

The Effect of the Use of Augmented Reality (AR) Media on the Mathematical Problem-Solving Ability of Grade IV Elementary School Students

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Abstract

The low mathematical problem-solving ability of fourth-grade elementary school students is an educational challenge that requires innovative learning media solutions. This study aims to determine the effect of using Augmented Reality (AR) media on the mathematical problem-solving ability of fourth-grade elementary school students. The research method used was a quasi-experiment with a nonequivalent control group design, involving two classes selected through purposive sampling. Data were collected using test instruments in the form of essay questions that had been tested for validity and reliability. The data analysis technique included prerequisite tests (normality and homogeneity), independent samples t-test for hypothesis testing, and N-Gain analysis to measure the effectiveness of the treatment. The results showed that the class that used AR media obtained a higher average post-test score than the control class that used conventional media. Statistical analysis using an independent samples t-test showed a significant difference between the two groups. Furthermore, observational data on student activities showed an increase in engagement and interaction with mathematical concepts during learning. In conclusion, the use of Augmented Reality (AR) media had a positive and significant effect on improving the mathematical problem-solving skills of fourth-grade elementary school students.

Keywords: Augmented Reality, Problem-Solving Ability, Learning Media

Abstrak

Rendahnya kemampuan pemecahan masalah matematika peserta didik kelas 4 Sekolah Dasar menjadi tantangan pendidikan yang memerlukan solusi media pembelajaran inovatif. Penelitian ini bertujuan untuk mengetahui pengaruh penggunaan media Augmented Reality (AR) terhadap kemampuan pemecahan masalah matematika peserta didik kelas IV Sekolah Dasar. Metode penelitian yang digunakan adalah kuasi eksperimen dengan desain nonequivalent control group design, melibatkan dua kelas yang dipilih melalui teknik purposive sampling. Data dikumpulkan menggunakan instrumen tes berupa soal uraian yang telah diuji validitas dan reliabilitasnya. Teknik analisis data yang digunakan meliputi uji prasyarat (normalitas dan homogenitas), uji-t sampel independen untuk pengujian hipotesis, serta analisis N-Gain untuk mengukur efektivitas perlakuan. Hasil penelitian menunjukkan bahwa kelas yang menggunakan media AR memperoleh rata-rata nilai post-test yang lebih tinggi dibandingkan kelas kontrol yang menggunakan media konvensional. Analisis statistik menggunakan uji-t sampel independen menunjukkan perbedaan yang signifikan antara kedua kelompok. Selanjutnya, data observasi aktivitas peserta didik menunjukkan peningkatan keterlibatan dan interaksi dengan konsep matematika selama pembelajaran. Simpulannya, penggunaan media Augmented Reality (AR) berpengaruh positif dan signifikan terhadap peningkatan kemampuan pemecahan masalah matematika peserta didik kelas IV Sekolah Dasar.

Kata kunci: Augmented Reality, Kemampuan Memecahkan Masalah, Media Pembelajaran



INTRODUCTION

Mathematics has long been recognized as an essential foundation in primary education, not only as a discipline but as a tool for developing logical, analytical, systematic, and creative thinking skills. In the context of the 21st century, where the complexity of problems is increasing, the ability to solve problems (problem solving) is the main competency that every individual must have. This ability represents the peak of cognitive activity in mathematics, where students not only apply memorized procedures, but also analyze, plan strategies, and evaluate solutions to problems that are not routine. However, the reality in the field shows that the achievement of mathematical problem-solving skills of elementary school (SD) students in Indonesia is still far from expectations. International studies such as PIRLS and TIMSS, as well as national assessments such as AKM, have consistently placed the abilities of Indonesian students, particularly in the domain of reasoning and problem-solving, in the category of concern (Mullis et al., 2020). The data is not just a statistical number, but a reflection of the phenomenon of learning in the classroom that still faces many fundamental challenges.

