself integrates various natural sciences disciplines [3–5] while Social Sciences integrates multiple social sciences [6–10]. This subject integration aligns with curriculum changes aimed at improving the quality of student learning outcomes and simplifying complex concepts to be more comprehensible for students. The existence of such textbooks, like IPAS, remains crucial, especially in elementary education, for equipping students with literacy and numeracy skills not only in Natural Sciences [11] but also in Social Sciences [2]. These textbooks are elementary learning resources oriented towards developing students' cognitive knowledge, literacy, and numeracy skills and fostering values education.

Augmented Reality (AR) implementation in Indonesia is relatively nascent, notably accelerated during the COVID-19 pandemic. According to the Ministry of Education and Culture [12], there has been a concerted effort to leverage technology, including AR, within the educational framework, specifically under the Merdeka Belajar curriculum program, which allows schools to adopt new technologies as educational media. AR aims to create interactive learning experiences.

Learning activities support the application of AR through project-based learning, providing students with hands-on learning experiences. Integrating AR into the curriculum involves designing learning materials that align with students' interests and needs. Research on using AR as an educational medium has demonstrated its potential to enhance students' literacy skills. This is grounded in two interrelated theoretical frameworks, which posit that all learning occurs within a specific context and that the quality of learning outcomes stems from the interaction between individuals, their environment, objects, processes, and culture both inside and outside the classroom. The individual's level of development and prior experiences also play a critical role [13].

To bridge the gap in literacy and numeracy skills rooted in traditional textbooks, integrating digital technology into textbooks is paramount. The development of IPAS textbooks with Augmented Reality (AR) integration aims to present more engaging textbooks for students. AR-enhanced IPAS books offer more realistic phenomena than standard textbooks [14]. Consistent with studies by Azuma and Kaufmann [15], AR technology uniquely combines real and virtual life, making learning more interactive and real-time with 3D features. Researches [16–18] also indicate that AR books can enhance students' understanding and motivation in their learning. Accordingly, using AR books can facilitate increased student motivation, which in turn is expected to

improve literacy and numeracy skills as well as digital literacy [19].

Additional studies, such as those in biology, have shown that using AR books can improve students' academic performance [20]. Similarly, in physics, AR books can enhance students' performance and attitudes towards learning [21]. In social studies, AR books provide captivating real-world experiences, allowing closer insights into museums, historical heritage, and values [22–25]. According to Gopalan *et al.* [26], learning with AR-based textbooks boosts learning motivation. This is corroborated by Dünser and Hornecker [27], who found that AR books promote interactive learning with real-world phenomena. Likewise, Tetep *et al.* [28] noted that AR books transform abstract historical objects into concrete ones.

The AR IPAS textbook is utilized as a learning medium to support the achievement of literacy and numeracy skills for students, creating a classroom experience akin to real-world learning. The pedagogical principle of using this medium fosters independent, student-centered learning [29, 30]. In addition to enhancing digital literacy skills among students, it also promotes teachers' abilities to integrate digital literacy-based learning media, ensuring that teachers possess sufficient knowledge and understanding of educational media [31]. Integrating AR learning media enables students to embark on concrete, hands-on experiences. According to Dale's Cone of Experience, learning is more effective when it progresses from direct, concrete experiences to abstract verbal symbols [32]. The more concrete the message, the more accessible for students to comprehend the material.

II. Literature Review

In this section, we discuss the literature review that covers the study of augmented reality and the nature of literacy and numeracy skills in IPAS (Science, Environment, and Technology) learning in detail. The literature review is elaborated on in the following section.

A. Augmented Reality (AR) and Augmented Reality (AR) Book

The definition of Augmented Reality (AR) leads to a spectrum of technologies that integrate computer-generated materials, such as texts, images, and videos, into users' perceptions of the real world. According to Azuma and Kaufmann [15, 33], defined the implementation of AR based on its characteristics as a combination of real-world and virtual elements that are interactive in real-time and registered in 3D. Augmented reality technology is one solution to enhance problem-solving and spatial abilities [34]. Augmented reality media can visualize objects in three dimensions, showcasing the potential of using virtual and augmented reality technology to teach spatial geometry to elementary school students [35]. Other researchers have defined AR systems as a combination of real and computer-generated information in a natural environment, interactive in real-time, which aligns with virtual and physical objects [36]. An augmented reality-based learning system makes programming concepts tangible [37]. According to all definitions of AR, bringing virtual elements to real-world environments is a characteristic of AR technologies.

Based on its application in educational research, there is a growing body of research investigating the use of AR in education. For instance, in physics education research, researchers have explored the role of AR as a learning tool to enhance conceptual understanding of electricity concepts. This research is based on the foundation that sub-microscopic phenomena, such as electron movement, cannot be effectively represented in practical physical works [38]. In a different context of physics education, AR technologies have been integrated into physics learning to implement problem-based learning [21]. The findings have indicated that learning achievement and attitudes toward learning physics increased significantly. In biology, the use of AR in the learning process has also been found to enhance students' motivation, although there has been no significant improvement in students' achievements in the biology course [20]. In the context of social studies, AR technologies have been utilized to offer students new experiences or revitalize old ones at museums, heritage sites, and other areas of historical value [22–25]. The use of Augmented Reality-based media can address various types of problems in science education [39]. Empirical evidence has demonstrated that integrating AR technology in both natural science and social science subjects has positively impacted learning outcomes, motivation, and attitudes.

The huge benefits AR technologies provide in learning have attracted many researchers to integrate AR technologies into textbooks. Although the role of AR technologies seems similar to other forms of media, which infused multiple representations to the learning process, this can be an interesting aspect to investigate. For instance, Gopalan et al. have investigated how the role of science textbooks in integrating AR technology could enhance students' motivation [26]. Student engagement in blended learning is higher when using augmented reality media [40]. The result showed that lower secondary school students' motivation toward science learning increased. Other researchers also investigated the potential benefits of AR books when children read story books, and it showed that the children were driven to actively interact with real-world phenomena provided [27]. The contribution of virtual reality and augmented reality systems to enhancing learning includes using augmented reality to represent numbers as physical objects [18]. These two examples of the research in the AR book have shown that it positively impacted both motivation and students' interaction during reading activities.

