Al-Bidayah : jurnal pendidikan dasar Islam
Volume 17 Number 1, June 2025
ISSN: 2549-3388 (online)
Available online at https://ejournal.uin-suka.ac.id/tarbiyah/albidayah
Submitted: May 9, 2024, Accepted: June 30, 2025

Development of Augmented Reality-Based Game-Based Learning Integrated with Character Values to Improve Literacy and Problem-Solving Skills of Elementary School Students

Herisa Hardiyanti Sholeha[1], Zakiyah Ismuwardani[2], Mochamad Guntur[3], Anasya Putri Febgiyo[4], Nonih Nur Syah Lukiyah[5]

Institut Prima Bangsa, Indonesia[1,2,3,4,5]
E-mail: herisahardiyantisholeha@gmail.com[1], zakiyahismuwardani773@gmail.com[2], gunturmath@gmail.com[3], anasyaputriii232@gmail.com[4], nonihnursyahlukiyah@gmail.com[5],

DOI: 10.14421/al-bidayah.v17i1.10299

Abstract

Conventional learning practices are often ineffective in building values such as responsibility, honesty, cooperation, and discipline. Meanwhile, normative verbal moral approaches are also unable to touch on students' real experiences. Therefore, alternative learning media are needed that can integrate cognitive and affective learning simultaneously through a contextual and enjoyable approach. This research aims to develop game-based learning based on augmented reality integrated with character values as an alternative learning method that is more interactive, interesting, and easily accessible by teachers and students. The method used in this research is the ADDIE development method (analysis, design, development, implementation, and evaluation). Integrated with NIS, this research was conducted in elementary schools in the Cirebon district. The instruments include validation sheets, observations, literacy and problem-solving tests, and character value measurement questionnaires. The results showed that the augmented reality-based educational game developed met the eligibility criteria in terms of learning content, visual appearance, and integrity of character values. This can be seen from the results of literacy skills obtained, showing that the student's pretest score was 60, which increased to 85 in the posttest, an increase of 41.7%. And problem-solving skills were obtained by students' pretest score of 55, which increased to 80 in the posttest, with a rise of 45.5%. This study presents a novel integration of augmented reality with game-based learning and character Education at the elementary level, which has rarely been explored in previous research. Theoretically, it contributes to the intersection of digital pedagogy and frameworks for character development. Practically, it offers an innovative and empirically tested learning medium that supports literacy and problem-solving enhancement while fostering values such as responsibility, cooperation, and discipline. Thus, the results of game-based learning based on augmented reality prove that this medium is efficacious in improving students' literacy and problem-solving skills while strengthening the character of discipline, responsibility, and cooperation.

Keywords: game based learning; augmented reality; literacy; problem solving

Introduction

The education system is growing. The development of the education system has undergone a significant transformation along with the times, technology, and the needs of society (Helaluddin & Syawal, 2018). However, current learning has not reflected the suitability between learner characteristics and technological developments. The learning process remains conventional, with the dominance of direct interaction between teachers

and students, utilising textbooks and blackboards (Sholeha et al., 2022). Several studies have demonstrated that Augmented Reality (AR)-based learning media can enhance students' understanding of abstract material (Bursali & Yilmaz, 2019; Yildirim & Seckin-Kapucu, 2021). The study by Bursali and Yilmaz (Bursali & Yilmaz, 2019), for example, showed that the use of AR applications in secondary school students can significantly improve reading comprehension and learning retention. Therefore, it is essential to develop AR-based learning media that also integrate character values so that learning is not only cognitively effective but also supports student character development.

Various studies have demonstrated that Augmented Reality (AR) in learning can increase student attraction, conceptual understanding, and motivation (Czok et al., 2023; Lee et al., 2024). The use of AR also promotes an immersive and interactive learning experience, which supports critical thinking and problem-solving (Lampropoulos & Kinshuk, 2024). The utilisation of technology as an alternative learning innovation in the current education system can overcome the challenges of conventional learning (Pangondian, 2019). Most students already have and understand the use of gadgets, and the current education system has supported school infrastructure facilities; this is in line with the future educational goals of increasing the competitiveness of adaptive human resources in technological developments to answer the challenges of future developments (Azmi, 2016). However, there are still many who have not been able to optimise technology in the education system optimally (Ngafifi, 2014). As is the case in basic Education, most of the characteristics of students prefer to play rather than learn (Sholeha et al., 2020). As a result, elementary school students today play more games than learn using books. Students playing games is a common thing, especially in today's global era (Qodr, 2020). Therefore, in answering this problem, teachers are required to be enthusiastic about understanding the characteristics of students by providing interactive learning (Syachtiyani & Trisnawati, 2021).