This phenomenon of low problem-solving ability can be observed directly in many grade IV elementary schools. At this level, students begin to be faced with more complex and abstract mathematical concepts, such as geometry (the nature and area of a flat building), fractions, and measurements. However, the dominant learning approach is often still conventional and teacher-centered. The learning was mostly filled with lectures, followed by practice solving similar procedural problems from textbooks. The learning media used also tend to be limited, static, and less interactive, such as whiteboards, two-dimensional drawings, or simple physical props. This condition results in mathematics learning being perceived as a boring, scary, and irrelevant activity to students' daily lives (Jupri & Drijvers, 2021). In fact, in the context of modern education, cognitive, emotional, and behavioral engagement of students is the key to deep and meaningful learning (Fredricks et al., 2020).

To bridge the gap between the need for innovative learning and the reality of conventional approaches, it is necessary to examine the limitations of traditional media more deeply. The limitations of conventional media in representing abstract and dynamic concepts are the main problem. For example, when learning the concepts of symmetry, cubes, or webs of space, students rely only on flat images or physical models that have limited viewpoints. This requires a high spatial visualization ability from students, which is not necessarily possessed by all children. Without adequate visual comprehension, learners simply memorize formulas without understanding the essence of concepts, making it difficult to apply them in the context of new problem-solving (Huang et al., 2021). As a result, when faced with non-routine problems or contextual problems, learners show symptoms such as confusion about understanding the core of the problem, not knowing where to start, and inability to design and execute appropriate solution strategies (OECD, 2021).

In facing this challenge, the world of education is required to innovate, especially in utilizing the advancement of digital technology that has integrated with the lives of generation Z and Alpha. One of the innovations that has received great attention in the last decade is the use of immersive technologies such as Augmented Reality (AR). Augmented Reality (AR) is a technology that integrates digital information (in the form of text, images, 3D animations, or videos) into the real-world environment in real-time, so that users can interact with the digital content as if they were part of reality (Azuma, 2021). In education, AR offers a new paradigm by presenting "abstract objects" to "digitally concrete", allowing students to see, manipulate, and explore with mathematical objects that have been difficult to access.

The potential of AR to transform learning is supported by various contemporary learning theories. First, from the perspective of Cognitivism Theory and Constructivism, AR provides an ideal platform for *active learning* and *discovery learning*. According to this theory, knowledge is actively built by learners through interaction with their environment. AR creates a rich learning environment where learners can directly manipulate virtual objects, conduct experiments, and observe cause-and-effect relationships, thereby building a deep conceptual understanding (Bacca et al., 2021). This process is in line with Bruner's enactive-iconic-symbolic stage, where AR facilitates *the enactive* (learning by doing) and *iconic* (learning through image/visual) stages before moving into the *symbolic* stage (formal mathematical notation).

Second, Sweller's Cognitive Load Theory provides an explanation for why traditional media can hinder the learning of complex concepts. The intrinsic cognitive load (material difficulty) of 3D geometry or multi-step problems is already high. If the material representation is poor (e.g., a 2D image for a 3D object), then the extrinsic load increases, leaving little room in working memory for the actual problem-solving process. A well-designed AR, according to the multimedia principles of Mayer (2021), can reduce this extrinsic load. By presenting visual and verbal information in an integrated and spatial-contiguous (contiguous) manner, AR helps learners process information more efficiently, so that cognitive resources can be allocated for higher-level thinking activities such as analysis and synthesis (Ibrahim & Ali, 2020).

Third, the Vygotskyian approach of Social Constructivism emphasizes the importance of social interaction and cultural tools in learning. AR can serve as a sophisticated mediation tool. In the context of the Zone of Proximal Development (ZPD), AR can provide digital scaffolding—for example by displaying visual prompts, step-by-step animations, or work templates—that help learners complete tasks that are slightly above their current abilities, with the help of technology (Radu et al., 2021). In addition, AR facilitates collaborative learning, where learners can jointly explore 3D models, discuss, and develop problem-solving strategies, so that knowledge is socially constructed.