B. Literacy-Numeracy Skills and AR Book

In this era of incessant misinformation, where information comes and goes, we are faced with deciding whether to share certain information. We must base our decision on accurate and appropriate information to share information. Simultaneously, recognizing patterns in daily problems is essential for children in school and adults in their daily lives. All these issues relate to 'literacy' and 'numeracy,' which are invaluable in supporting lifelong learning. The development of literacy and numeracy programs for students offers new insights with practical advice and suggestions on how to enhance student motivation and improve learning outcomes and experiences by incorporating Augmented Reality media into their teaching [41]. Literacy is comprehending, utilizing, and reflecting on written texts to achieve a specific goal. On

the other hand, numeracy encompasses a range of skills, from basic arithmetic and logical reasoning to advanced mathematics and interpretative communication skills [42].

Currently, many countries have faced literacy and numeracy problems in the context of elementary skills. The rationale for this is that literacy and numeracy skills are the foundation of lifelong learning. In other contexts, literacy and numeracy are also basic social and cognitive skills, which the social interaction and daily can be a part of literacy and numeracy [43, 44]. The implementation of augmented reality media aims to enhance literacy and numeracy skills, social skills, problem-solving abilities, and learning performance [45]. Although these are connected to daily life, training and fostering literacy and numeracy skills require an appropriate approach and media so children will experience meaningful learning. Traditionally, textbooks as agents used to support student learning. This is familiar to engage activities, such as reading, to foster literacy and numeracy in science education [46] and social studies [47]. Improvements in literacy and numeracy skills, as well as students' critical thinking abilities, and the implementation of problem-based learning supported by augmented reality books among elementary school students [48]. However, using the textbook's integrated technologies presenting multimodal representation, such as AR books, may provide potential benefits to foster literacy and numeracy skills. Increased knowledge acquisition and skill development occur after engaging in augmented reality media learning activities [31]. The reason for this is that AR technologies themselves have succeeded in improving motivation, comprehension, and autonomous work [49, 50].

III. METHOD

This study employs an experimental design, specifically utilizing a quasi-experimental methodology. The chosen research design is the nonequivalent control group design, wherein the experimental and control groups are not randomly selected. Both groups undergo a pre-test at the outset. The experimental group engages with IPAS learning media based on Augmented Reality, whereas the control group uses conventional textbooks supplemented with printed images. Both groups conclude with a post-test [51]. The research design can be interpreted below:

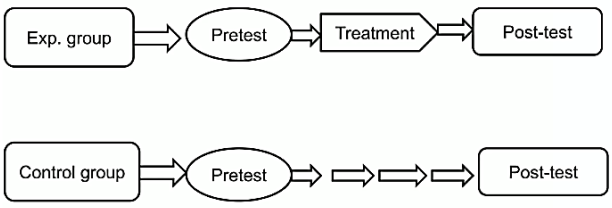


Fig. 1. Design pattern nonequivalent control group design.

Based on the research design in Fig. 1, the research procedure was conducted in both the experimental and control classes to compare the two. In both the experimental and control classes, the initial step involved administering a pretest for each class. The experimental class served as the trial group using augmented reality media to teach IPAS to fourth-grade elementary school students about Forces and Their Applications. In contrast, the control class acted as the comparison group using conventional IPAS textbooks with the same subject matter, namely Forces and Their Applications. The next step involved providing the experimental class with treatment by applying augmented reality media to their learning, while the control class did not receive this treatment. The final step involved administering a posttest to both the experimental and control classes to measure improvements in learning outcomes, with the expectation that students would enhance their literacy and numeracy skills. The post-test results can then be analyzed to compare the improvement between the experimental and control classes. The materials used in the pretest and posttest refer to the content found in the AR book IPAS (Table 1), which includes:

Table 1. Pretest and Posttest materials

Class	Pretest Materials	Posttest Materials
Experiment Group	1. Changes in the state of matter in everyday life	1. Changes in the state of matter in everyday life
	2. Forces and their applications	2. Forces and their applications
	3. Energy in everyday life	3. Energy in everyday life
Control Group	1. Changes in the state of matter in everyday life	1. Changes in the state of matter in everyday life
	2. Forces and their applications	2. Forces and their applications
	3. Energy in everyday life	3. Energy in everyday life

Source: AR-Book based IPAS Book, 2023

The population for this study comprises all students from 10 elementary schools in Garut Regency for the 2023/2024 academic year, representing the entire set of subjects or objects targeted by the research with specific characteristics. The researchers' sampling technique is purposive sampling, which involves selecting data sources based on particular considerations. The sample for this study consists of 120 students across ten elementary schools. Data analysis techniques in this research involve pre-test and post-test results, analyzed to identify improvements in students' literacy and numeracy skills. The analysis uses normalized N-Gain tests and correlation sample effectiveness analysis to evaluate the effectiveness of the AR-Book IPAS media utilized.

IV. RESULTS AND DISCUSSION

A. Results of Literature Study

The Publish or Perish analysis demonstrates the positive significance of implementing Augmented Reality (AR) media in various school subjects. Research by Pellas [42] indicates that the combination of AR media provides the potential for new learning experiences for students and positively impacts their motivation and academic performance. Demitriadou *et al.* [35] shows found that AR media for elementary students enhances their understanding of 3D application materials and increases their interest in interactive science learning.

AR media can enhance students' literacy and numeracy skills. Kellems and Eichelberger [39] highlighted that implementing AR-based learning media improves students' literacy and problem-solving abilities in scientific content, particularly in science education. Cheng and Tsai [18] further corroborated these findings, stating that AR-based game

media enhances collaborative learning among students, aligns with 21st-century skill demands, and provides direct learning experiences with environments that construct students' knowledge.

Further research on the relevance of AR media implementation in improving students' literacy and numeracy skills is presented byYu *et al.* [52], who found that AR-based learning media can train teachers to combine learning materials with students' surroundings ecologically, thus fostering literacy skills. Kao and Ruam, [37] reported that developing AR media in education can create tangible learning programs, significantly increasing interactivity and learning outcomes. Saphira and Prahani [49] found that integrating AR-based learning media enhances students' critical thinking skills, fostering literacy skills in science education.

According to Guntur and Setyaningrum [34] stated that AR media combines real and virtual learning, enhancing students' skills. Khairiree [40] noted that implementing AR-based learning media improves learning regulation. Gavish *et al.* [53] reinforced these findings, stating that complex learning combined with interactive media increases students' interest and enjoyment.