Additionally, Game-Based Learning (GBL) offers a fun and engaging approach to learning that promotes active participation. The integration of GBL with AR enables a more immersive learning experience, which not only enhances learning outcomes but also promotes self-confidence and social collaboration (Ullah et al., 2022). However, most studies still focus on cognitive aspects, while affective aspects, such as character values, have not been thoroughly explored (Lampropoulos et al., 2023). Therefore, learning

media innovations that are not only technologically attractive but also support the strengthening of values such as responsibility and cooperation are important in the current context of basic Education.

In addition, there is still a learning process that has not been maximised in training students' literacy skills and directly involving them in solving a problem, so students become spoiled, and their abilities become minimal (Asriadi, 2021). Literacy is an essential skill that students must possess, so until now, it is still considered an ability (Simaremare et al., 2022). Learning using conventional methods results in students being challenged to direct, so students' character values are still low (Nasaruddin, 2018).

Strengthening character values is an integral part of the education curriculum (Rahmad Wahyugi1, 2021). However, many technology-based learning media have not been designed to support strengthening student character (Amalia & Najicha, 2023). This study aims to evaluate the effectiveness of AR-based GBL learning media integrated with character values in improving the literacy, problem-solving, and character-building skills of elementary school students.

Based on the description above, it is necessary to innovate in developing learning media (Sahronih et al., 2019). One of them is to innovate and develop a learning process that can attract students' attention, such as the learning process using game-based learning. Game-based learning is used based on augmented reality (AR) and is integrated with character values (Hung et al., 2014). The existence of character-integrated learning media from AR that can visualise abstract learning to be contextual by linking daily events and be designed in Android-based games can turn into game-based learning (Bakri et al., 2021). Thus, students can learn while playing by solving problems systematically.

With AR-based game-based learning integrated with character values, teachers can interact with students digitally and not solely focus on traditional learning or existing printed books. The main objective of this research is to make learning more engaging and interactive for students (Rotelli & Monreale, 2023). The application of AR-based game-based learning involves a learning process that involves teachers, students, and other supporting infrastructure. In addition, it also pays attention to usability and user experience so that the application can be used easily by teachers and students.

Research Methods

The methodology used in this research is Research and Development (R&D). The Research and Development method is commonly referred to as development research, with the development design using ADDIE (Analyse, Design, Develop, Implement, and Evaluate) (Iswati, 2019; Mimin Ninawati et al., 2021). ADDIE was chosen in this study because it provides a systematic, flexible, and appropriate development framework for the needs of technology-based learning media development (Iswati, 2019). ADDIE allows the development process to be carried out in a gradual and structured manner, starting from the identification of needs to the evaluation of the effectiveness of the developed media (Mimin Ninawati et al., 2021). Thus, researchers find it more suitable for large-scale curriculum development; ADDIE is more practical to use in the context of developing applicable AR-based media in elementary schools. The main advantage of ADDIE lies in its iterative and adaptive approach, allowing researchers to make improvements at each stage based on the results of validation and trials. Therefore, this model is considered the most relevant for producing learning media that is effective, efficient, and by the characteristics of the end-users, namely, primary school teachers and students.

This research method is designed by integrating Game-Based Learning (GBL), Augmented Reality (AR), and character Education theories as a conceptual basis for designing, developing, and evaluating learning media. GBL Theory offers a framework for incorporating game elements to foster student motivation and engagement in meaningful learning. AR Theory is used as an interactive visualisation approach to help students understand abstract concepts in a contextualised manner. Meanwhile, Character Education Theory becomes the basis for designing game content that incorporates values such as responsibility, cooperation, and honesty. These three theories served as the basis for preparing instruments, indicators of success, and evaluation stages, which were subsequently implemented in the ADDIE model used as a development framework in this study. Thus, each stage in the ADDIE model not only reflects the technical process of media development but also incorporates the pedagogical principles of GBL Theory, the visual approach of AR Theory, as well as the systematic integration of character values developed in the game content.

The development of AR-based game-based learning will involve experts in material development, media, and user experience. An expert test is conducted to ensure that learning media in the form of AR-based game-based learning is feasible for implementation in schools. The instruments used to collect data in this study are interviews, observations, scales, and tests. This research was conducted at an elementary school in Cirebon Regency during the second semester of the 2023/2024 academic year. The research subjects consisted of fifth-grade students, classroom teachers, and subject matter and media experts. The research grid used is presented in the following table.

