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Integration Augmented Reality-Based Game-Based Learning through the SAMR Model in Elementary Literacy and Problem-Solving Instruction

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ABSTRACT

This study aims to make learning more engaging and interactive for students by integrating AR-supported game-based learning into the SAMR model. The integration of Augmented Reality (AR)-supported Game-Based Learning (GBL) using the SAMR model in Cirebon Regency. The study employed a quantitative descriptive approach supported by classroom observations, literacy and problem-solving tests, and teacher interviews. The participants were 168 elementary school students from schools implementing GBL–AR–SAMR learning and comparison classes alongside more conventional learning approaches. Data were analyzed using descriptive statistics and independent two-sample t-tests. The results showed that students participating in GBL–AR–SAMR learning achieved higher literacy and problem-solving outcomes than students in comparison classes. The average literacy score increased from 58.3 before implementation to 79.20 after implementation, while the average problem-solving score increased from 52.0 to 77.00. The independent two-sample t-test indicated a statistically significant difference between the two groups ($p < 0.05$). The integration of the SAMR model allowed teachers to shift from merely replacing media to redefining the learning experience. This article offers a unique perspective by developing AR-based learning practices within the local context of Cirebon, with implications for digital literacy, creativity, and students' readiness to face the challenges of the digital age.

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1. INTRODUCTION

The education system has undergone significant transformations in line with the times, technological developments, and community needs. The learning process in education has changed with the use of technology in its activities [1]. This is due to the development of the 5.0 industrial revolution, so that the use of technology has become a representation of

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community activities in general, including in the field of education [2]. The rapid development of digital technology has transformed educational practices worldwide, requiring schools to adopt innovative learning approaches that foster students' higher-order thinking skills. In the context of 21st-century education, literacy and problem-solving skills are considered essential competencies because they enable students to critically interpret information, make informed decisions, and solve complex real-world problems [7]. These competencies are particularly important for elementary school students because they form the foundation for lifelong learning and future participation in a knowledge-based society.

Despite their importance, literacy and problem-solving skills among Indonesian students remain a challenge. Results from the Programme for International Student Assessment (PISA) indicate that Indonesian students continue to perform below the OECD average in reading literacy, mathematics, and scientific reasoning. The findings suggest that many students experience difficulties in interpreting information, evaluating evidence, and applying knowledge to contextual situations [8]. Preliminary observations conducted in elementary schools in Cirebon Regency also revealed that students often rely on memorization rather than analytical reasoning when solving literacy and problem-solving tasks. In addition, teachers reported difficulties in integrating digital technologies into classroom instruction due to limited pedagogical experience and learning resources.

The use of technology as an alternative innovation in the learning process can overcome the challenges of conventional learning [3]. Most students already own and understand how to use gadgets, which are supported by the education system. This aligns with the future goal of education, which is to increase human adaptability to technological developments to overcome future challenges [4]. However, many have not yet optimally implemented technology in the education system [5]. For example, in primary education, most students tend to prefer playing rather than studying. As a result, more elementary school students prefer playing games to studying from books. It is common for students to prefer playing games, especially in today's digital era [6].

The current learning process is still conventional, with teachers and students meeting in the classroom and using textbooks and blackboards to deliver material. In addition, there are still teachers who have not maximized their efforts in training students' literacy skills and in involving students directly in problem-solving, resulting in minimal student abilities [9]. Literacy skills are basic skills that students must have, making them an important area of focus [10]. Another skill that remains a concern is problem-solving [11]. Conventional learning methods make it difficult for students to understand the learning material [12]. Therefore, to address the above issues, it is necessary to utilize augmented reality-based game-based learning, which can make learning more interesting, especially when presenting learning material using the SAMR model at the elementary school level. This integration is expected to enable AR to visualize abstract learning concepts by relating them to everyday life events and designing them into a game-based learning experience. Thus, students can learn more enjoyably, for example, by playing a game or by solving problems systematically [13].

This limitation indicates an important research gap. Although previous studies have demonstrated the benefits of AR and GBL separately, little is known about how their

integration through the SAMR model influences literacy and problem-solving skills among elementary school students. Furthermore, empirical evidence from Indonesian elementary schools remains scarce, especially in regional contexts where technology integration is still developing.