The literature review in this study focuses on Augmented Reality (AR) books and literacy and numeracy skills, conducted using the Publish or Perish software. The search results for previous research articles are presented in Table 2 below:

To ascertain the positioning and presence of research on AR-Book IPAS with literacy and numeracy skills in education, all obtained articles were analyzed using VOSviewer software. Essentially, VOSviewer positions the nodes of variables in a two-dimensional spatial network, where the strength of the connections between nodes is related to the proximity of their locations [54].

Table 2. Article search data of publish of perish

No	Citations	Title of the articles	Year	Author(s)
1	367	Augmenting the learning experience in elementary and secondary school education: A systematic review of recent trends in augmented reality game-based learning	2019	N Pellas, P Fotaris, I Kazanidis, D Wells [42]
2	224	Comparative evaluation of virtual and augmented reality for teaching mathematics in elementary education	2020	E Demitriadou, KE Stavroulia, A Lanitis [34]
3	78	Using video-based instruction via augmented reality to teach mathematics to middle school students with learning disabilities	2020	RO Kellems, C Eichelberger [39]
4	63	An in-depth analysis of the interaction transitions in a collaborative Augmented Reality-based mathematic game	2019	YW Cheng, Y Wang, IL Cheng [18]
5	53	A systematic review of augmented reality game-based Learning in STEM education	2022	J Yu, AR Denham, E Searight [53]
6	51	Designing and evaluating a high interactive augmented reality system for programming learning	2022	GYM Kao, CA Ruan [37]
7	33	Profile of senior high school students' critical thinking skills and the need of implementation PBL model assisted by augmented reality book	2022	HV Saphira, BK Prahani [49]
8	32	Can augmented reality improve problem-solving and spatial skill?	2020	MIS Guntur, W Setyaningrum [34]
9	4	Augmented Reality and Blended Learning: Engaging Students Learn Word Problems with Bar Model and the Geometer's Sketchpad	2019	K Khairiree [40]
10	1	Augmented Virtuality Systems as a Tool for Improving Numeracy Decision-Making Among Children	2022	N Yuviler-Gavish, Z Treiger, E Horesh [53]

Source: Publish or perish analysis, 2024.

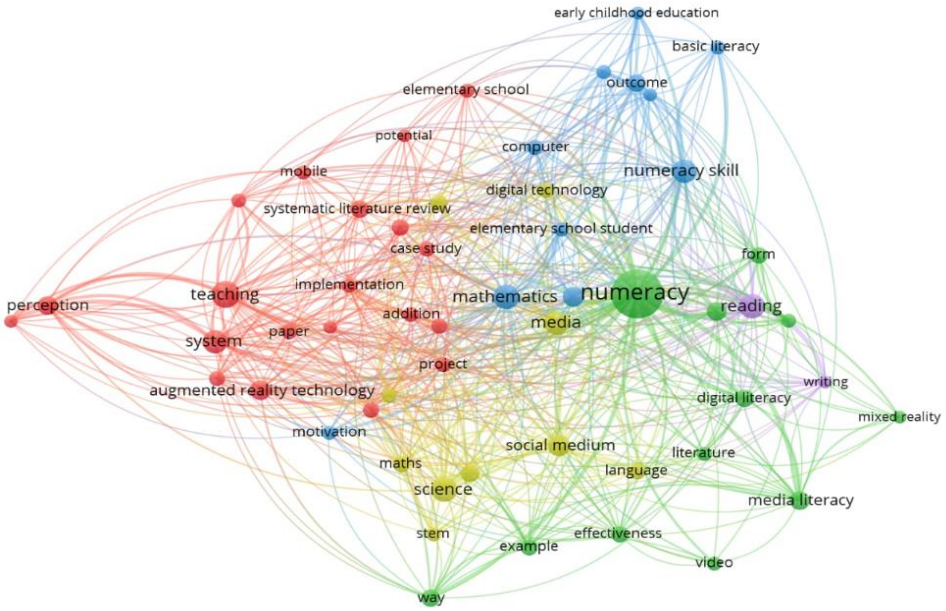


Fig. 2. VOSviewer analysis of lieteracy and numeracy skills through augmented reality.

Based on the analysis of Fig. 2, teachers should implement student-centered learning to enhance students' literacy and numeracy skills. This approach enables students to develop their abilities, foster critical thinking, and cultivate high levels of creativity.

B. Results of Data Analysis

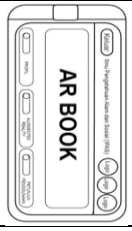
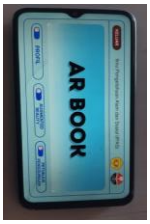
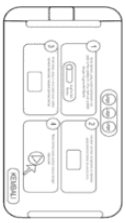
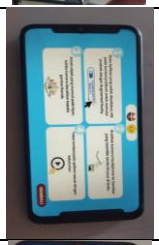
In addition to the literature review analysis, this phase employs pretests and posttests involving 120 students from 10 elementary schools in Garut Regency, related to implementing augmented reality media in IPAS learning. The pretest data analysis can be identified from the normality test results between the control and experimental classes, where the experimental class was treated with the A-Book IPAS media, and the control class used conventional textbooks. The analysis results can be interpreted as follows:

1) Analysis of AR-book IPAS structures

The implementation of learning with the IPAS book in this study was developed by integrating Augmented Reality (AR) technology, combining contextual elements from real and virtual environments in the form of animations. The integration pattern of AR media into the IPAS Book was carried out at the application stage by combining Science (IPA) and Social Studies (IPS) lessons, focusing on topics such as green consumerism and the water cycle, using markerless technology.

The structure of the AR-Book that has been designed and can be implemented is shown in Table 3:

Table 3. AR-Book IPAS media's structures

Fixture	AR-Book IPAS Structure	Implementation	Information
Main Menu			The main menu display contains several buttons, including the augmented reality menu to access the AR camera, the user guide, and the profile menu
AR Camera Menu			The AR Camera menu displays the phone's camera view.
Usage Instructions Menu			The User Guide menu displays information about the steps for using the application, and there is a back button if the user wishes to return to the main menu.
Profile Menu			This menu displays information about the developer profile of the IPAS Book.