Table 1
Research Grid

ADDIE Stage	Activity	Objektive
Analysis	Analysis of needs, student characteristics, and learning challenges	Identify problems and media development needs
Design	Media concept development, game design, and character value integration	Design media according to cognitive and affective objectives
Development	Creation of AR-based media prototypes and validation by experts	Produce media suitable for testing.
Implementation	Limited testing in fifth-grade elementary schools in Cirebon	Assessing the effectiveness of media in real learning
Evaluation	Final assessment based on learning outcomes data and student and teacher feedback	Determining the efficacy and revision of media development

Source: Model ADDIE

To measure the effectiveness of the developed learning media on improving students' literacy and problem-solving skills, a quasi-experimental approach was used through pre-tests and post-tests. The instruments used in this study are as follows. The literacy test consists of multiple-choice questions and short essays that measure three main aspects: (a) Ability to read and understand texts, (b) Ability to analyse information, (c) Ability to identify the main ideas in a text. The problem-solving test was designed in the form of contextual questions based on stories or real-life situations, which measured: (a) Ability to identify problems, (b) Ability to formulate relevant solutions, (c) Ability to evaluate and select the best solution.

The instruments were validated through expert judgment by two experts in elementary Education and one senior teacher, with results indicating a high level of content validity. For reliability testing, a limited trial was conducted on students outside the main sample. The analysis using Cronbach's Alpha yielded values of 0.84 for the

literacy instrument and 0.86 for problem-solving, which fall into the high-reliability category ($\alpha > 0.80$). The data obtained from the research results were analysed using quantitative and qualitative approaches. For quantitative data, in the form of pre-test and posttest results of students' literacy and problem-solving abilities, inferential statistical analysis techniques were employed using t-tests with the aid of SPSS version 24.

Additionally, the media validation scores from subject matter experts, media experts, teachers, and students were analysed using quantitative descriptive analysis. Meanwhile, qualitative data, in the form of observations of learning activities, teacher responses, and student responses, were analysed using thematic analysis. This analysis included the stages of data coding, theme identification, and interpretation of meaning based on the narratives that emerged during the learning process. This approach was used to gain a deeper understanding of how learning media influences student interaction and the application of character values during the learning process. The stages of this research are illustrated in the following figure.

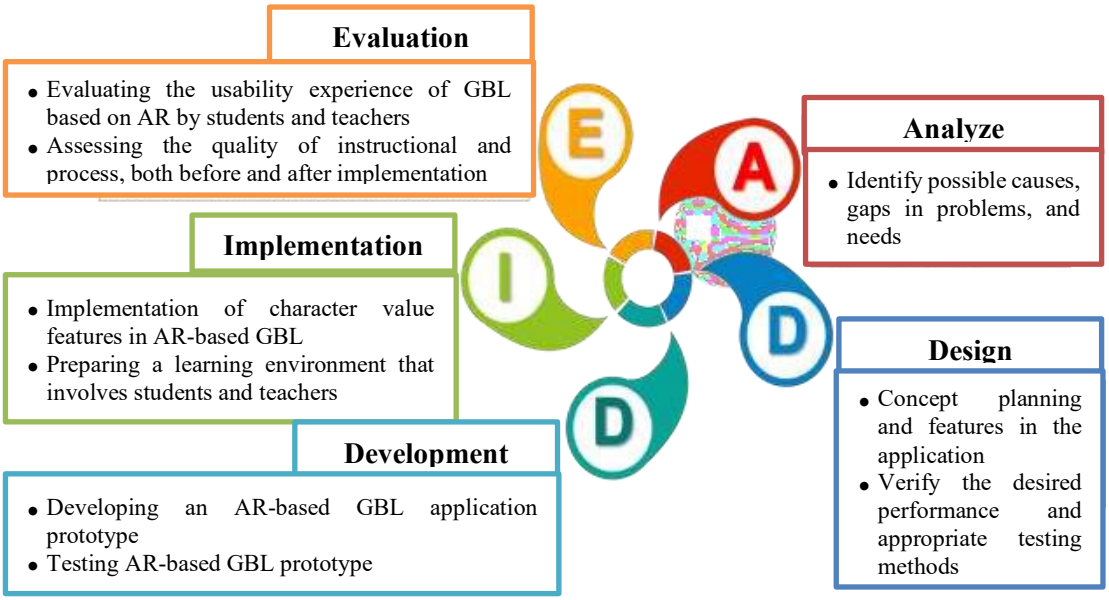

Figure 1
Research Flowchart
Source: Personal Document

In addition, in this research, there is an implementation process of game-based learning based on augmented reality conducted by 1) teachers in teaching the use of the application in the context of learning in the classroom; 2) teachers conducting guidance to students; 3) observing the interaction of teachers and students during the learning

process; and 4) collecting data on learning experiences using game-based learning based on augmented reality.