The novelty of this study lies in its investigation of the combined implementation of Augmented Reality, Game-Based Learning, and the SAMR framework in elementary education. Unlike previous studies that focused on a single technological intervention, this research examines how these three components interact to support the development of literacy and problem-solving among elementary school students in Cirebon Regency. Therefore, this study aims to analyze the implementation of AR-based Game-Based Learning using the SAMR model and to examine its relationship with students' literacy and problem-solving skills. The findings are expected to contribute to the growing body of knowledge on technology-enhanced learning and provide practical guidance for teachers, schools, and policymakers in designing more effective digital learning environments.

2. METHOD

This study used a descriptive, quantitative method and was conducted with several elementary school teachers in Cirebon Regency. The descriptive quantitative method is a study that aims to systematically, factually, and accurately describe the conditions of variables using numerical data without providing an experimental treatment. This study selected learning environment characteristics using the SAMR model. The SAMR model considers the use of technology during the learning process. The population used in this study consisted of 168 students and five teachers. The sampling technique used in this study was saturated sampling, in which the population size was equal to the sample size. Thus, the sample consisted of 168 students and five teachers. Data collection used questionnaires, observation, and interviews to obtain descriptive data to explain the relationship between SAMR and the use of AR technology during the learning process. Through this case study, data on teachers' competence in using technology during the learning process, especially AR, can be collected. The SAMR development model is shown in Figure 1 below.

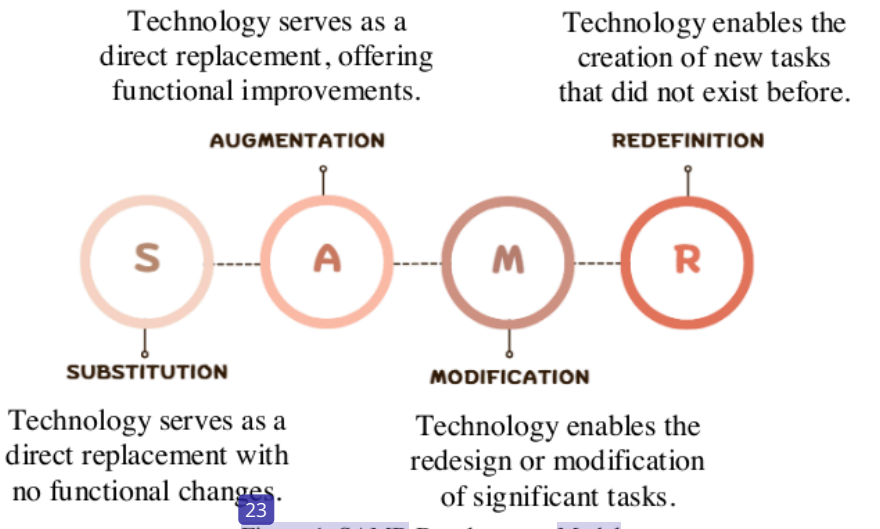

Figure 1. SAMR Development Model

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The implementation of the SAMR model was operationalized through four levels of technology integration. At the Substitution level, students used digital learning materials to replace traditional printed resources. At the Augmentation level, Augmented Reality applications provided interactive three-dimensional visualizations and immediate feedback. At the Modification level, students engaged in collaborative game-based activities that transformed conventional learning tasks through technology integration. Finally, at the Redefinition level, students completed authentic learning projects and problem-solving activities that would have been difficult to accomplish without AR technology and game-based learning environments.

The questionnaire in this study was based on grouping research subjects by gender, competency level, teacher status (contract or civil servant), and teacher education level. In addition, the intensity of technology use in learning was also reviewed. The Likert scale was used to determine the ability, competency, and class preparation in the use of integrated technology during the learning process. The flowchart for this study is shown below.

In addition, there is a process of implementing augmented reality-based game-based learning, which will be carried out by conducting training for teachers on the integration of augmented reality-based game-based learning using the SAMR model, guiding students in using augmented reality-based game-based learning using the SAMR model, observing teacher and student interactions during the learning process, and collecting data on student learning experiences and teacher responses to the integration of augmented reality-based game-based learning using the SAMR model. The aspects of this study include identifying learning models and student needs, selecting learning themes for integrating AR-based game-based learning, conducting field study observations, conducting literature reviews, and integrating AR-based game-based learning using the SAMR model.

3. RESULTS AND DISCUSSION

This finding focuses on the integration of augmented reality-based game-based learning using the SAMR model to improve the literacy and problem-solving skills of elementary school students. Observations during the learning process showed increased student motivation and active participation, especially during the Modification and Redefinition stages of the SAMR model, enabling the transformation of learning activities through AR technology. These findings support the theory that integrating AR into learning through the SAMR model effectively improves students' literacy and critical thinking skills [14].