Based on Table 3, the structure within the AR-Book IPAS, with the support of relevant features, it can significantly enhance students' literacy and numeracy skills when widely implemented among students. Through the existing marker-based AR-Book learning media, designated objects can only be displayed on the screen from one marker. The complexity of Augmented Reality (AR) media can bridge the gap between practical and theoretical learning by blending real and virtual components to create a unique learning experience. The completeness of the structure and features in the AR-Book IPAS provides students with the possibility of understanding learning materials engagingly.

2) Comparison of literacy and numeracy skills based on AR-book IPAS between the experimental class and the control class

Based on the analysis results comparing literacy and numeracy skills in the experimental class using AR-Book media in IPAS learning, the research was conducted on fourth-grade students in 10 elementary schools in Garut Regency, with 5 schools as the experimental group and 5 schools as the control group. This comparative analysis aims to review and analyze the differences in the improvement of students' literacy and numeracy skills when using the AR-Book IPAS compared to students using conventional textbooks. The analysis results can be identified from the following data analysis in Table 4 and 5:

Table 4. Results descriptive analysis of N-Gain test: Elementary school 1 (Experiment class)

Descriptive Analysis	N	Minimum	Maximum	Mean	Std. Deviation
N-Gain	24	0.16	0.72	0.4486	0.15946
Valid N (listwise)	24				

Source: Analysis results, 2024

Table 5. Results of effectiveness analysis: Elementary school 1 (Experiment class)

Effectiveness analysis		N	Correlation	Sig.
Pair 1	Before and after used AR-Book IPAS &	24	0.376	0.0071

Source: Analysis results, 2024

Based on Table 4, the descriptive analysis of N-gain, it can be identified that the N-gain value for Elementary School 1, as an experimental school implementing AR-Book in IPAS learning, is 0.4486, which falls under the medium category. Using paired sample correlation analysis in Table 5, the effectiveness test analysis shows a correlation value of 0.37. This indicates a significant correlation with a significance value of 0.007, less than 0.05. Therefore, using the AR-Book IPAS is categorized as effective, with a significance value lower than the alpha value.

Based on Table 6, the descriptive analysis of N-gain, it can be identified that the N-Gain value for Elementary School 2, as a control school implementing conventional textbooks in IPAS, is 0.1859, which falls under the low category. In Table 7, the effectiveness test analysis, using paired sample correlation analysis, shows a correlation value of 2.45. This indicates a non-significant correlation, with a coefficient value of 2.48, which is greater than 0.5. Therefore, the use of conventional IPAS textbooks is deemed ineffective.

Table 6. Results descriptive analysis of N-Gain test: Elementary school 2 (Control class)

Descriptive analysis	N	Minimum	Maximum	Mean	Std. Deviation
N-Gain	24	–0.75	0.50	0.1859	0.26236
Valid N (listwise)	24				

Source: Analysis results, 2024

Table 7. Results of effectiveness analysis: Elementary school 2 (Control class)

Effectiveness analysis		N	Correlation	Sig.
Pair 1	Before and After Used of Conventional IPAS book	24	0.245	0.248

Source: Analysis results, 2024

Based on Table 8, the descriptive analysis of N-gain, it can be identified that the N-gain value for Elementary School 3, as an experimental school implementing AR-Book in IPAS, is 0.454, which falls under the medium category. Based on Table 9, the effectiveness test analysis using sample correlations shows a correlation value of 0.521 and a significance coefficient of 0.009, less than 0.05. Therefore, it can be concluded that the AR-Book IPAS learning media is effective and correlated in the learning process.

Table 8. Results descriptive analysis of N-Gain test: Elementary school 3 (Experiment class)

Descriptive analysis	N	Minimum	Maximum	Mean	Std. Deviation
N-Gain	24	0.17	0.75	0.4543	0.16148
Valid N (listwise)	24				

Source: Analysis results, 2024

Table 9. Results of effectiveness analysis: Elementary school 3 (Experiment class)

Effectiveness analysis		N	Correlation	Sig.
Pair 1	Before and after used AR-Book IPAS &	24	0.521	0.009

Source: Analysis results, 2024

Based on Table 10, the descriptive analysis of N-gain, it can be identified that the N-gain value for Elementary School 4, as a control school implementing conventional textbooks in IPAS, is 0.113, which falls under the low category. In Table 11, the results of effectiveness test analysis using sample correlations shows a correlation value of –0.96 and a significance coefficient of 0.654, greater than 0.05. Therefore, conventional IPAS textbooks are deemed ineffective and uncorrelated with the learning process.

Table 10. Results descriptive analysis of N-Gain test: Elementary school 4 (Control class)

Descriptive Analysis	N	Minimum	Maximum	Mean	Std. Deviation
N-Gain	24	–0.67	0.50	0.1134	0.33892
Valid N (listwise)	24				

Source: Analysis results, 2024

Table 11. Results of effectiveness analysis: Elementary school 4 (Control class)

Effectiveness Analysis		N	Correlation	Sig.
Pair 1	Before and After Used of Conventional IPAS book	24	0.734	0.000

Source: Analysis results, 2024

Based on Table 12, the descriptive analysis of N-gain, it can be identified that the N-Gain value for Elementary School 5, as an experimental school implementing AR-Book IPAS, is 0.49, which falls under the medium category. Based on Table 13, the effectiveness test analysis using sample correlations shows a correlation value of 0.734 and a significance coefficient of 0.00, which is less than 0.05. Therefore, it can be concluded that the AR-Book IPAS media is effective in the learning process.

Table 12. Results descriptive analysis of N-Gain test: Elementary school 5 (Experiment class)

Descriptive Analysis	N	Minimum	Maximum	Mean	Std. Deviation
N-Gain	24	0.31	0.75	0.4998	0.11276
Valid N (listwise)	24				

Source: Analysis results, 2024

Table 13. Results of effectiveness analysis: elementary school 5 (Experiment class)

Effectiveness Analysis		N	Correlation	Sig.
Pair 1	Before and after used AR-Book IPAS &	24	0.734	0.000

Source: Analysis results, 2024

Based on Table 14, the descriptive analysis of N-gain, it can be identified that the N-Gain value for Elementary School 6, as a control school implementing conventional textbooks in IPAS, is 0.16, which falls under the low category. The effectiveness test analysis using sample correlations in the control class at Elementary School 6 shows a correlation value of –0.0116 and a significance coefficient of 0.589, greater than 0.05 as shown in Table 15. Therefore, conventional IPAS textbooks are deemed ineffective in the learning process.