Fourth, from a motivational and engagement standpoint, AR has a strong appeal. Recent research shows that AR-based learning experiences are often perceived by learners as game-like, challenging, and fun activities (Sailer & Homner, 2020). This can increase learners' intrinsic motivation, which is a key driver for perseverance and deep engagement in complex tasks. This high engagement is a prerequisite for achieving conceptual understanding and mastery of problem-solving skills (Sinatra et al., 2021).

The empirical facts from recent research are beginning to corroborate the above theoretical argument. A meta-analysis conducted by Garzón et al. (2022) concluded that AR has a medium to large effect on improving student learning outcomes compared to non-AR methods, with a stronger effect on the primary education level. A specific study in the field of mathematics by Çakıroğlu & Atabaş (2021) found that the use of AR significantly improved the conceptual understanding of spatial geometry of elementary school students. Similar research by Chen et al. (2022) shows that AR-based learning not only improves cognitive learning outcomes but also improves learners' critical and creative thinking skills, which are core components of problem-solving.

However, despite the growing evidence of AR's potential, the research context is still mostly conducted outside Indonesia or at higher education levels. Research that specifically tests the influence of AR on *the mathematical problem-solving ability of grade IV elementary school students in Indonesia* is still limited. In fact, as revealed by Haryanto et al. (2022), the effectiveness of an educational technology is greatly influenced by contextual factors such as curriculum, learning culture, and infrastructure readiness. Therefore, research that tests these technologies in a local context is needed to provide valid and relevant evidence.

Based on an in-depth description of the problem phenomenon, theoretical foundation, and support for previous research data above, the formulation of the problem in this study is: How does the use of Augmented Reality (AR) media affect the mathematical problem-solving ability of grade IV elementary school students?

More specifically, the objectives of this study are to:

1. Analyze the difference in mathematical problem-solving skills between students who learn using Augmented Reality (AR) media and students who learn using conventional media.
2. Examining the significance of the influence of the use of Augmented Reality (AR) media on improving the mathematical problem-solving ability of grade IV elementary school students.
3. Describe the activities and involvement of students during the mathematics learning process using Augmented Reality (AR) media.

Thus, this research is expected to make a meaningful empirical contribution to the development of technology-based learning theory, especially in the field of basic mathematics education. Practically, the results of this research are expected to be a reference for teachers, schools, and curriculum developers in designing and implementing innovative learning that can overcome the problem of students' low mathematical problem-solving skills.

METHODS

This study was conducted to test the influence of the use of Augmented Reality (AR) media on students' mathematical problem-solving skills. To achieve this goal, this study uses a quantitative approach with a *quasi-experimental design* method. The selection of this method is based on the consideration that in the context of research in schools, it is often not possible to randomize research subjects into groups perfectly without disrupting the existing classroom structure (Creswell & Creswell, 2018). The design applied in this study is Nonequivalent Control Group Design. In this design, two naturally formed groups (two whole classes) were selected, then one group was given a treatment (experimental class) and the other group was not (control class), without a random assignment process. The initial ability of both groups was measured first to ensure relative equality before treatment was given.

The research was carried out at State Elementary Schools in Cepogo District in the even semester of the 2025/2026 school year. The population in this study is all grade IV students in the sub-district. Sampling was carried out by purposive sampling technique. The selection of the sample was based on the consideration that the school had relatively homogeneous characteristics judging from the previous semester's mathematics report card scores and came from an equivalent socio-economic background. From these several schools, two schools were selected as experimental groups and as control groups. This decision also considers the readiness of infrastructure, such as the availability of gadgets (*smartphones/tablets*) and adequate internet connections in the experimental class.

This study involved two main variables, namely the Independent Variable The use of learning media, which consisted of two levels: (a) Augmented Reality (AR) Media for the experimental group, and (b) Conventional media (textbooks, whiteboards, and physical teaching aids) for the control group. Dependent Variable Students' mathematical problem-solving skills.