Result

The results of the needs analysis show that students in elementary schools have a strong interest in technology-based media. Technology-based media, such as games and gadgets, are often used by students (El Iq Bali, 2019). However, in reality, students are also usually challenged to be motivated if learning is done traditionally in the classroom. There are still teachers who have difficulty integrating character values into daily teaching. Character values such as responsibility, cooperation, and honesty are consistently applied during learning. For example, students are challenged to complete missions in groups, which requires communication and collaboration (Amalia & Najicha, 2023). In addition, the game scenarios featuring moral dilemmas help students understand the importance of honesty and responsibility in decision-making. This learning media makes it easier for students to teach abstract concepts through AR visualisation (Yusri, 2020). However, some teachers expressed the need for additional training to maximise the utilisation of this technology.

This increases the urgency of developing educational media based on game-based learning using AR technology (Bursali & Yilmaz, 2019). So, with the existence of learning media that integrates the character of AR, abstract learning can be visualised as contextual by linking daily events (Simaremare et al., 2022). Using augmented reality features can allow students to learn the material presented visually and practically (Nistrina, 2021). Through the use of AR, students can see simulated 3D objects related to the learning material (Yildirim & Seckin-Kapucu, 2021). This not only makes learning more interesting but also helps students understand abstract concepts through visual representations (Zafeiropoulou et al., 2021). The image of students using game-based learning with augmented reality integrated with character values can be seen in the following image.

Figure 2
Students using game-based learning with augmented reality integrated with a character.
Source: Personal Document

Based on Figure 2, when students use game-based learning media with augmented reality (AR) technology, they experience a learning process that is different from conventional learning. In the game, students not only interact with text and images but also see learning objects appear in real life in their surroundings through the camera on their devices (tablets/smartphones). For example, when learning about environmental cleanliness, students can see a simulation of a pile of trash on the school grounds that they must virtually clean up as part of the game's mission. The augmented reality (AR) display in this learning media is designed to present virtual objects that can interact with the real world through mobile devices such as smartphones or tablets. When students point their device cameras at markers or specific pages in the module, three-dimensional objects automatically appear on the screen. These objects can be characters, props, environments, or thematic illustrations that are relevant to the learning material. Environmental cleanliness can be seen in the following image.

Figure 3
Augmented reality display on the app
Source: Personal Document

As shown in Figure 3, when students scan the page featuring a trash bin, a 3D simulation of a pile of trash and a virtual character providing instructions appear. Students are asked to select actions that reflect values of responsibility and environmental care, such as sorting organic and inorganic waste by dragging them to the appropriate trash bins. The AR visual display is bright, interactive, and proportionate to the real-world environment. Objects move when touched or selected, and some sections include audio narration explaining the game's context. The display also features assessment icons such as scores, levels, and stars to provide immediate feedback on students' actions.

Figure 4
Example of a quiz in the game-based learning app
Source: Personal Document

Figure 4 shows one of the quizzes featured in the app, titled "Types of Waste," which aims to assess students' understanding of waste classification based on its characteristics while instilling values of responsibility and environmental awareness. This quiz appears after students complete an AR simulation showcasing various types of waste, such as dry leaves scattered across a virtual school environment.

Each challenge in the game is designed not only to test their cognitive understanding (such as reading information or solving puzzles) but also to instil character values. For instance, in one game level, students are given the option to complete a task alone or collaborate with a "virtual friend," where only through collaboration can they complete the mission more efficiently. Student responses indicate high enthusiasm for this approach. They feel challenged yet motivated because the learning is presented in the form of a game with a level system, points, and rewards. This enhances their engagement, both emotionally and cognitively (Nisa et al., 2018). From observations and interviews, it was revealed that students not only learn the lesson content but also actively reflect on their actions in the game, such as the importance of helping each other or not giving up when facing challenges. The integration of character values into the game makes learning feel less didactic. These values emerge naturally through the storyline, challenges, and choices students must make. This aligns with the experiential learning approach (Kolb, 1984), where meaningful learning occurs when students experience, reflect on, and apply knowledge and attitudes directly. Thus, the use of AR-based games integrated with character values not only enhances students' cognitive abilities but also creates a fun, meaningful, and contextually character-building learning experience in line with the principles of the Merdeka Curriculum.