Table 14. Results descriptive analysis of N-Gain test: Elementary school 6 (Control class)

Descriptive analysis	N	Minimum	Maximum	Mean	Std. Deviation
N-Gain	24	–0.50	0.51	0.1620	0.25532
Valid N (listwise)	24				

Source: Analysis results, 2024

Tabel 15. Results of effectiveness analysis: Elementary school 6 (Control class)

Effectiveness Analysis		N	Correlation	Sig.
Pair 1	Before and After Used of Conventional IPAS book	24	–0.116	0.589

Source: Analysis results, 2024

Based on the descriptive analysis of N-gain in Table 16, it can be identified that the N-Gain value for Elementary School 7, as an experimental school implementing AR-Book-based learning media in IPAS, is 0.478, which falls under the medium category. In Table 17, the results of effectiveness test analysis using sample correlations in the experimental class at Elementary School 7 shows a correlation value of 0.684 and a significance coefficient of 0.000, which is less than 0.05. Therefore, the implementation of AR-Book in IPAS is effective in the learning process

Table 16. Results of descriptive analysis of N-Gain test: Elementary school 7 (Experiment class)

Descriptive analysis	N	Minimum	Maximum	Mean	Std. Deviation
N-Gain	24	0.17	0.68	0.4780	0.11792
Valid N (listwise)	24				

Source: Analysis results, 2024

Tabel 17. Results of effectiveness analysis: Elementary school 7 (Experiment class)

Effectiveness Analysis		N	Correlation	Sig.
Pair 1	Before and after used AR-Book IPAS	24	0.684	0.000

Source: Analysis results, 2024

Based on Table 18, the descriptive analysis of N-gain it can be identified that the N-Gain value for Elementary School 8, as a control school implementing conventional textbooks in IPAS, is 0.19, which falls under the low category. In Table 19, the effectiveness test analysis using sample correlations in the control class at Elementary School 8 shows a correlation value of –0.97 and a significance coefficient of 0.653, greater than 0.05. Therefore, implementing conventional IPAS textbooks is ineffective in the learning process.

Table 18. Results descriptive analysis of N-Gain test: Elementary school 8 (Control class)

Descriptive Analysis	N	Minimum	Maximum	Mean	Std. Deviation
N-Gain	24	0.05	0.52	0.1909	0.29104
Valid N (listwise)	24				

Source: Analysis results, 2024

Table 19. Results of effectiveness analysis: Elementary school 8 (Control class)

Effectiveness analysis		N	Correlation	Sig.
Pair 1	Before and after used AR-Book IPAS	24	0.097	0.653

Source: analysis results, 2024

Based on Table 20, the descriptive analysis of N-gain, it can be identified that the N-Gain value for Elementary SCHOOL 9, as an experimental school implementing AR-Book in IPAS, is 0.50, which falls under the high category. In Table 21, the effectiveness test analysis using sample correlations in the experimental class at Elementary School 9 shows a correlation value of 0.193 and a significance coefficient of 0.03, which is less than 0.05. Therefore, the implementation of AR-Book in IPAS is effective in the learning process.

Table 20. Results descriptive analysis of N-Gain test: Elementary school 9 (Experiment class)

Descriptive analysis	N	Minimum	Maximum	Mean	Std. Deviation
N-Gain	24	0.11	0.78	0.5075	0.17762
Valid N (listwise)	24				

Source: analysis results, 2024

Table 21. Results of effectiveness analysis: Elementary school 9 (Experiment class)

Effectiveness analysis		N	Correlation	Sig.
Pair 1	Before and after used AR-Book IPAS	24	0.193	0.366

Source: Analysis results, 2024

Based on Table 22, the descriptive analysis of N-gain, it can be identified that the N-Gain value for Elementary School 10, as a control school implementing conventional textbooks in IPAS, is 0.08, which falls under the low category. In Table 23, the effectiveness test analysis using sample correlations in the control class at Elementary School 10 shows a correlation value of –0.16 and a significance coefficient of 0.45, greater than 0.05. Therefore, the implementation of conventional textbooks in IPAS learning is ineffective.

Table 22. Results descriptive analysis of N-Gain test: Elementary school 10 (Control class)

Results Descriptive Analysis of N-Gain Test					
	N	Minimum	Maximum	Mean	Std. Deviation
NGain	24	0.05	0.53	0.0896	0.3046
Valid N (listwise)	24				

Source: Analysis results, 2024

Table 23. Results of effectiveness analysis: Elementary school 10 (Control class)

Effectiveness analysis		N	Correlation	Sig.
Pair 1	Before and after used Book IPAS conventional	24	-0.161	0.452

Source: Analysis results, 2024

Thus, it can be classified that the recapitulated N-Gain value in the experimental class shows an increase of 57.34%, significantly improving with the use of AR-Book media in the learning process. In contrast, the control class showed an increase of 17.83%, which is lower than that of the experimental class, as shown in Table 24.

Table 24. Recapitulation of the comparison between the Experimental class and the Control class in improving literacy and numeracy

No		Elementary School Class	N-Gain value	Amount
1		Elementary School 1 (Experiment)	10.77%	
2		Elementary School 3 (Experiment)	10.91%	
3	Exp.	Elementary School 5 (Experiment)	12.01%	**57.34%**
4		Elementary School 7 (Experiment)	11.46%	
5		Elementary School 9 (Experiment)	12.19%	
1		Elementary School 2 (control)	4.47%	
2		Elementary School 4 (control)	2.73%	
3	Cont.	Elementary School 6 (control)	3.89%	**17.83%**
4		Elementary School 8 (control)	4.59%	
5		Elementary School 10 (control)	2.15%	

Source: Summary of analysis results ms. Excel 2010, 2024.

To determine the impact size of using the AR-Book in IPAS, the researcher used the effect size to assess the magnitude of the impact. The processed effect size data showed a value of 1.46, indicating that the use of the AR-Book in IPAS has a huge impact compared to the control class that did not use the AR-Book in IPAS. The effect size data can be seen in Table 25 below:

Table 25. Effect size

No	Grade	Mean	Standard deviation	samples	Effect size
1	Exp. (5 Class)	83.95	4.78	120	
2	Cont. (5 Class)	76.94	4.80	120	1.46

3) Student responses to the use of AR-book IPAS in improving literacy and numeracy

Based on the analysis results regarding student responses to the use of AR-book-based media in IPAS learning for fourth-grade elementary school students, the improvement in literacy and numeracy from the survey analysis can be interpreted and summarized in Fig. 3.