Data on problem-solving skills were collected using test instruments in the form of essay questions. The test instruments were prepared based on the indicators of problem-solving ability adapted from the Polya measures, namely: (1) understanding the problem, (2) planning the solution, (3) executing the solution plan, and (4) re-examining the results. Before use, the test instrument is first validated by two experts (validators), namely a mathematics education lecturer and an experienced elementary school mathematics teacher. Validation includes aspects of the suitability of the material with

the curriculum, question construction, and language. After revision based on validator input, the instrument is tested (*test-out*) on other classes outside the research sample. Trial data were analyzed to test the validity of the question items using Pearson's Product Moment correlation and reliability using the Alpha Cronbach formula. The results of the analysis showed that all questions were valid ($r\text{-count} > r\text{-table}$) and the instrument was declared reliable with an Alpha coefficient of 0.86, which is included in the high category (Fraenkel et al., 2019).

In addition to the test, observation sheets are also used to observe student activities and engagement during the learning process in the experimental class. The observation sheet contains cognitive, emotional, and behavioral engagement indicators adapted from Fredricks et al. (2020). Observations were made by two trained observers. The implementation of the research follows the following procedure:

1. Preparation Stage: Create an AR media design for the topic "Geometry: Properties and Area of Flat Builds" using an AR development app. AR media is designed so that students can see flat building objects in 3D, manipulate (rotate, zoom), and solve contextual problems integrated in the application.
2. Pretest Stage: Both groups (experiment and control) were given the same initial test (*pretest*) to measure their initial math problem-solving ability.
3. Treatment Implementation Stage: Treatment is given for 6 meetings with the same time allocation.
 - a. Experimental Group: Learning using AR media. Learning follows syntax: (a) perception with real phenomena, (b) exploration of mathematical objects through AR, (c) AR-assisted discussion and problem-solving, (d) presentation of results, and (e) reflection.
 - b. Control Group: Learn by conventional methods using packet books, teacher explanations on the board, and physical props such as plywood and scissors.
4. Observation Stage: During the treatment, the observer fills out an observation sheet in the experimental classroom to document student involvement.
5. Posttest Stage: After the entire treatment is completed, both groups are given a final test (*posttest*) with a level of difficulty equivalent to *the pretest* to measure their problem-solving ability after the treatment.

The data that has been collected is analyzed quantitatively with the following steps:

 1. Analysis Prerequisite Test: A normality test was carried out for the distribution of *pretest* and *posttest* data using the Shapiro-Wilk test and the variance homogeneity test using the Levene test.
 2. Pretest Data Analysis: To ensure that there was no significant difference in initial ability between the two groups, a comparison test was performed *using* the Independent t-Test (if the data is normal and homogeneous) or the Mann-Whitney Test (if not parametrically qualified).
 3. Posttest Data Analysis (Hypothesis Testing): The research hypothesis was tested by analyzing the difference in *posttest* scores between the experimental and control groups. If the data meets parametric requirements, an Independent t-test is used. Otherwise, use the Mann-Whitney Test. The null hypothesis (H₀) is rejected if the significance value (p-value) < 0.05, which means that there is a significant difference.
 4. Gain Analysis: To see the effectiveness of the treatment, the increase in scores from *pretest* to *posttest* in each group was analyzed by calculating the normalized *N-Gain* value. The N-Gain value was then interpreted and compared between the two groups.
 5. Observation Data Analysis: Qualitative data from observation sheets are analyzed descriptively by calculating the percentage of occurrence of each

engagement indicator to provide a supporting qualitative picture of quantitative findings.

RESULTS AND DISCUSSION

Research Results

1. Data Description and Prerequisite Test Analysis Before conducting hypothesis testing, *pretest* and *posttest data are first analyzed* to determine their characteristics and feasibility. The results of the normality test using Shapiro-Wilk and the homogeneity test using Levene's Test can be seen in Table 1.