The results of this study suggest that the integration of augmented reality and game-based learning media can enhance students' literacy and problem-solving skills. Integrating AR and gamification in learning encourages students' cognitive engagement and enhances the retention of abstract concepts (Lampropoulos & Kinshuk, 2024). In addition, students' ability to cooperate and discuss when solving challenges in the game demonstrates that game-based learning can develop collaborative problem-solving skills, which are essential for 21st-century skills (Ullah et al., 2022).

Not only cognitive aspects, this media also supports character Education. The study by Zainuddin (Syamsijulianto et al., 2021) noted that digital media design

incorporating ethical narratives and moral decision-making can enhance students' affective values, such as responsibility and empathy. In the Indonesian context, this is highly relevant to the Merdeka Curriculum, which emphasises character integration into all aspects of learning.

In addition, the results of improved literacy and problem-solving scores support the argument that the use of AR creates an immersive and authentic learning environment. AR can directly connect learning materials with the real world, allowing students to understand and apply the concepts taught more easily (Czok, Krug, Müller, Huwer, Kruse, et al., 2023). Therefore, the media developed in this study not only enriches learning strategies but also shows a new direction in the development of relevant and meaningful educational technology.

Meanwhile, character values can be integrated through game scenario design. For example, in one challenge, students are asked to solve puzzles in groups, which encourages cooperation and communication (Abdillah Dalimunthe, 2016). In another challenge, students had to choose actions based on moral scenarios, such as helping other characters in the game, which reinforced the values of honesty and responsibility. During the learning session, students demonstrated the behaviour of discussing and sharing strategies with their peers to solve the mission. This reflects genuine cooperation outside of learning (Sapta & Nisa, 2024).

Based on the results of the product trial, game-based learning based on augmented reality integrated with character values is declared feasible.

Based on the results of product trials, game-based learning integrated with augmented reality and character values is declared feasible. This is seen from the eligibility category based on the score range, with the classification:

Table 2
Category Score

Score Range	Category
0-20	Not feasible
21-40	Less feasible
41-60	Quite feasible
61-80	Worthy
81-100	Very feasible

Source: (Sukiman 2012)

Based on the results of quantitative assessments conducted by material experts, media experts, teachers, and students. Material experts gave a score of 39, media experts gave a score of 47, teachers gave a score of 62, and students gave a score of 76. All four are included in the feasible category. The results of the material experts' suggestions can be seen in the following table.

Table 3
Advice from subject matter experts

No.	Aspects Assessed	Suggestions/Input from Material Experts	Follow-up/Improvements
1	Material Suitability	The material needs to be adjusted to the learning outcomes in the Merdeka Curriculum	Revise the content to align with the applicable CP and TP
2	Theme Integration	The integration of learning themes is still not explicit enough	Add instructions on the relationship between sub-themes in the game narrative
3	Literacy Question Relevance	Some questions are too difficult for fifth-grade elementary school students	Simplify question sentences and adjust text complexity
4	Character Values in Materials	Character values need to be presented in a realistic story context	Develop scenarios and characters that include character dilemmas
5	Language Suitability of the Material	The language in the material is too formal and technical	Adjust the language to the cognitive development level of elementary school students

Source: Personal Document

Based on the results of validation by subject matter experts, several important aspects were found that need to be strengthened, particularly regarding the alignment of content with the Learning Outcomes (CP) of the Merdeka Curriculum. The recommendations highlight the need to adjust the complexity level of the content and the format of the questions to align with the characteristics of fifth-grade elementary school students. For example, some literacy questions were found to contain abstract terms, so sentence simplification and restructuring of the text context were conducted to make them more communicative and applicable. Additionally, input regarding the integration of character values into narratives and learning scenarios is a key consideration. Subject matter experts emphasise that character values are more effectively instilled when they emerge in dilemmatic situations that prompt moral decision-making rather than through

normative quotes or dialogues. Therefore, researchers added game missions that include choices of attitudes and actions for students in specific situations. Input from subject matter experts enhances the instructional quality and content substance developed in the media. The implementation of these suggestions makes the media not only technically and visually sound but also substantively valid and aligned with the principles of meaningful learning (Astuti et al., 2024), which emphasises the connection between learning material and the cognitive structure of learners. In addition, there are also media expert assessments that can be seen in the following table.

Table 4
Recommendations from media experts.