The analysis results show that the average literacy scores of students in classes that have integrated GBL–AR–SAMR are in the moderate to high range, while those of the comparison class using conventional learning are in the moderate range. The average, minimum, maximum, and standard deviation values were calculated for each class, and the distribution of scores in the GBL–AR classes shifted toward higher values, with more students in the high category than in the comparison class. A similar pattern was observed in problem-solving skills: classes with AR game integration showed higher average scores and more homogeneous score distributions than those that used this technology less frequently. This descriptive picture provides an initial basis for the conclusion that there are

differences in skill tendencies between the two natural groups in the elementary schools studied.

3.1 Improvement in literacy skills

Table 1. Descriptive Statistics of Literacy Skills

	N	Mean	SD	Minimum	Maximum
GBL-AR-SAMR	168	79,20	7,84	62	93

The results of literacy tests conducted before and after the intervention showed a significant improvement. At the time of implementation, 30% of students answered inferential questions correctly (summarizing the content of the reading). Most (70%) could answer only literal questions, such as naming, counting, and identifying shapes. The average test score was in the fair category (58.3). Based on the test results, the majority of students were in the fair category in understanding narrative and expository reading. Students tended to identify explicit information but had difficulty interpreting implicit meanings and drawing conclusions [13].

Meanwhile, during implementation, after using AR-based Game-Based Learning, 80% answered inferential and evaluative questions. The average score increased to 79,20. The study's results showed a significant improvement. Students were able to relate the information in the reading to the 3D visualization generated by AR, thereby deepening their understanding. In this case, AR serves as visual scaffolding that bridges abstract text with concrete representations, enabling students not only to read but also to construct meaning.

3.2 Improvement in problem-solving

Table 2. Descriptive Statistics of Literacy Skills

	N	Mean	SD	Minimum	Maximum
GBL-AR-SAMR	168	77,00	8,12	58	92

The math questions required students to understand the context, extract information, and model it using mathematical operations. During the test, students averaged 52, with the dominant pattern being direct addition/subtraction without rereading the question. Only five students made notes/sketches to understand the problem. Meanwhile, in the research implementation, the average score increased to 77,00. A total of 118 students (70%) began using new strategies, such as making diagrams, drawing diagrams, or trying alternative solutions.

In contextual problem-solving tests, students initially tended to use direct calculation procedures rather than analyze the problem. However, after the intervention, students began to show strategic development. For example, students identified key information, created visual representations through picture notes, discussed with friends, and tried more than one alternative solution. The integration of AR into game challenges allowed students to "experience" problems in context [15]. For example, when faced with a story problem about food distribution at a party, AR displays animations of food and the number of guests, making it easier for students to model the problem mathematically [16]. This supports

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Vygotsky's constructivist theory, in which real-world context-based learning experiences facilitate the formation of scaffolding [17]. In contextual math problems, students initially perform calculations without carefully rereading the problem.

Class observations indicate that integrating AR-based GBL can make previously passive students more active in asking questions and participating in discussions. The challenge element in AR games provides healthy competitive encouragement, while the collaboration element in completing missions encourages students to work together [18]. Interviews with teachers show that students often make mistakes because they rush to answer. After using AR games, students are given challenges that require them to solve problems through missions. From the interviews, students stated that learning with AR is more fun and helps them avoid boredom quickly. Teachers also reported that students were more focused during learning, and even those with low concentration levels showed increased attention. These findings align with the findings of Billinghurst & Duenser [19], who reported that AR increases students' emotional engagement due to its immersive nature.

3.3 Effectiveness of the SAMR model

The implementation of the SAMR model in this case study proved effective in facilitating the transition from traditional to digital learning.

1. Substitution: AR replaces printed media/static images, making learning more interesting.
2. Augmentation: Interactive AR features add value; for example, students can move 3D objects to understand concepts.
3. Modification: Game-based challenges change the structure of learning activities, from simply reading questions to completing missions that require problem-solving strategies.
4. Redefinition: Students have the opportunity to create mini projects in the form of AR-based interactive stories that would be impossible with traditional methods.