Table 1. Normality and Homogeneity Test Results of Pretest and Posttest Data

Groups	Test	Statistics	df	Sig.	Remarks
The pre-test exp.	Normality	0.971	28	0.621	Normal Data ($p > 0.05$)
Pretest Control	Normality	0.962	30	0.363	Normal Data ($p > 0.05$)
Posttest Eksp.	Normality	0.966	28	0.462	Normal Data ($p > 0.05$)
Posttest Control	Normality	0.957	30	0.275	Normal Data ($p > 0.05$)
Pretest	Homogenites	0.745	1,56	0.392	Varian Homogen ($p > 0.05$)
Posttest	Homogenites	1.128	1,56	0.293	Varian Homogen ($p > 0.05$)

Based on Table 1, all *pretest* and *posttest* data from both groups were normally distributed ($p > 0.05$) and had homogeneous variance ($p > 0.05$). Thus, the requirements to use parametric analysis (*independent samples t-test*) are met.

2. Results of Pretest Data Analysis (Initial Equivalence) This analysis aims to ensure that there is no significant difference in mathematical problem-solving ability between the experimental and control groups before the treatment is administered. The results of the independent t-test on *the pretest* score are presented in Table 2.

Table 2. Independent T-Test Results Problem-Solving Ability Pretest Score

Groups	N	Mean	Hours of deviation	t	df	Sig. (2-tailed)
Eksperimen	28	45.36	8.217	-0.412	56	0.682
Control	30	46.17	9.054			

The results in Table 2 show that the significance value (Sig.) is 0.682, which is much greater than $\alpha = 0.05$. This means that there was no significant difference between the average *pretest* scores of the experimental group (M=45.36) and the control group (M=46.17). In other words, the students' initial math problem-solving ability in both groups was at an equal level, so any differences in *the posttest* could be considered as a result of the treatment given.

3. Results of Posttest Data Analysis and Hypothesis Testing After going through the learning process for 6 meetings, students' mathematical problem-solving skills were measured again through *posttests*. The comparison of the average *posttest* score and the calculation of improvement (*N-Gain*) is presented in Table 3.

Table 3. Comparison of Posttest Scores and Normalized N-Gain

Groups	N	Mean Pretest	Mean Posttest	Mean Increase	N-Gain	Category: N-Gain
Eksperimen	28	45.36	82.14	36.78	0.67	Medium
Control	30	46.17	65.23	19.06	0.35	Medium

The data in Table 3 shows that the average posttest score of the experimental group (82.14) is descriptively higher than that of the control group (65.23). The increase in the score (*gain*) and normalized N-Gain values of the experimental group were also higher. To test the significance of this difference, an independent t-test was performed on *the posttest score*. The results are presented in Table 4.

Table 4. Independent T-Test Results Posttest Score Problem-Solving Ability

Groups	N	Mean	Hours of deviation	t	df	Sig. (2-tailed)	Conclusion
Eksperimen	28	82.14	7.892	8.247	56	0.000	H0 Rejected
Control	30	65.23	9.451				

The results of the statistical test in Table 4 show a t-value of 8.247 with a significance (p-value) of 0.000 (< 0.05). Thus, the null hypothesis (H0) is rejected and the alternative hypothesis (Ha) is accepted. This proves that there is a significant difference between the mathematical problem-solving skills of students who learn using Augmented Reality (AR) media and students who learn using conventional media. The higher average scores in the experimental group indicated that the influence of AR media on improved problem-solving skills was positive.

4. Results of Student Engagement Observations Supporting qualitative data from observation sheets during 6 meetings in experimental classes showed a high level of student involvement. The average percentage of engagement indicators can be seen in Figure 1.