No.	Aspects Assessed	Suggestions/Input from Material Experts	Follow-up/Improvements
1	Content	Add a brief explanation before the game mission begins	Add a narrative introduction at the beginning of the text-based game
2	Visual/Display	Some icons are too small and unreadable on mobile phone screens	Enlarge icon size and convert to high resolution
3	Language and Instructions	Use simpler language to suit elementary school students	Adjust instruction sentences using child-friendly vocabulary
4	Game Flow	The final level challenge is too difficult and disproportionate	The difficulty levels are restructured, made gradual (easy → hard)
5	Character Value Integration	The value of cooperation is not depicted in the game	Add group challenges and special points for teamwork

Source: Personal Document

The validation results from subject matter experts and media experts provided a number of important inputs to improve the quality of the learning media developed. Table 3 presents some of the main suggestions covering aspects of material, visuals, instructions, game flow, and character value integration. This validation process not only serves to assess the initial suitability of the media but also acts as a reflective mechanism for iterative improvement. One important example is adjusting the opening narrative to help students understand the game's context, as well as revising the final challenge to align with the cognitive level of elementary school students. By implementing these inputs, the learning media becomes more adaptive to user characteristics and meets good

pedagogical standards. This aligns with the principles of feedback-based instructional design, where expert involvement in the validation process is key to maintaining the quality and relevance of the media (Simaremare et al., 2022).

All four are included in the feasible category. The notes on the validation of game-based learning trials show that some questions and answers are wrong, so each question must be considered and rechecked to ensure that it is not wrong (Guntur et al., 2023). If the questions and answers are not correct, it will confuse the students (Fahyuni & Istikomah, 2016). Therefore, the questions and answers contained in game-based learning must be rechecked. The expert media assessment in this study is presented in the following table.

Results of pre-test and post-test measuring literacy skills

Table 5
Results of pre-test and post-test measuring literacy skills

Literacy aspect	**Average score** ***pre-test***	**Average score** ***post-test***	**Increase**
Reading and understanding the text	60	85	41,7%
Analyze information	58	83	43,1%
Identify the main idea	62	87	40,3%
Overall average	**60**	**85**	**41,7%**

Source: Personal Document

Based on Table 2, there was a significant increase in all aspects of students' literacy skills after the use of augmented reality-based learning media. The average score increased from 60 to 85, representing a 41.7% improvement. The most significant increase was seen in the aspect of analysing information (43.1%), followed by reading and understanding text (41.7%) and identifying main ideas (40.3%).

These results indicate that AR-based media, designed to be interactive, can strengthen the literacy skills of elementary school students. This finding is reinforced by research conducted by Bursali & Yilmaz (2019), which demonstrated that AR applications can significantly enhance reading comprehension and student engagement. Another support comes from (Fatmawati, 2020), who stated that interactive visual presentations in digital media can facilitate the process of critical reading and understanding meaning in a contextual context. The combination of AR and game-based learning is not only effective in improving cognitive aspects but also in increasing

students' active participation in literacy activities based on direct experience (Lampropoulos & Kinshuk, 2024).

These questions are presented in the form of interactive stories, where students must read the narrative and make decisions based on the information available. Literacy test results showed an increase in the average student score after using this media (Fajri et al., 2023). Educational games can increase students' learning motivation and encourage literacy through hands-on experience in games (Ullah et al., 2022). A learning that integrates AR elements helps students understand information in a more contextualised way and makes it easier for students to foster literacy (Ayun, 2021). Visualisation of objects in the game allows students to see the direct relationship between text and images (Tanu Wijaya et al., 2020).

Results of pre-test and post-test measuring problem solving

Table 6
Results of pre-test and post-test measuring problem-solving

Problem-solving aspect	**Average score** ***pre-test***	**Average score** ***post-test***	**Increase**
Identify the problem	55	80	45,5%
Formulate a solution	57	82	43,9%
Evaluate a solution	54	79	46,3%
Overall average	**55**	**80**	**45,5%**

Source: Personal Document

Based on Table 3, to determine the effectiveness of Augmented Reality (AR)-based learning media on students' problem-solving abilities, an inferential quantitative analysis was conducted using a paired sample t-test. This test aimed to compare the mean pre-test and posttest scores for problem-solving abilities given to students before and after using the media. Based on the data analysis, it was found that the average pre-test score was 55, while the average posttest score increased to 80, representing a 45.5% improvement. The t-test results indicated that this improvement was statistically significant ($p < 0.05$), suggesting that the developed learning media contributed to enhancing students' problem-solving abilities. The most crucial growth occurred in the element of evaluating solutions (46.3%), indicating that students are beginning to think reflectively about the problem-solving steps they take. These results align with research

by Widana (2021), which states that the use of visual-based learning technology, such as AR, can improve logical and systematic thinking skills.