Based on the data experiment class for five school in Fig. 3 about the percentage diagram, the data from the student responses are symbolized as follows:

1) Blue for Elementary School Experiment 1
2) Red for Elementary School Experiment 2
3) Green for Elementary School Experiment 3
4) Purple for Elementary School Experiment 4
5) Light Blue for Elementary School Experiment 5

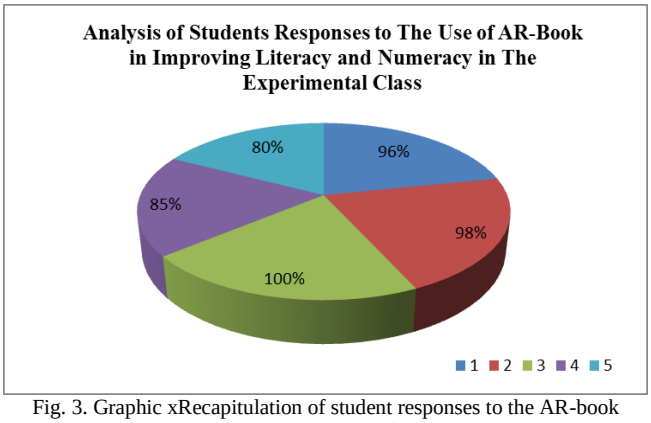


Fig. 3. Graphic xRecapitulation of student responses to the AR-book media. Source: Analysis Microsoft excel 2010, 2024

Thus, as seen from the diagram above, the student responses to the AR-Book IPAS media show a high response rate, with an average percentage of 91.8%, which falls under the very high category. Enhancing literacy and numeracy is one of the objectives of this study, as increasing students' interest in literacy and numeracy is a factor that can influence the learning outcomes aimed to be achieved from the educational goals.

C. Discussion

The research findings on implementing Augmented Reality (AR) media to enhance literacy and numeracy skills among fourth-grade elementary school students indicate positive outcomes. The study revealed that AR-based media learning activities improved students' literacy and numeracy skills. This AR learning media was applied in IPAS education. The impact of AR media can be identified by comparing students' performance before and after the intervention [54]. Communicative and interactive media can increase students' engagement and literacy and numeracy skills because students find engaging media enjoyable [20]. Learning with AR media provides students with unexpected knowledge and experiences, allowing them to observe significant events that are challenging to comprehend directly, making the learning process more captivating and fostering a high level of curiosity about the material presented [40]. Furthermore, using learning media in teaching can stimulate new desires and interests, enhance literacy and numeracy in learning activities, and even psychologically impact students.

Data analysis comparing the experimental and control classes highlights the importance of presenting material suitable for students and the effectiveness of the learning process [2, 34]. The IPAS learning concept should be further optimized by integrating AR technology as a tech-based modality [39]. Literacy and numeracy as creative competencies indicate skills development [28]. In the digital era, teachers of all ages must be proficient in managing or using technology, particularly AR, to deliver instructional material uniquely, intelligently, innovatively, and creatively [55].

The implementation of AR media is designed to develop student's literacy and numeracy skills through the AR-Book, which combines complex problem-solving and teamwork to create engaging educational experiences [51]. Additionally, AR-based learning focuses on engagement as an educational activity integrating literacy skills and 21st-century competencies. This approach is designed for active, interactive, inspiring, enjoyable, challenging, motivating, and autonomous learning tailored to students' interests and talents in IPAS education [56]. Integrating AR media with IPAS content can enhance effectiveness and increase students' interest in learning.

Therefore, implementing AR media to improve students' literacy and numeracy skills can significantly impact educational outcomes. This approach addresses the challenges faced by 21st-century educators, supporting students' learning success. Literacy and numeracy skills, particularly in IPAS education, are part of digital literacy, which gradually informs students about social phenomena observed in society.

Based on the findings from the research and student responses regarding implementing Augmented Reality (AR) media in the learning process, it can be concluded that this media significantly enhances students' literacy and numeracy skills, particularly in IPAS subjects for fourth-grade elementary students.

The implementation of the AR-Book IPAS marks the beginning of efforts to address the challenges presented by curriculum changes within the Merdeka Curriculum, which has been applied in several model schools known as "Sekolah Penggerak". Introducing IPAS as a subject in the Merdeka Curriculum at the elementary level necessitates the utilization of AR-based IPAS textbooks. While the current implementation is limited to Sekolah Penggerak, it will be expanded beyond Garut Regency to a national level.

Given that this has become a national policy within the Merdeka Curriculum, the government must ensure the program's sustainability by providing the necessary infrastructure to support future curriculum policies. This includes supplying AR media and laboratory facilities to support the application of digital textbooks to enhance literacy and numeracy skills. This research will undoubtedly serve as the foundation for developing student competencies in line with advancements and changes in information technology and learning design in schools.

V. Conclusions

Based on the research findings, it can be concluded that implementing AR-Book media in IPAS learning enhances students' literacy and numeracy skills. Digital-based literacy and numeracy skills in IPAS foster students' understanding of social and natural phenomena gradually observed in society. This approach ensures that students can easily recall and comprehend IPAS learning materials. The role of educators is crucial in guiding students to gain direct experience through information and communication technology-based learning. Therefore, IPAS learning requires using engaging and creative learning media that are easily accessible and interactive for students.

This study is a preliminary recommendation for the government to focus on supporting the implementation of the Merdeka Curriculum policy, which has been applied by several model schools known as "Sekolah Penggerak" in Indonesia. Given that this policy is now in place, the implementation of the Merdeka Curriculum must support the necessary facilities and infrastructure required by schools that its nationwide adoption will impact. Thus, essential facilities such as augmented reality laboratories, digital

technology media, and information technology must be developed in schools across Indonesia to keep pace with technological advancements, digitalization, and accelerated educational accessibility.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

Tetep: Conceptualization and writing initial draft, review and editing, resources management, supervise. Ali Ismail: Metodology, Validation, investigation, Analysis and Data Curation, supervision. Iman Nasrulloh: Software, visualization, Data Curation. Sela Oktariza: Project Adminitrastion, collect data and resources. All authors had approved the final version.