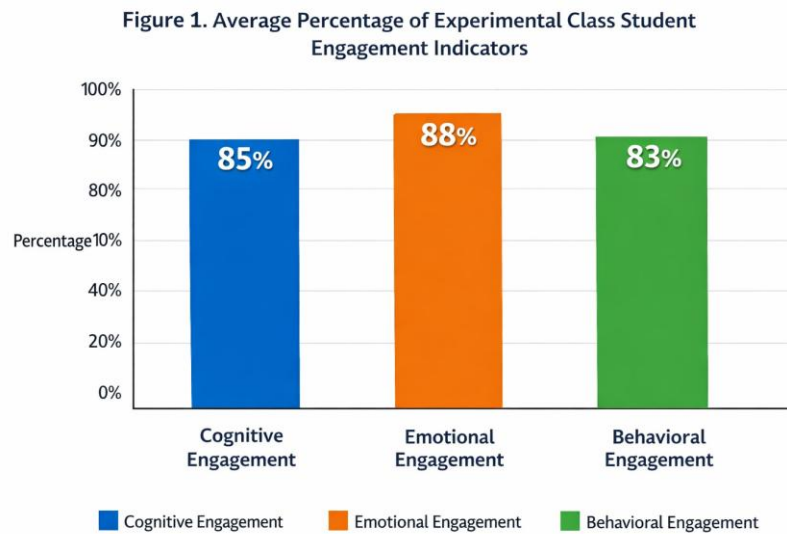


Figure 1. Average Percentage of Experimental Class Student Engagement Indicators

- Cognitive Engagement (focus, ask, strategize): 85%
- Emotional Engagement (enthusiastic, happy, curious): 88%
- Behavioral Engagement (actively manipulating AR, collaborating, completing tasks): 83%

Observation noted that students were very enthusiastic and active in exploring geometric objects through AR. They were seen discussing to plan problem-solving strategies, showing each other findings on the device screen, and being more confident in conveying ideas. The learning environment feels more lively and interactive.

Discussion

The finding that the experimental group had a significantly higher posttest score ($M=82.14$) compared to the control group ($M=65.23$) is consistent with the results of previous studies. Relevance to previous research: This result aligns with the meta-analysis by Garzón et al. (2022), who reported that AR has a medium to large effect size on learning outcomes in primary education. Similarly, Chen et al. (2022) found that AR-based learning improved students' critical and creative thinking skills, which are core components of problem-solving. Causal factors: The main factor causing this difference is AR's ability to reduce extraneous cognitive load (Sweller, 2020). Conventional media present geometric concepts in 2D static images, forcing students to mentally rotate and visualize objects—a process that consumes working memory capacity. In contrast, AR presents 3D objects that can be manipulated directly (rotated, zoomed, and disassembled), eliminating the need for mental conversion. This aligns with Mayer's (2021) multimedia principle, where integrated visual and verbal information reduces extraneous processing. Impact of the result: The reduced cognitive load allows students to allocate more cognitive resources to higher-order thinking processes such as analyzing problems, designing solution strategies, and evaluating answers. Consequently, students in the AR group demonstrated better performance in all stages of Polya's problem-solving framework, especially in planning and executing solutions.

Sub-chapter 2: AR as a Tool for Active Learning and Knowledge Construction

The observation data showing high cognitive engagement (85%) and behavioral engagement (83%) supports the finding that AR facilitates active learning. Relevance to

previous research: This finding is in line with Çakıroğlu & Atabaş (2021), who reported that AR increases learning achievement and retention because it provides immersive hands-on experiences. It also confirms the work of Bacca et al. (2021) that AR supports constructivist learning environments. Causal factors: The main factor is the affordance of AR to enable *enactive* and *iconic* learning (Bruner's stages). When students physically interact with AR objects—turning a cube to see all sides, or overlaying a grid to measure area—they actively construct knowledge rather than passively receive information. This process of *discovery learning* leads to deeper conceptual understanding. Additionally, AR provides immediate visual feedback, allowing students to test hypotheses and correct misconceptions in real time. Impact of the result: Students in the AR group were more proficient in applying concepts to new problem-solving contexts. They did not merely memorize formulas (e.g., area of a square = side × side) but understood why the formula works because they had explored the relationship between side length and area through AR manipulation. This conceptual robustness explains their superior performance on non-routine problems in the posttest.