This context shows that even though digital facilities are not yet fully available, AR integration can be done with the support of simple devices (mobile phones/tablets) and Android-based applications [20], [21]. This shows the great potential of AR to expand access to and improve the quality of learning in rural areas. Based on this, it strengthens the argument that AR-based GBL is not merely a media innovation but can change the learning paradigm. Student literacy is no longer limited to reading text; it now involves the skills of interpretation, analysis, and integration of visual information. Meanwhile, problem-solving abilities develop as students are encouraged to face challenges that resemble real-life situations [4]. However, several challenges have been identified, including limited access to AR devices for some students, the need for teacher training to integrate AR into lesson plans, and the need for a flexible curriculum to accommodate new technology. Thus, the success of implementation depends heavily on school support and regional education policies.

An independent two-sample t-test analysis was then used to compare the average literacy scores between classes that used GBL–AR–SAMR and those that did not, in a quasi-experimental framework. The t-test results showed that the t-value for literacy scores was greater than the t-table value at the 0.05 significance level, with a p-value (Sig.) of 0.05. This means there was a statistically significant difference in average literacy scores between the

two classes, even though the researchers did not provide a direct experimental treatment. This finding is interpreted to mean that in the real context of the elementary schools studied, classes that more intensively used AR games and SAMR principles tended to have higher literacy levels than classes whose learning was still dominated by conventional methods, so that the integration of GBL–AR–SAMR correlated with better literacy achievement [14], [22].

The exact t-test was also applied to problem-solving scores. The results showed a similar pattern: the average problem-solving scores of classes with GBL AR SAMR integration were higher than those of the comparison class, and the independent two-sample t-test produced a t-value that again exceeded the t-table value with a p-value below 0.05. In other words, the difference in average problem-solving scores between the two classes was statistically significant, despite the study not being a controlled experiment [23]. Substantively, the researchers interpreted that students who were accustomed to completing missions, challenges, and scenarios in AR games that were designed in line with the levels of Substitution, Augmentation, Modification, and Redefinition demonstrated better abilities in understanding problem situations, choosing strategies, and determining solutions, compared to students who were more often exposed to conventional exercises in textbooks.

From a theoretical perspective, these findings are consistent with the concept that game-based learning and augmented reality can increase student motivation, engagement, and depth of cognitive processes. The integration of AR makes texts, objects, and problem situations more concrete and contextual so that students do not just read or calculate abstractly, but also see, manipulate, and make decisions in an information-rich virtual environment [14]. When the SAMR framework is applied, learning does not stop at media substitution. Still, it moves on to the stages of augmentation, modification, and redefinition, where new tasks that were previously impossible without technology can be designed [24]. It is in this situation that literacy skills develop not only as the ability to read written text, but also to interpret instructions, understand narratives in games, and connect information between screens and the real world. In contrast, problem-solving develops through practicing choosing strategies, trying solutions, and reflecting on the consequences of choices in the game.

Substantively, this series of results shows that integrating Augmented Reality-based Game-Based Learning using the SAMR model has a more substantial, real-world influence on improving the literacy and problem-solving skills of elementary school students than conventional learning [14], [24], [25]. Students who were actively involved in AR game activities structured in stages according to the SAMR level not only showed higher test scores but also demonstrated better thinking patterns in understanding texts, interpreting information, and developing problem-solving strategies [26]. Thus, based on the results of the t-test conducted, the application of GBL–AR–SAMR in the elementary school context, including in areas such as Cirebon Regency, can be declared statistically effective in improving the quality of student learning outcomes in literacy and problem-solving.

4. CONCLUSION

The integration of augmented reality-based game-based learning using the SAMR model effectively improves the literacy and problem-solving skills of elementary school students. The use of the SAMR model helps map the development of technology integration from substitution to transformation of learning. The SAMR model provides a step-by-step framework for teachers to transform conventional learning into an immersive digital learning experience. This case study in Cirebon confirms that device limitations do not hinder innovation, as long as there is a clear methodological framework. The recommendation for the future is to implement this model more widely, alongside the development of varied content, to ensure the sustainability of student skill improvement. Thus, this study confirms that device limitations do not hinder innovation, as long as there is a clear methodological framework. Therefore, the application of GBL-AR within the SAMR framework should be maintained and further developed as an innovative learning approach in elementary schools, as it has been shown to correlate with strong literacy and problem-solving achievement. The integration of technology, such as AR games, not only increases students' interest in learning but also provides opportunities for repeated practice in reading and problem-solving in engaging, challenging situations. This study also confirms that the descriptive quantitative approach can give a clear empirical picture of the actual conditions of GBL–AR–SAMR integration and student ability profiles, thereby serving as a basis for decision-making by teachers, schools, and researchers for program development and further research with more in-depth designs.

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