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REFERENCES

[1] PISA, OECD, 2022 & 2023. [Online]. Available: https://www.oecd.org>OECD>Publications

[2] Tetep, A. Ismail, I. Nasrulloh, and A. Puspa, "The development of AR books for thematic contents of science and social studies in elementary school to foster literacy and numeracy skills," *Migration Letters*, vol. 21, no. 5, pp. 195–209, 2023.

[3] E. L. Chiappetta and D. A. Fillman, "Analysis of five high school biology textbooks used in the united states for inclusion of the nature of science," *Int. J. Sci. Educ.*, vol. 29, no. 15, pp. 1847–1868, 2007. doi: 10.1080/09500690601159407

[4] J. Ball, S. G. Paris, and R. Govinda, "Literacy and numeracy skills among children in developing countries," *Learning and Education in Developing Countries*, New York: Palgrave Macmillan US, 2014, pp. 26–41. doi: 10.1057/9781137455970_2

[5] Trianto, "To design progress of innovative learning model," *Journal Research and Policy*, vol. 3, no. 1, pp. 90–100, 2011. (in Indonesian)

[6] NCSS. (1994). Social Studies education. American Association. [Online]. Available: https://www.socialstudies.org/

[7] Barth and Shemis, "Citizenship: The curriculum phantom core of social studies curriculum," *Journal Theory and Research in Social Education*, vol. 13, no. 2, pp. 21–29, 1978.

[8] N. Soemantri, *Renewing Ideas of Social Studies Education*, Bandung. PPS-UPI: Remaja Rosda Karya, 2001. (in Indonesian)

[9] Sapriya, *Social Studies Education in Concept and Learning*, Bandung: Remaja Rosda Karya, 2012. (in Indonesian)

[10] Tetep *et al*., "Students perception towards Kahoot learning media and its influence towards students' motivation in learning social studies and civic education," *The Innovation of Social Studies Journal*, vol. 4, no. 1, pp. 99–108, 2022.

[11] S. Gumilar and A. Ismail, "The representation of laboratory activities in Indonesian physics textbooks: A content analysis," *Research in Science & Technological Education*, vol. 41, no. 2, pp. 614–634, 2023. doi: 10.1080/02635143.2021.1928045

[12] The Ministry of Education and Culture of Indonesia. [Online]. Available: https://partnership.kemdikbud.go.id/ (in Indonesian)

[14] A. Rofi *et al*., "The implementation of augmented reality to improve student literacy," *Jurnal Elementaria Edukasia*, vol. 6, no. 1, 2023. https://doi.org/10.31949/jee.v6i1.4754 (in Indonesian)

[15] H. Kaufmann, "Collaborative augmented reality in education," *Institute of Software Technology and Interactive Systems, Vienna University of Technology*, pp. 2–4, 2003.

[16] T. W. Torregrosa, "Interviews with Japanese FLES students: Descriptive analysis," *Foreign Lang. Ann*., vol. 30, no. 1, pp. 98–110, 2005. doi: 10.1111/j.1944-9720. 1997.tb01320.x

[17] K. H. Cheng and C. C. Tsai, "The interaction of child–parent shared reading with an augmented reality picture book and parents' conceptions of learning," *British Journal of Educational Technology*, vol. 47, no. 1, pp. 203–222, 2016. doi: 10.1111/bjet.12228

[18] E. Roumba and I. Nicolaidou, "Augmented reality books: Motivation, attitudes, and behaviors of young readers," *International Journal of Interactive Mobile Technologies (iJIM)*, vol. 16, no. 16, pp. 59–73, 2022. doi: 10.3991/ijim.v16i16.31741

[19] I. Syekh, N. Cirebon, and C. Email, *Digital Lietarcy as a Bridge Character Education through Society 5.0 era*, 1945, pp. 176–194. (in Indonesian)

[20] C. Erbas and V. Demirer, "The effects of augmented reality on students' academic achievement and motivation in a biology course," *J. Comput. Assist. Learn*., vol. 35, no. 3, pp. 450–458, 2019. doi: 10.1111/jcal.12350

[21] M. Fidan and M. Tuncel, "Integrating augmented reality into problem based learning: The effects on learning achievement and attitude in physics education," *Comput. Educ*., vol. 142, 103635, 2019. doi: 10.1016/j.compedu.2019.103635

[22] J. Challenor and M. Ma. "A review of augmented reality applications for history education and heritage visualization," *Multimodal Technologies and Interaction*, vol. 3, no. 2, 39, 2009. doi: 10.3390/mti3020039

[23] M. Raghaw, J. Paulose, and B. Goswami, "Augmented reality for history education," *International Journal of Engineering and Technology (UAE)*, vol. 7, pp. 121–125, 2018.

[24] K. Y. T. Lim and R. Lim, "Semiotics, memory and augmented reality: History education with learner-generated augmentation," *British Journal of Educational Technology*, vol. 51, no. 3, pp. 673–691, 2020.

[25] N. A. N. Ibharim, S. Z. Ramli, S. A. Zahari, N. A. A. Edyanto, and M. A. A. Zawawi, "Learning history using augmented reality," *International Journal of Multimedia and Recent Innovation (IJMARI)*, vol. 3, no. 1, pp. 1–10, 2021.

[26] V. Gopalan, A. N. Zulkifli, and J. A. A. Bakar, "A study of students' motivation using the augmented reality science textbook," *AIP Conference Proceedings*, AIP Publishing, 020040, 2016. doi: 10.1063/1.4960880

[27] A. Dünser and E. Hornecker, "Lessons from an AR book study," in *Proc. the 1st International Conference on Tangible and Embedded Interaction*, 2007, pp. 179–182. doi: 10.1145/1226969.1227006

[28] T. Tetep, J. Jamilah, A. Ismail, E. Mulyana, and T. Widyanti, "History visualization using augmented reality," *Journal of Physics: Conference Series*, 2019. doi: 10.1088/1742-6596/1402/7/077032

[29] M. S. Dewi, Y. Abidin, and M. H.Arifin, "Implementation of Google earth media in social studies learning," *Qusi Experimental Study in Elementary School*, vol. 8, pp. 14182–14196, 2024. (in Indonesian)

[30] A. Palancı and Z. Turan, "How does the use of the augmented reality technology in mathematics education affect learning processes? A systematic review," *International Journal of Curriculum and Instructional*, 2021.