Sub-chapter 3: AR as Digital Scaffolding and Motivational Driver

The high level of emotional engagement (88%) indicates that AR significantly boosts student motivation and positive attitudes toward mathematics. Relevance to previous research: This result is consistent with Sailer & Homner (2020), who found that gamified and immersive learning experiences increase intrinsic motivation. Radu et al. (2021) also confirmed that AR acts as effective digital scaffolding within students' Zone of Proximal Development (ZPD). Causal factors: Several factors contribute to this effect. First, the novelty and interactive nature of AR create a *game-like* experience that appeals to the digital generation. Second, AR provides just-in-time support (e.g., visual prompts, step-by-step animations) that helps students work through challenges without feeling frustrated. This scaffolding allows students to operate within their ZPD, gradually reducing dependence on external help. Third, collaborative features of AR (students discussing while exploring 3D models together) foster social interaction and peer learning, which aligns with Vygotsky's social constructivism. Impact of the result: Increased emotional engagement leads to persistence and effort in solving complex problems. Students who are curious and enthusiastic are more likely to spend extra time exploring, asking questions, and checking their work. This positive disposition toward mathematics is a crucial outcome beyond mere test scores, as it supports long-term learning and problem-solving habits.

Sub-chapter 4: Integration of Findings and Implications for Holistic Problem-Solving

Taken together, the three factors above work synergistically to improve all stages of Polya's problem-solving model. Relevance to previous research: This integrated finding supports the work of Huang et al. (2021) and Ibáñez & Delgado-Kloos (2021), who argued that AR enhances both cognitive and affective domains in mathematics learning. Causal factors: (a) AR visualization helps students *understand the problem* better, especially story problems involving spatial contexts. (b) Hands-on exploration gives students more data and intuition to *plan a solution* strategy. (c) Immediate feedback and scaffolding enable accurate *execution of the plan*. (d) Engaging features encourage students to *re-examine* their results by using simulation features in AR. Impact of the result: The experimental group not only achieved higher posttest scores but also demonstrated more systematic problem-solving processes. They were observed to be more confident, less anxious, and more willing to tackle challenging problems. This holistic improvement suggests that AR media can be a powerful tool for addressing the persistent problem of low mathematical problem-solving ability in elementary schools.

CONCLUSION

Based on the results of the research and discussion, the following conclusions can be drawn in accordance with the three research objectives:

1. Differences in mathematical problem-solving skills: There is a significant difference in mathematical problem-solving skills between fourth-grade elementary school students who learn using Augmented Reality (AR) media and those who learn using conventional media. The experimental group's average posttest score (82.14) was higher than that of the control group (65.23), and the independent t-test showed a significance value of 0.000 ($p < 0.05$). This proves that AR media produces better problem-solving abilities compared to conventional methods.
2. Significance of the influence of AR media: The use of Augmented Reality (AR) media has a positive and significant effect on improving the mathematical problem-solving ability of fourth-grade elementary school students. The N-Gain analysis showed that the experimental group had a moderate improvement (0.67), which was higher than the control group (0.35). The statistical test confirmed that this difference was not due to chance but was caused by the AR treatment.
3. Student activities and involvement: Observations during the learning process revealed high levels of student engagement in the experimental class. The average percentages were 85% for cognitive engagement (focus, asking questions, strategizing), 88% for emotional engagement (enthusiasm, curiosity, enjoyment), and 83% for behavioral engagement (manipulating AR, collaborating, completing tasks). These findings indicate that AR media creates an interactive, motivating, and meaningful learning environment that supports the development of problem-solving skills.

In summary, Augmented Reality (AR) media is an effective and innovative learning tool for improving mathematical problem-solving skills in elementary school students. Theoretically, this study supports Cognitive Load Theory, Constructivism, and Engagement Theory. Practically, teachers and curriculum developers are encouraged to integrate AR media into mathematics instruction, especially for abstract topics such as geometry. Future research should explore AR's effectiveness on other mathematical topics, at different education levels, and in long-term retention studies.

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