Theoretically, these results align with Polya's (Putra et al., 2022) view of problem-solving Theory, which states that problem-solving ability encompasses four main stages: (1) understanding the problem, (2) designing a plan, (3) implementing the plan, and (4) evaluating the results. In the AR-based learning media developed these four processes are explicitly facilitated through the design of context-based game challenges that include visual scenarios. For example, students are asked to solve social or environmental problems through interactive visual simulations, which encourage them to think critically and make decisions.

Additionally, this approach aligns with Vygotsky's (Lasmawan & Budiarta, 2020) of the Zone of Proximal Development (ZPD), where students can achieve higher-level thinking potential (such as problem-solving) when supported by media appropriate to their cognitive development. With the assistance of AR-based media, students receive concrete visual representations that serve as scaffolding for understanding and solving problems. Thus, these findings indicate that AR-based learning media designed contextually and interactively are not only visually appealing but also pedagogically support students' logical, analytical, and reflective thinking processes, which are at the core of problem-solving skills at the elementary school level.

This finding is also supported by the study of Surya et al. (2020), which states that open-ended questions and interactive visual challenges encourage students to be more active in identifying and solving problems creatively. Internationally, Czok, Krug, Müller, Huwer, Kruse, et al. (2023) stated that the integration of Augmented Reality in science learning has been shown to improve critical thinking and problem-solving skills, as it provides a realistic context that closely approximates authentic situations. In addition, problem-based learning strategies based on visual contexts can encourage elementary school students to explore and evaluate better alternative solutions (Setiyaningsih & Subrata, 2023).

Discussion

Augmented reality (AR) can enhance students' conceptual understanding and problem-solving skills, suggesting that visual and interactive approaches have a direct

impact on the cognition of elementary school students. This can be explained by the dual coding Theory of Paivio (Zedadra et al., 2019), which states that information presented verbally and visually simultaneously will be easier to understand and remember. In this context, the use of AR, which allows the combination of the real world with virtual objects, helps students form more concrete mental representations of abstract concepts (Suryandari, 2023).

The increase in problem-solving abilities is likely due to students' active involvement in completing challenges in AR-based games. This process encourages self-exploration, collaboration, and decision-making, all of which are important components of meaningful learning (Surya et al., 2020). Additionally, high emotional involvement in the gaming experience facilitates the easier embedding of information in students' long-term memory.

This finding is consistent with the results of a study by Czok, Krug, Müller, Huwer, Kruse, et al. (2023), which demonstrated that integrating interactive technologies, such as AR, can significantly enhance learning outcomes, particularly in science and engineering. However, this study also highlights the need for further research to assess the long-term effects on affective aspects, such as student character formation (Czok, Krug, Müller, Huwer, & Weitzel, 2023). This is an important note because it integrates character values into the media, which is an innovative and relatively new approach compared to previous studies that focus solely on cognitive aspects. Compared to the study by Lampropoulos & Kinshuk (2024), which concluded that educational games can improve learning outcomes, this study adds a richer pedagogical dimension by combining AR technology and character values. In other words, not only is the cognitive aspect improved, but also the affective and social aspects. This is the primary contribution of this study, which distinguishes it from previous studies.

However, there are contextual differences that need to be taken into account. Most previous studies have been conducted at the secondary or tertiary Education level, whereas this study focuses on elementary school students in Indonesia. Age and cultural contexts can influence how students respond to technology, so these positive results indicate that contextually designed learning media, referring to the characteristics of Indonesian elementary school students, can provide optimal results.

Thus, the technological revolution in Education provides new opportunities for creating interactive and innovative learning methods. One approach that is gaining popularity is game-based learning (GBL), where learning is packaged in a game format to increase student interest and motivation (Lampropoulos et al., 2023). The use of augmented reality (AR) in GBL opens up opportunities to create more engaging and immersive learning experiences (Lampropoulos & Kinshuk, 2024). However, the biggest challenge in the implementation of this technology is to ensure that the content not only improves cognitive competence but also supports the strengthening of student character (Sapta & Nisa, 2024).

Learning that is integrated with character education is one of the main focuses of the Merdeka Curriculum implemented in Indonesia (Wati et al., 2020). The integration of character values such as responsibility, cooperation, and honesty into technology-based learning media is a necessity (Rahmad Wahyugi, 2021). Therefore, this research aims to develop AR-based game-based learning integrated with character values, with a focus on improving the literacy and problem-solving skills of elementary school students (Czok, Krug, Müller, Huwer, & Weitzel, 2023). Learning in elementary schools using AR allows students to connect with real-world environments through digital objects (Cahyaningrum et al., 2023). This provides a contextualised learning experience, which can increase engagement and retention of information. In this study, students were able to connect abstract concepts such as gravitational force with direct observation through AR simulations.