[31] M. Mahdayeni, "Global issues of e-learning, e-book, e-journal and information of educational system," *International Proceeding of Seminary of The Challenging Educational Moslem Management (Law of Moslem and Melayu Language 4.0 Era*, pp. 311–326, 2019. (in Indonesian)

[32] V. K. Shrotryia and U. Dhanda, "Content validity of assessment instrument for employee engagement," *Sage Open*, vol. 9, no. 1, 2019. doi: 10.1177/2158244018821751

[33] R. T. Azuma, "A survey of augmented reality," *Presence: Teleoperators & Virtual Environments*, vol. 6, no. 4, pp. 355–385, 1997.

[34] M. I. S. Guntur, W. Setyaningrum, and H. Retnawati, "Can augmented reality improve problem-solving and spatial skill?" *Journal of Physics: Conference Series*, 2020.

[35] E. Demitriadou, K. E. Stavroulia, and A. Lanitis, "Comparative evaluation of virtual and augmented reality for teaching mathematics in elementary education," *Education and Information Technologies*, vol. 25, no. 1, pp. 381–401, 2020.

[36] T. Höllerer and S. Feiner, "Mobile augmented reality," *Telegeoinformatics: Location-Based Computing and Services*, vol. 21, pp. 221–260, 2004.

[37] G. Y. M. Kao and C. A. Ruam, "Designing and evaluating a high interactive augmented reality system for programming learning," *Journal Computers in Human Behavior*, 2022

[38] A. Ismail, I. Festiana, T. I. Hartini, Y. Yusal, and A. Malik, "Enhancing students' conceptual understanding of electricity using learning media-based augmented reality," *Journal of Physics: Conference Series*, IOP Publishing, 032049, 2019.

[39] R. O. Kellems and C. Eichelberger, "Using video-based instruction via augmented reality to teach mathematics to middle school students with learning disabilities," *Journal of Learning*, 2022.

[40] K. Khairiree, "Augmented reality and blended learning: Engaging students learn word problems with bar model and the geometer's sketchpad," in *Proc. the 24th Asian Technology*, 2019.

[41] N. Pellas, P. Fotaris, I. Kazanidis, and D. Wells, "Augmenting the learning experience in elementary and secondary school education: A systematic review of recent trends in augmented reality game-based learning," *Virtual Reality*, vol. 23, no. 4, pp. 329–346, 2019.
[42] J. Ball, S. G. Paris, and R. Govinda, "Literacy and numeracy skills among children in developing countries," *Learning and Education in Developing Countries*, New York: Palgrave Macmillan US, 2014, pp. 26–41. doi: 10.1057/9781137455970_2
[43] F. Xiao, L. Barnard-Brak, W. Lan, and H. Burley, "Examining problem-solving skills in technology-rich environments as related to numeracy and literacy," *International Journal of Lifelong Education*, vol. 38, no. 3, pp. 327–338, 2009. doi: 10.1080/02601370.2019.1598507
[44] L. Tett, M. Hamilton, and Y. Hillier, *Adult Literacy, Numeracy and Language: Policy, Practice and Research: Policy, Practice & Research*, McGraw-Hill Education (UK), 2006.
[45] A. Zubaidi and M. J. Shodiq, "The developing of learning Media of Maharah Al-Kalam base Tiktok social media application," *Journal of Arabic Studies*, vol. 6, no. 1, pp. 119–134, 2021. (in Indonesian)
[46] K. S. Tang, S.-W. Lin, and B. Kaur, "Mapping and extending the theoretical perspectives of reading in science and mathematics education research," *Int. J. Sci. Math. Educ*., vol. 20, no. S1, pp. 1–15, 2022. doi: 10.1007/s10763-022-10322-1
[47] T. L. Shreiner, "Data literacy for social studies: Examining the role of data visualizations in k–12 textbooks," *Theory Res. Soc. Educ*., vol. 46, no. 2, pp. 194–231, 2018. doi: 10.1080/00933104.2017.1400483
[48] H. V. Saphira and B. K. Prahani, "Profile of senior high school students' critical thinking skills and the need of implementation PBL model assisted by augmented reality book," *Indonesian Journal of Science Education*, 2022.
[49] Y. Wang, B. Zhang, R. Zhang, Y. Wei, Y. Wang, and R. Zhu, "Microplastic pollution research based on the VOS viewer software: research trends, ecological effects, and testing methods," *Atmosphere (Basel)*, vol. 14, no. 5, 838, 2023. doi: 10.3390/atmos14050838
[50] T. Ciloglu and A. B. Ustun, "The effects of mobile AR-based biology learning experience on students' motivation, self - efficacy, and attitudes in online learning," *J. Sci. Educ. Technol.*, vol. 32, no. 3, pp. 309–337, 2023. doi: 10.1007/s10956-023-10030-7
[51] J. W. Creswell, "Research design: Qualitative, quantitaive and mixed methode," *Jakarta: Pustaka Pelajar*, 2016. (in Indonesian)
[52] J. Yu, A. R. Denham, and E. Searight, "A systematic review of augmented reality game-based learning in STEM education," *Journal Educational Technology Research*, 2022.
[53] N. Yuviler-Gavish, Z. Treiger, E. Horesh *et al*., "Augmented virtuality systems as a tool for improving numeracy decision-making among children," *Simulation & Gaming*, vol. 53, no. 4, pp. 317–334, 2022.
[54] M. Mayfield, "Creating training and development programs: using the ADDIE method," *Development and Learning in Organizations: An International Journal*, vol. 25, no. 3, pp. 19–22, 2014. doi: 10.1108/14777281111125363
[55] Y. W. Cheng, Y. Wang, I. L. Cheng, and N. S. Chen, "An in-depth analysis of the interaction transitions in a collaborative augmented reality-based mathematic game," *Interactive Learning Environments*, 2019.
[56] A. D. Nincarean, L. E. Phon, M. H. A. Rahman, N. I. Utama, M. B. Ali, N. D. A. Halim, and S Kasim, "The effect of augmented reality on spatial visualization ability of elementary school student," *International Journal on Advanced Science Engineering Information Technology*, vol. 9, no. 2, pp. 624–629, 2019.