In the study, students also felt more motivated to learn due to the fun and interactive learning format. Teachers noted that students were more enthusiastic in group discussions and took more initiative in completing learning tasks. (Ullah et al., 2022) Teachers play an important role in facilitating the use of this media. Previous teacher training helped them understand how to integrate these games into learning (Lee et al., 2024). This shows the importance of teacher capacity building in supporting the adoption of educational technology (Guntur & Purnomo, 2024a). In this regard, proposed solutions include the use of simpler AR devices and the development of offline content for areas with limited access to technology (Lampropoulos et al., 2022).

The results of this study confirm previous findings that game-based learning (GBL) supported by augmented reality (AR) technology can significantly enhance

students' cognitive abilities while strengthening character values , such as cooperation, responsibility, and honesty (Guntur & Purnomo, 2024; Guntur & Purnomo, 2024b). This finding aligns with the research of Maulana (2025), which found that integrating game elements into learning encourages active student involvement and stimulates continuous learning motivation.

However, compared to the study by Wati et al. (2020), which emphasises the use of AR to deliver visually appealing learning content, this study adds a stronger pedagogical dimension by integrating character values into the game design itself. In this case, the approach used in this study is more holistic because it not only pursues entertainment and visual aspects but also designs explicit learning scenarios that shape students' character through moral and collaborative challenges within the game.

When compared to the study of Lampropoulos et al. (2022) in a foreign context, this study shows consistency in the effectiveness of AR-based GBL in improving learning outcomes. However, Lampropoulos's approach focuses more on middle and high school students and has not examined the integration of character values directly. This demonstrates that the primary contribution of this study lies in the context of basic Education in Indonesia, specifically in the integration of cognitive and affective aspects simultaneously.

The findings of this study align with previous studies by Bursali and Yilmaz (Hidayat et al., 2024), which demonstrated that AR-based learning media can significantly enhance students' reading comprehension and retention. In addition, the results of improving literacy and problem-solving also support the findings of Hung (Zedadra et al., 2019), which stated that game-based learning could increase students' motivation, self-efficacy, and learning achievement. However, this study expands on the contribution by integrating character values, which have not been comprehensively studied in previous research. With this approach, AR is not only a visual aid but also a vehicle for character-building in the context of basic learning.

The implications of these results suggest that innovative learning media based on AR and games have great potential for integration into the Merdeka Belajar curriculum, particularly in thematic and character Education. Teachers can utilise this technology to create a fun and meaningful learning atmosphere without neglecting the strengthening of character values. Therefore, it is essential to provide training and enhance the capacity of

teachers to utilise educational technology, particularly in designing and integrating character Education values into educational games.

Although the results of this study show positive outcomes, several limitations need to be considered. First, the implementation was conducted on a limited scale in one area (Cirebon Regency). Hence, the generalisation of the results to a broader context still requires further research. Second, technical limitations, such as teachers' skills in operating the application and the availability of AR devices in some schools, are a challenge. Third, this study has not thoroughly examined the long-term impact of media use on student character. Therefore, further research with a broader area and time coverage is needed to strengthen the findings and see the sustainability effect of using this AR-based learning media.

Conclusion

This research concludes that modified learning media, such as games based on augmented reality technology integrated with character values, are effective in improving literacy and problem-solving skills of elementary school students. In addition, this media is also able to strengthen character education through significant contributions to the development of relevant educational technology, while achieving national education goals. Game-based learning media based on augmented reality integrated with character values is proven effective in improving literacy, problem solving, and strengthening the character of elementary school students. In addition to providing a fun learning experience, this media also supports the achievement of national education goals, especially in the development of cognitive competence and student character. Further research is needed to evaluate the long-term impact and expand the application of this media in various educational contexts.

Acknowledgment

We want to thank all the participants involved in this study.

Declaration Of Conflicting Interests

All authors of this study declare that there is no conflict of interest.

Funding

This research is funded by the Bima grant, which was awarded in 2024 under the criteria for beginner lecturer research (PDP).

Orcid iD

Herisa Hardiyanti Sholeha		https://orcid.org/0000-0003-1031-7020
Zakiyah Ismuwardani		https://orcid.org/0009-0006-9361-0474
Mochamad Guntur		https://orcid.org/0000-0001-6226-7999
Anasya Putri Febgiyo		-
Nonih Nur Syah Lukiyah		-

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